Title:	Document Version:
D2.2 BESOS architecture and transferability roadmap to other smart cities	1.0

Project Number:	Project Acronym:	Project Title:
FP7-SMARTCITIES-2014	BESOS	Building Energy Decision Support for Smart cities

Contractual Delivery Date:	Actual Delivery Date:	Deliverable Type*-Security*:
M36 (September 2016)	M36 (September 2016)	R-PU

*Type: P: Prototype; R: Report; D: Demonstrator; O: Other.

**Security Class: PU: Public; PP: Restricted to other programme participants (including the Commission); RE: Restricted to a group defined by the consortium (including the Commission); CO: Confidential, only for members of the consortium (including the Commission).

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Abstract:

This document provides the final version of BESOS reference architecture and BESOS common information model. It also introduces the next steps to transfer this architecture to other smart cities.

Keywords:

BESOS Reference Architecture, Common Interfaces, BESOS Data Model, energy management, energy information, energy platform, EMSs, ESCOs/Facility Managers

Revision History

Revision	Date	Description	Author (Organisation)
v0.1	27.07.2016	ToC	ETRA
v0.2	28.07.2016	Revision Section 2 and 3	HYPERTECH
v0.3	03.08.2016	Section 1	ETRA
v0.4	04.08.2016	Section 4.3 (initial)	ETRA
v0.5	10.08.2016	Section 4.4	ETRA
v0.6	22.08.2016	Initial section 5	ETRA
v0.7	23.08.2016	Section 4.3	HYPERTECH
V0.8	15/09/2016	Section 4.1	LISBOA E-NOVA
V0.8	15/09/2016	Section 4.1	LISBOA E-NOVA
V0.9	20/09/2016	Architecture	PTIN
V1.0	30/09/2016	Final Edition	ETRA

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1. Introduction

1.1. PURPOSE OF THE DOCUMENT

The BESOS project aims at evolving existing neighbourhoods with decision support system in order to enable a coordinated management of public infrastructures in cities and, simultaneously, to promote sustainability and energy efficiency by providing citizens with relevant information that encourages the change of consumer habits.

The main objective of WP2 is the definition of the reference architecture skilled to support the next generation functionalities envisioned for the smart city grid. The design took into account requirements extracted from the scenarios and related use cases, defined in BESOS deliverable D1.1 (1), and also the main business models and performance indicators (D1.2 (2) & D1.3 (3)) in order to derive the core components of the future smart city energy management systems.

This document presents the reviewed version of the BESOS reference architecture and Common Information Model, with the last modifications made after the second round of trials. It describes the final BESOS architecture and CIM, the details on interfaces and workflows of the main types of entities examined in the architecture namely:

- Energy Management Systems (EMS) that encapsulates every energy system;
- Gateways which integrate the EMS into BESOS service platform;
- Open Trustworthy Energy Services Platform (OTESP) that provides to applications a set of energy service enablers;
- Applications where the service logic and user interfaces resides.

In addition the document also present the transferability of the project approach to other Smart Cities.

The purpose of the document is to serve as final version of both the architecture and the CIM, whilst providing some hints on the next steps to transfer the know-how obtained in this project to other cities.

1.2. STRUCTURE OF THE DOCUMENT

The project is structured around 3 main sections: In section 2 and 3 the architecture and the CIM proposed by the project are reviewed for the last time. Most of the information provided in this section was already available at the two previous versions of the architecture and CIM (D2.1.1 and D2.1.2).

Section 4 includes a description on how the BESOS results are embedded on the Smart City approach followed by Lisbon and Barcelona, ensuring in this way that the results obtained in the project are in line with a higher Smart City vision on both sites. The section also includes a BESOS proposal for a CIM, and the roadmap to influence the Open Urban Platform initiative within the integrated infrastructure action cluster of the Smart Cities EIP.

2. BESOS Overall Architecture

2.1. OVERVIEW

The BESOS Architecture, as presented already in the 1st version of the deliverable D2.1.1, was designed to fulfil requirements defined in D1.1, and its main sub-systems and interfaces are depicted in Figure 1. Following the transferability and expandability requirements for the whole solution, the BESOS architecture can be instantiated in distributed ways and it is designed to be agnostic of EMS devices by supporting standard and extensible interfaces enabling its use in any city in the world independently of its size or location. The main components of the system architecture are further presented:

- **Energy Management Systems (EMS)** every BESOS energy system, such as Wind farms, EV infrastructure, public lighting system, traffic lighting, public buildings, etc. is encapsulated by an EMS.
- **Gateways** are used to integrate the EMS into BESOS service platform (OTESP). They aggregate EMS data and transform it towards BESOS standard data model that is supported by OTESP.
- **Open Trustworthy Energy Services Platform (OTESP)** will act as an Energy Service Platform providing to BESOS Applications a set of reusable energy service enablers built on top of all EMS comprised in a Smart City.
- **Applications** are developed on top of OTESP service enablers with all the service logic and User Interfaces needed by the different BESOS actors.

Apart from the functional view of the system, the main interfaces of the BESOS reference architecture were also defined. The interfaces description shows how the components of the high-level architecture interact with each other and also ensure the interoperability between the components of the system. In addition to the interfaces definition, the main workflows among the components, towards the services addressed in the project, were also considered. A detailed narrative description of the workflows is provided as part of the 1st version of the document. and a detailed services definition is provided in the 2nd version of the deliverable. Taking into account the main interfaces to be supported by BESOS platform (as presented in Figure 1), along with the final version of the Common Data model delivered through the pilot sites adaptation, the detailed specifications of the BESOS services are provided as part of this document. We have to point out that the overall analysis is provided in line with the development work of the respective components and therefore this updated version covers also the requirements defined during the development phase of the platform.

Details on the development and deployment of the system are not provided as this information is described in details on WP3, WP4 and WP5 deliverables. Though, the overall approach is considered as fully distributed towards the provision of a modular solution that best fits on mass scale applications. Taking into account the final version of Reference Architecture is provided in the next schema.

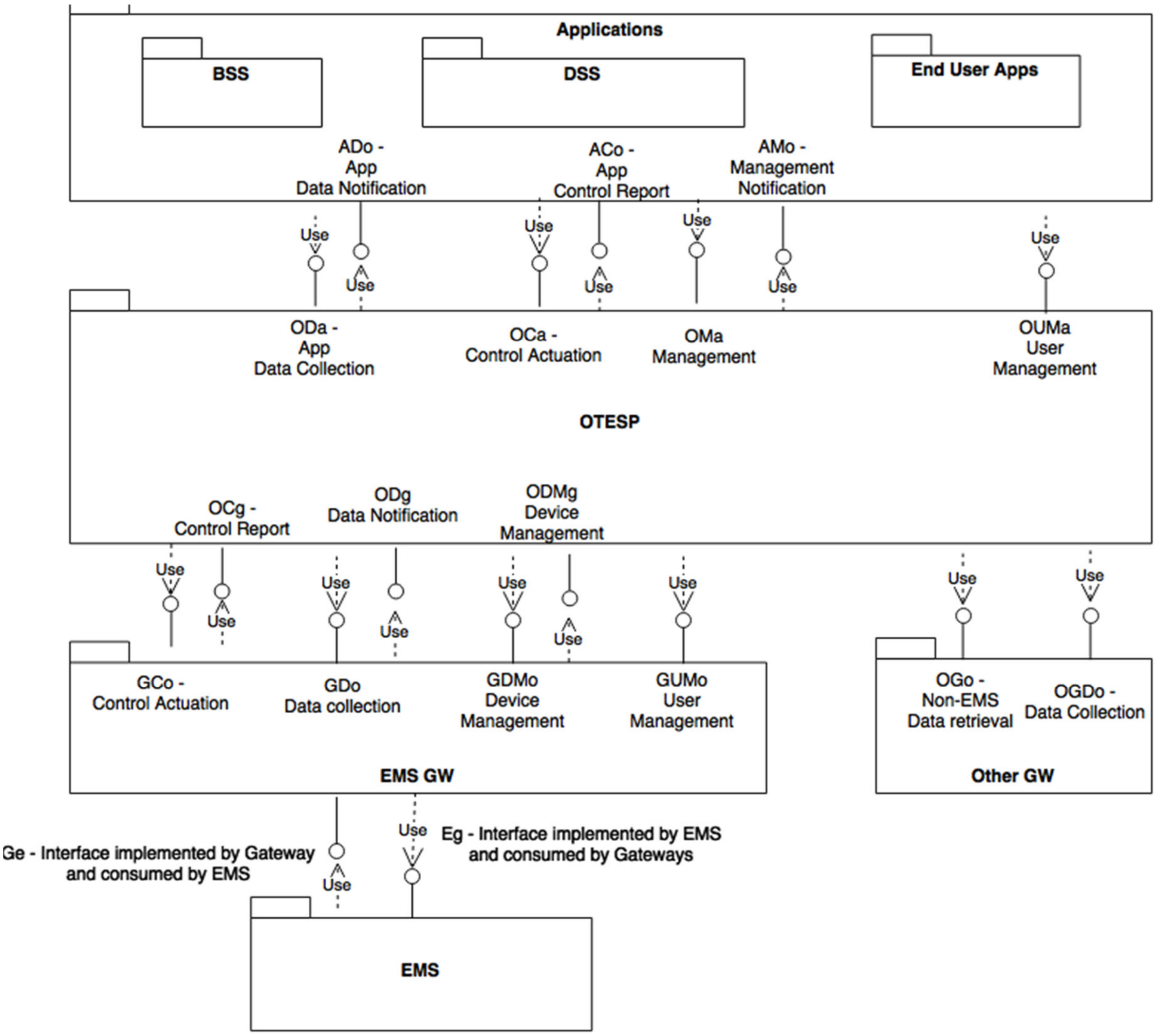

Figure 1 - BESOS High Level Architecture

2.2. FUNCTIONAL ENTITIES

The main functional entities defined on reference architecture are further mapped to the respective physical entities of BESOS ecosystem. A short narrative description of the respective entities is provided.

2.2.1. Energy Management System (EMS)

An EMS represents Energy Consumers and Energy Suppliers systems. It wraps energy consuming devices (e.g. public buildings) and energy supplier devices (e.g. wind generation) that are under OTESP control. An Energy Consumer EMS provides energy consumption data per device and may also provide commands to control energy consumption when supported. Similarly, an Energy Supplier EMS provides energy production data per device and may also provide commands to control energy production when supported. In addition, an Energy Supplier EMS should also provide supplier prices. An Energy Consumer EMS should also provide user management capabilities. Both Energy Consumer and Supplier EMS systems should provide device discovery and device management functionalities. Energy Management Systems are not considered part of the BESOS architecture though; direct interfaces with gateways are defined and further described as part of the architecture.

2.2.2. Gateways

Gateways are used to aggregate EMS data and to transform it towards BESOS common data model. This means an EMS Gateway provides uniform interfaces towards the OTESP to retrieve and actuate on EMS. This functionality can be distributed among different instances that can be co-located or not with an EMS. Different Gateway topologies could be used including one Gateway per EMS or one Gateway integrating more than one EMS. A gateway can also be used to aggregate other data sources needed by OTESP beside EMS, for example, weather forecast data provided by Internet services. Therefore, the term "Gateway" is defined in an abstract way to provide the semantically enhanced element that describe a single or multiple physical entities.

2.2.3. Open Trustworthy Energy Services Platform (OTESP)

The OTESP is an Energy Service Platform providing to BESOS applications a set of reusable energy service enablers built on top of all EMS comprised in a Smart City. OTESP service enablers are agnostic from EMS in order to minimize impacts on applications when existing EMS are updated or when new EMS are added. It stores and processes data retrieved from EMS via synchronous (request and response) or asynchronous (pub/sub) interfaces. It also actuates on EMS according to OTESP internal decisions or due to requests performed by the DSS Cockpit App.

2.2.4. Applications

BESOS Applications are developed on top of OTESP service enablers with all the service logic and User Interfaces needed by the different BESOS actors. Three main types of BESOS applications are distinguished:

- **Business Balanced Score Card (BBSC):** this app is used by Smart City managers to audit Key Performance Indicators (KPIs) and Service Level Agreements of all public services and infrastructures involved.
- **Decision Support System Cockpit (DSSC):** this app is used by Smart City operators to monitors EMS data and actuate on EMS by defining and applying coordinated strategies to improve overall Energy Efficiency of a smart city.
- **Mobile Application for behavioural modification (BMA):** A mobile application oriented to inform school children about energy consumption and, at the same time, promote energy efficiency habits.

The business services are defined to cover the requirements for BESOS project. Though, we have to point out that the development process is fully modular to support the expandability and further transferability of the solution on different cases.

2.3. INTERFACES

The BESOS reference architecture includes a set of interfaces enabling the interaction between different components of the high-level architecture (depicted in Figure 1). The description given here is detailed in the documents that describe the different components in their corresponding work packages. Further, the taxonomy of interfaces is provided for a clear view of the system Architecture. The definition of interfaces is provided to cover both synchronous and asynchronous communication between the different layers of reference architecture. The development of interfaces follows the main objective of the project towards the definition of a fully scalable solution to fit on different use cases on smart city level.

Interfaces to be implemented by Applications.

ADo - Interface implemented by Applications to asynchronously receive relevant data notifications (Data related to Metrics & KPIs).

ACo - Interface implemented by Applications to asynchronously receive reports about the EMS devices control. (Data related to control commands and EMS status).

AMo - Interface implemented by the end user Application to asynchronously receive data related to the configuration and management of EMS devices mediated by OTESP (Data related to specific attributes of system Entities).

Interfaces to be implemented by the OTESP (Application Layer).

ODa - Interface implemented by the OTESP to retrieve end-user related data from the EMS Devices

OCa - Interface implemented by the OTESP to send commands and to control EMS devices.

OMa - Interface implemented by the OTESP to manage the EMS devices

OUMa - Interface implemented by the OTESP to manage App users' account including Data Access control. This is a service of high interest, as BESOs platform handles privacy related aspects.

Interfaces to be implemented by the OTESP (Gateway Layer).

ODg - Interface implemented by the OTESP to receive asynchronous data notifications from the EMS devices mediated by the GW.

OCg - Interface implemented by the OTESP to receive asynchronous reports about the EMS devices control mediated by EMS Gateways.

ODMg - Interface implemented by the OTESP to handle EMS devices registration and status notification.

Interfaces to be implemented by Gateways (OTESP Layer).

GDo - Interface implemented by the EMS Gateway to retrieve data from the EMS devices mediated by the Gateway.

GCo - Interface implemented by the EMS Gateway to send commands and to control the EMS devices mediated by the Gateway.

GDMo - Interface implemented by the EMS Gateway to manage the EMS devices mediated by the Gateway.

GUMo - Interface implemented by the EMS Gateway to manage the EMS users mediated by the Gateway, including consumers (e.g. Data Access control).

OGo - Interface implemented by the EMS Gateway (Other) to retrieve data from the EMS devices mediated by the Gateway. This service is on S&P EMS that set the common repository and the forecasting engine of the system. Though this interface is critical for the development of 3rd party applications towards the integration with BESOS platform.

OGDo- Interface implemented by the Gateway to receive asynchronous data notifications from the EMS devices mediated by the OTESP. This service is on S&P EMS that set the common repository and the forecasting engine of the system. This service is mirrored to OGo to support both synchronous and asynchronous calls.

Interfaces to be implemented by Gateways (EMS Layer).

Eg - Interface implemented by EMS and consumed by Gateways towards polling of data and setting control commands.

Ge - New interface created making possible EMS to directly push the information to the Gateway layer.

2.4. CONCLUSIONS

This section presented an overview of the conceptual BESOS architecture. It consists of a set of EMS representing energy consumers and suppliers systems, the Gateways responsible for the aggregation of EMS data and for its transformation towards BESOS standard data model, the OTESP service platform that provides a set of reusable energy service enablers, and, finally, the Applications which encompass all the service logic and User Interfaces needed by the different BESOS actors. Finally, the interfaces that allow the exchange of data between these entities were also described in this chapter.

3. BESOS Common Information Model (CIM)

The goal of this section is to report any updates delivered in BESOS CIM, following the submission of the concrete BESOS CIM version in M24.We are reporting minor updates in the current version of CIM, associated with the integration of additional asset types during the 3rd project period.

Following the methodological approach (1st and 2nd version of the deliverable) and the initially defined concepts, an updated and final version of BESOS Common Information Model is provided. This version of CIM takes into account the final list of pilot asset specifications, as documented in Deliverable D4.2.2 (7). Furthermore, special focus is delivered on the requirements for transferability of BESOS architecture to other Smart Cities as addressed by Task 1.3, setting a critical parameter of BESOS framework.

3.1. CONCEPTUAL DATA MODELLING – UPDATED VERSION

We have adopted the initial taxonomy on data model where the whole set of data attributes was broken down to 7 logical modules in order to facilitate cohesion and reusability, as having one big monolithic model that includes all concepts would not be very usable.

The logical modules also correspond to physical ones, so there are 7 XSD files (8) that set the BESOS CIM model and the analysis is performed for the definition of the final concepts and attributes in the 3rd version of BESOS CIM.

Location

This module includes concepts used to capture **information related to location**, as well as two concepts that are used throughout the data model and have been included here for convenience:

a. **IdentifiedObject**. This is the concept that most other concepts in the data model extend, either directly or indirectly (base class). It has been adopted from the IEC CIM and has 3 properties that its subclasses inherit – a unique ID and 2 names. Though this class is not of direct use in BESOS project, it is pointed out in order to highlight the structural and hierarchical approach of the proposed data model.
b. **Status.** This concept is introduced in the IEC CIM to be used as a generic container to hold status-related information that can be associated with any other concept. Its values are textual, and should not be confused with enumerated status references, e.g. the ones used for devices.

These are general concepts defined in IEC CIM, further inherited in BESOS CIM to manage the hierarchy of BESOS data model. This is a modelling aspect that supports the structural management of the document (data model), enabling that way the transferability of our approach in different domains.

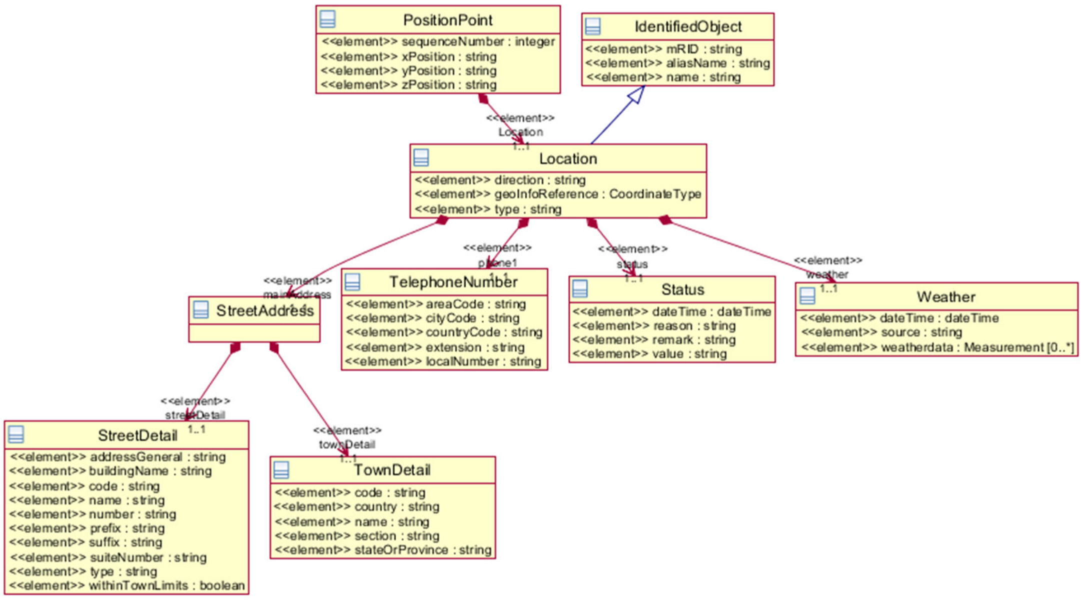

Figure 2 - Location Module Overview

The extended "Location" Module was provided to address the project requirements for the expandability and transferability of the platform. Though, within BESOS project a subset of the supported classes were utilized taking into account the business scenarios examined in the project.

Organisation & Users

This module includes concepts capturing information about organisations as well as users. The trustworthiness of the platform is a core aspect examined in the project and therefore a dedicated data structure is considered in order to address the permission rights for the users examined. Different types of permission types are defined and therefore an enumeration structure is describer to clearly specify the system functionalities. In addition, and as a way to support permissions management, the users are responsible to set limitations on metrics and assets that are available for monitoring and control.

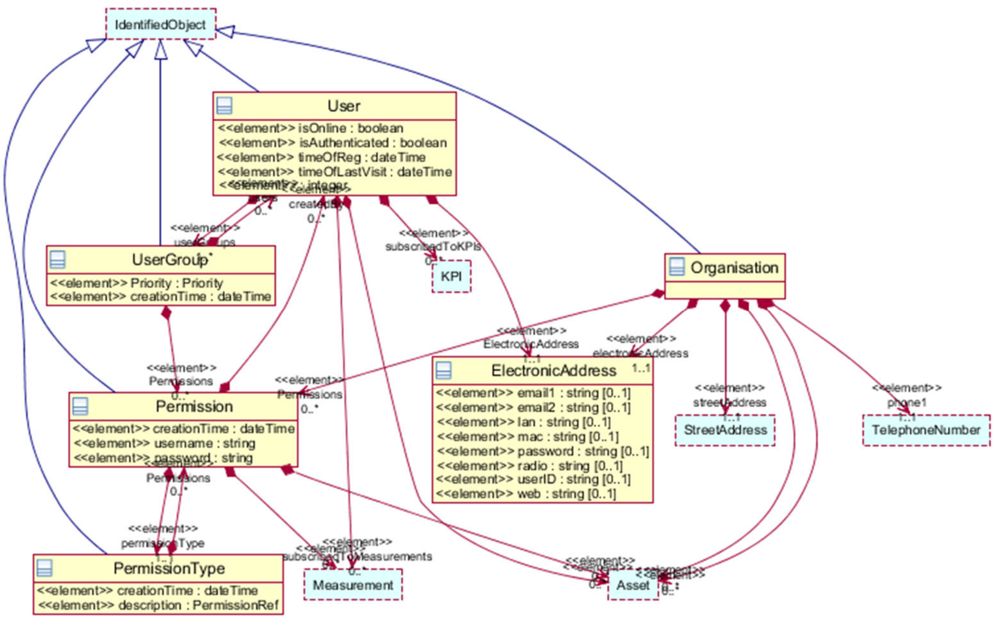

Figure 3 - Organisation & Users Module Overview

This is one of the main objectives of the project (to ensure privacy and security in the services offered by BESOS project) and thus a detailed analysis is provided in this section. We have adopted a dynamic approach to define different permission instances considering:

- Permission ref enumeration: None, Only monitoring, Monitoring and control
- Permission time & duration: Considering permission activation at a specific time and for a specific duration
- Permission on specific assets: This is an association of permission instance with specific assets of the portfolio
- Permission on specific metrics: This is an association of the permission instance with specific metrics of the associated asset. This approach enables a modular management of metrics types and asset types
- Permission for specific users: This is an indirect association via asset type (assets are associated with users)

Addressing this modular approach, we are defining a flexible framework for managing the different permission types associated with the operation of asset types.

A **Permission class** granted on an Asset. It extends IdentifiedObject and therefore a unique ID is defined per permission.

creationTime	1..1	dateTime	Permission time of creation.
createdBy	0..1	User	User who created this permission
duration	1.1	dateTime	Permission duration.
Username	1..1	String	The username for permissions access
Password	1..1	String	The password for permissions access
permissionType	1..1	PermissionType	Type of permission
onAssets	0..n	Asset	Assets this permission applies to.
onMetrics	0..n	Measurements	Defines the list of metrics permitted for management

Table 1 - Permission class

PermissionType.

Permissions can be organized in data types. It extends IdentifiedObject.

creationTime	1..1	dateTime	PermissionType time of creation.
description	0..1	PermissionRef	PermissionType enumeration.
permission	0..n	Permission	Permissions of this type.

Table 2 - Permission Type

This is a generic data type, to manage the different classes of permissions in an hierarchical way.

PermissionRef.

This is the enumeration type for the definition of permissions types addressed in BESOS project.

NONE	There is no permission on asset
MONITORING	Only monitoring permission
MONITORING_CONTROL	Monitoring & Control permission

Table 3 - Permission Ref

The extension of the respective classes is provided to address privacy issues as examined in BESOS project. The overall analysis is performed from the semantic representation point of view and further inherited in the technical implementation of OTESP developments in WP3.

Asset Structure

This module is the main innovation of IEC CIM, further adopted in BESOS CIM interpretation. It does not contain detailed information about asset specific data types or measurements, rather it defines the generic concept of an asset and its main elements.

Therefore, the role of this module is to act as the generic framework that can be further inherited for the management of each physical asset integrated in the project. By decoupling the high level functionalities by the asset specific functionalities, we provide a modular approach that can be easily transferred to other case studies. The generic asset class, as defined for BESOS project, is presented in the following figure:

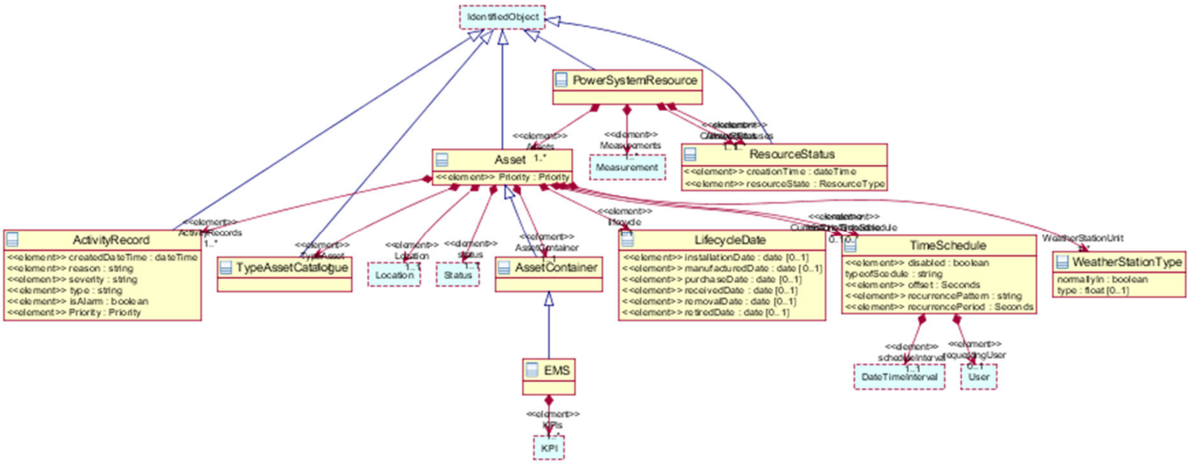

Figure 4 - Asset Structure Module Overview

Assets Representation

Following the representation of the generic asset type in previous section, we proceed with the specific asset representations in this section. This module includes concepts capturing information from specific types of Assets. Therefore, this analysis is BESOS project specific, as we define the classes associated with the integration of specific physical devices examined in the project. An updated version of this module is reported in the document, considering the integration of additional physical asset types (with different attributes) during the 3rd project period.

We have to point out that a modular approach is considered on the definition of asset representation types. Each physical asset is represented with a specific class, enabling that way the expandability and transferability of BESOS CIM. We can easily remove the list of specific asset types from our model, and further add additional classes associated with the operational characteristics of different physical devices. The list of asset types defined in BESOS CIM, cover the different physical assets integrated in BESOS project from the different pilot sites:

- **Generation asset types**, including wind and PV generation.
- **Public buildings**, including monitoring of HVAC and lighting devices.
- **Domestic buildings**, considering the specific use cases examined in the project.
- **Segment Controllers & PoL,** associated with the management of Public Lighting.
- **Road** asset type, associated with traffic management and traffic lighting operation.
- **Charging, EV plug and association with EVs,** considering the management of EV fleet in a coordinated way.

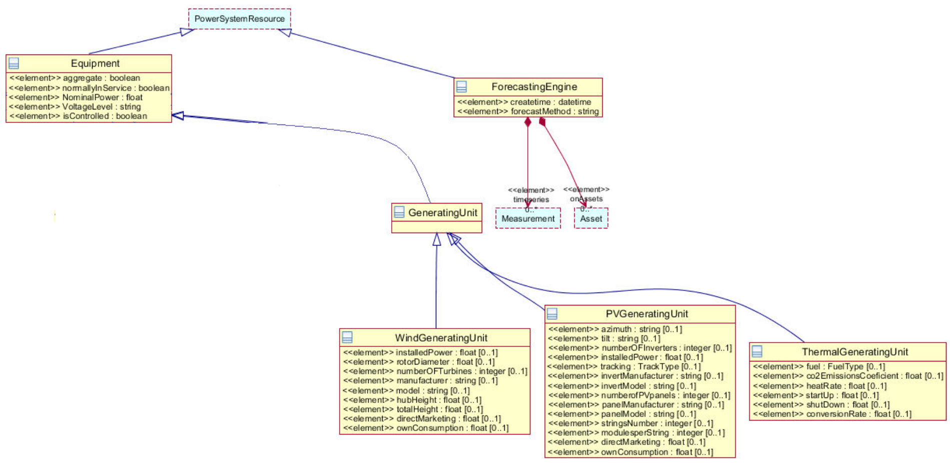

Figure 5 - Asset Representation Module - Generation Units

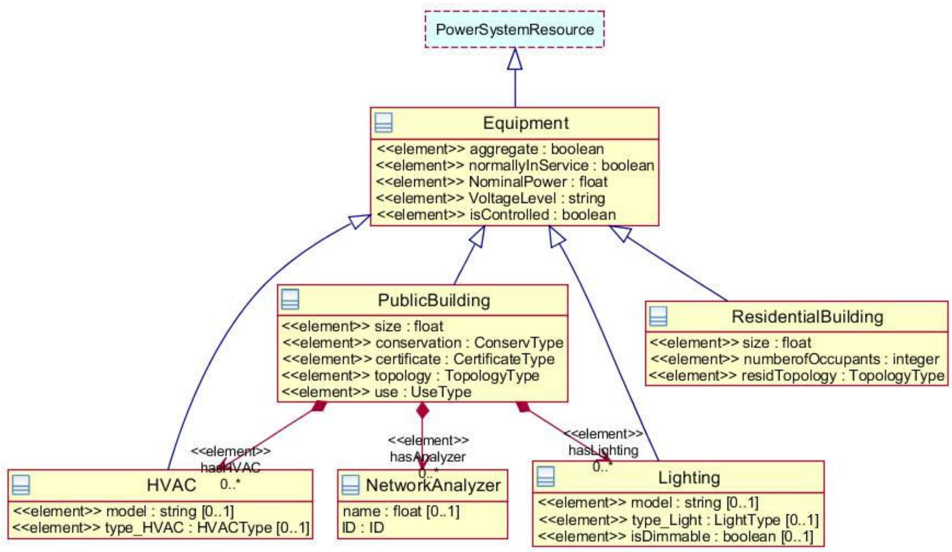

Figure 6 - Asset Representation Module - Building Units

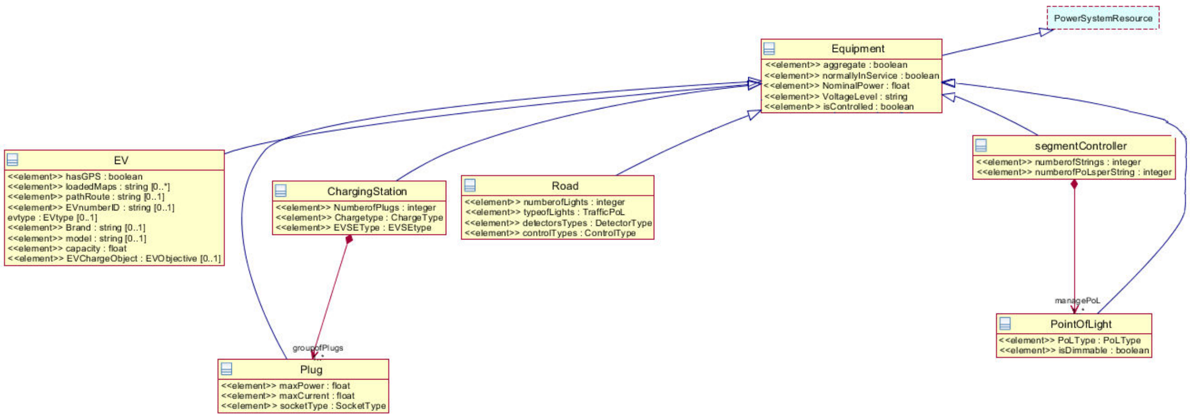

Figure 7 - Asset Representation Module – Additional Assets

In order to support the transferability of BESOS CIM to different domains and case studies, we are presenting a class associated with the operation of a physical device not examined in BESOS project. This is a thermal generation unit associated with the generic "equipment" class like the rest of assets examined in the project.

ThermalGeneratingUnit

Thermal Generation Unit is a core asset, modelled within IEC CIM standard, and therefore most of the attributes have been adopted from the standard.

fuel	**0..1**	**FuelType**	Defines the type of fuel used in generating unit
co2EmissionsCoeficient	**0..1**	**float**	Defines the CO2 emissions rate for the calculation of CO2 emissions
heatRate	**0..1**	**float**	Defines the heat ratio transformation of the thermal unit
startUp	**0..1**	**float**	Defines the Start up ratio of the thermal generating unit
shutDown	**0..1**	**float**	Defines the Shut Down ration of the thermal generating unit
conversionRate	**0..1**	**float**	Defines the conversion rate to the estimation of thermal unit performance

Table 4 - Thermanl Generation Unit

Each thermal unit is characterized by a set of parameters that define the operational aspects of the unit. Here, we define the parameters that are defined by IEC CIM towards the alignment of BESOS CIM with IEC standards.

FuelType

This is an enumeration type for the type of fuel used by generating unit

DIESEL	Diesel fuel
CRUDEOIL	Crude oil fuel
NATURAL_GAS	Natural Gas fuel
GASOIL	Gasoil fuel
COAL	Coal fuel
BIOMASS	Biomass fuel

Table 5 - Fuel Type

As a main innovation of BESOS, we highlight the role of Forecasting Engine. This is the software component that provides accurate generation and consumption forecasting, taking into account time series of energy production/ consumption and weather data. The details about the algorithmic framework are reported in WP4, though the modelling representation of this component is reported as part of the data model.

Forecasting engine

The forecasting engine is considered as a "virtual" EMS entity and therefore should be expressed as part of the data model. The main parameters that define the operation of BESOS forecasting engine are:

- The asset types (individual and groups of assets) associated with the forecasting functionality
- Forecasting Method, considering the different algorithms evaluated for calculation of accurate forecasting
- Time series, considering pre-defined forecasts periodically updated to support different business applications.

creationTime	1..1	dateTime	Time of forecast activation
forecastMethod	1..1	string	The machine learning technique used for forecasting process
onAssets	0..n	Assets	List of Assets considered on the forecasting process
timeseries	0..n	Timeseries	List of forecasting time series defined by the engine

Table 6 - Forecast Engine

Measurements & Key Performance Indicators

This module includes concepts capturing information that help keep track of dynamically evolving attributes (Measurements) used themselves to display and aggregate as well as KPIs defined utilizing these measurements. The explicit definition of metrics and indicators is provided in the updated version of BESOS Data Model.

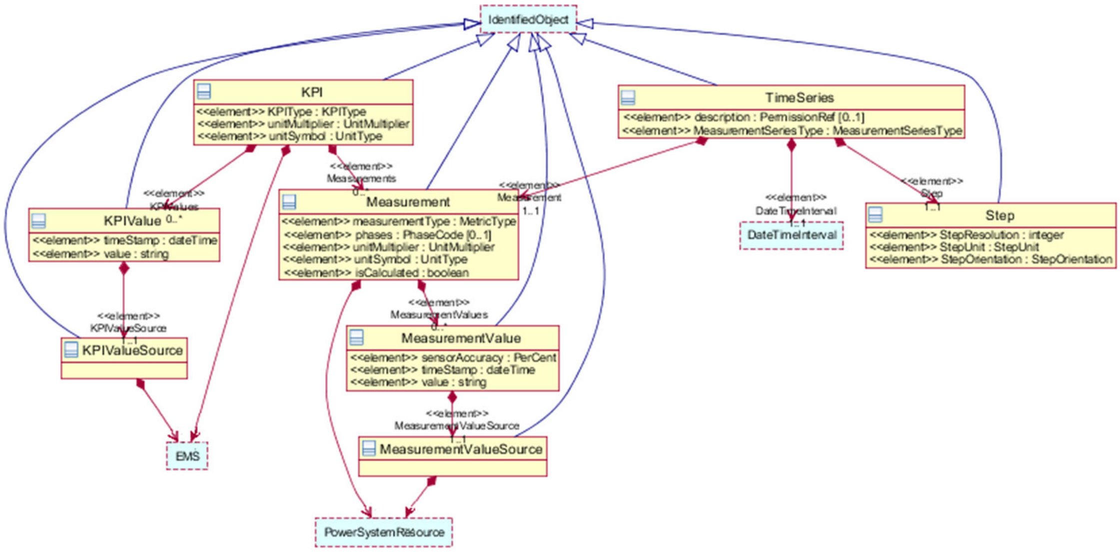

Figure 8 - Measurements & KPIs Module Overview

Following an abstract way for the management of KPIs and metrics (values and time series), enabling that way the easy transferability of this approach in other domains, we proceed with the specific definition of metric and KPI types defined within the context of BESOS project. This is the BESOS specific list of metrics and KPIs, easily adaptable to address additional metric and KPI values.

<u>MetricType</u>

This is an enumeration for the final list of metrics defined for BESOS project. Segmentation on high level domains is considered for the prompt presentation of the metrics. We have to point out that the list of metrics is aligned with detailed analysis delivered as part of T1.3 work “T1.3 New business Models to affect BESOS Architecture: SLAs vs. KPIs”.

Entities metrics		
ENTITY_COUNT	Number of Entities Count	Dimensionless
ENTITIES_USED	Number of Entities Used	Dimensionless
Energy Metrics		
ENERGY_CONSUMPTION	Energy Consumption	Wh
ENERGY_PRODUCTION	Energy Production	Wh
ENER-GY_PRODUCTION_MEAN	Energy Production Mean	Wh
POTEN-TIAL_ENERGY_PRODUCTION	Potential Energy Production	Wh
POTEN-TIAL_ENERGY_PRODUCTION_AFTER_INSTALLATION_EXPANSION	Potential Energy Production After Installation Expansion	Wh
PRIMARY_ENERGY	Primary Energy related to the generating unit	Wh
SECONDARY_ENERGY	Secondary Energy as the final energy consumption level	Wh
ENER-	Energy Consumption Forecast	Wh

GY_CONSUMPTION_FORECAST		
ENERGY_PRODUCTION_FORECAST	Energy Production Forecast	Wh
ENERGY_MANAGED	Energy Managed during the portfolio management	Wh
ENERGY_MANAGED_REQUESTED	Energy Managed Requested	Wh
ENERGY_PRODUCTION_CURTAILMENT_FORECAST	Energy Production Curtailment Forecast	Wh
ENERGY_PRODUCTION_CURTAILMENT	Energy Production Curtailment	Wh
ENERGY_CONSUMPTION_REDUCTION_FLEXIBILITY	Energy Consumption Reduction Flexibility	Wh
ENERGY_PRODUCTION_REDUCTION_FLEXIBILITY	Energy Production Reduction Flexibility	Wh
ENERGY_PRODUCTION_INCREASE_FLEXIBILITY	Energy Production Increase Flexibility	Wh
ENERGY_CONVERSION_EFFICIENCY	Energy Conversion Efficiency	%
POTENTIAL_CAPACITY_OF_POWER_PRODUCTION	Potential Capacity Of Power Production	W
STORAGE_CAPACITY	Storage Capacity/ State of Charge (for EVs)	Wh
MAX_PEAK_POWER_DEMAND	Max Peak Power Demand	W
ACTIVE_POWER	Active Power	W
ACTIVE_POWER_MIN	Active Power Min	W
ACTIVE_POWER_MAX	Active Power Max	W
REACTIVE_POWER	Reactive Power	Var
REACTIVE_POWER_MEAN	Reactive Power Mean	Var
REACTIVE_POWER_MIN	Reactive Power Min	Var
REACTIVE_POWER_MAX	Reactive Power Max	Var
VOLTAGE	Voltage	V
VOLTAGE_RMS	Voltage Rms	V
VOLTAGE_MIN	Voltage Min	V
VOLTAGE_MAX	Voltage Max	V
PHASE_VOLTAGE_A	Phase Voltage A	V
PHASE_VOLTAGE_B	Phase Voltage B	V
PHASE_VOLTAGE_C	Phase Voltage C	V
CURRENT	Current	A
CURRENT_MIN	Current Min	A
CURRENT_MAX	Current Max	A
PHASE_CURRENT_A	Phase Current A	A

PHASE_CURRENT_B	Phase Current B	A
PHASE_CURRENT_C	Phase Current C	A
PHASE_POWER_FACTOR_A	Power Factor Phase A	Dimensionless
PHASE_POWER_FACTOR_B	Power Factor Phase B	Dimensionless
PHASE_POWER_FACTOR_C	Power Factor Phase C	Dimensionless
AC_FREQUENCY	Ac Frequency	Hz
Business Metrics		
OPERATIONAL_COST	Operational Cost	euro
ENERGY_PRICE_PER_KWH	Energy Price Per Kwh	euro/ Wh
ENERGY_COST	Energy Cost	euro
INVESTMENT_BUDGET	Investment Budget	euro
INVESTMENT	Investment	euro
CO2_EMISSIONS	CO2 Emissions	Kg CO2
RES_PENETRATION	RES Penetration	%
TO-TAL_DISTORTION_HARMONICS_INDICATOR	Total Distortion Harmonics Indicator	%
POW-ER_AVAILABLE_PERCENT	Percentage of availability of the wind farm	%
POWER_ON_LEVEL	Dimming status of Point of Light	%
Weather/Environment Metrics		
TEMPERATURE	Temperature	oC
INSIDE_TEMPERATURE	Inside Temperature	oC
OUTSIDE_TEMPERATURE	Outside Temperature	oC
INFLOW_TEMPERATURE	Inflow Temperature	oC
OUTFLOW_TEMPERATURE	Outflow Temperature	oC
TEMPERATURE_SOL_AIR	Temperature Sol Air	oC
MINI-MUM_INDOOR_TEMPERATURE	Minimum Indoor Temperature	oC
MAXI-MUM_INDOOR_TEMPERATURE	Maximum Indoor Temperature	oC
RELATIVE_HUMIDITY	Relative Humidity	%
IN-SIDE_RELATIVE_HUMIDITY	Inside Relative Humidity	%
OUT-SIDE_RELATIVE_HUMIDITY	Outside Relative Humidity	%
ATMOSPHERIC_PRESSURE	Atmospheric Pressure	Pa
WIND_SPEED	Wind Speed	m/s
WIND_GUST	Wind Gust	m/s
WIND_DIRECTION	Wind Direction	rad
CLOUD_INDEX	Cloud Index	Dimensionless
CO2_CONCENTRATION	CO2 Concentration	ppm
SOLAR_RADIATION	Solar Radiation	W/m2
GONDOLA_ALIGNMENT	Gondola alignment in Wind turbines	%
Vehicles Metrics		

AVER-AGE_ENERGY_PER_KM	Average Energy per m	Wh/m
DISTANCE_IN_METRE	Distance In Metre	m
LITRES_CONSUMED_FUEL	Litres Consumed Fuel	Litre
AVER-AGE_LITRE_FUEL_PER_KM	Average Litre Fuel Per m	Litre/m
TRAFFIF_DENSITY	Vehicle Density	%
CAR_DETECTION	Car Detection	Boolean

Table 7 - Metric Type

KPIType

Following the definition of metrics listed for BESOS project, we then define the list of Key Performance Indicators examined in the project. The list of KPIs is aligned with the list of KPIs addressed within “T1.3 New business Models to affect BESOS Architecture: SLAs vs. KPIs”.

We have to point out that in BESOS, the KPIs are dynamically generated through a Complex event processing engine of OTESP. Therefore, the overall management of KPIs and metrics is an internal process handled by OTESP. Though, BESOS modelling framework is provided to ensure the flexible management of KPIs with metrics, enabling that way the transferability of this concept in other case studies. The list of KPIs specified within the context of BESOS project is presented:

CO2_DIFFERENCE	Difference in CO2 emissions
CO2_CHANGE	Change in CO2 emissions
CO2_GOAL_DEVIATION	Goal achievement deviation in CO2 emissions
CONS_DIFFERENCE	Difference in energy consumption
CONS _CHANGE	Change in energy consumption
CONS_GOAL_DEVIATION	Goal achievement deviation in energy consumption
RES_DIFFERENCE	Difference in renewable energy production
RES_CHANGE	Change in renewable energy production
RES_GOAL_DEVIATION	Goal achievement deviation in renewable energy production
COST_DIFFERENCE	Difference in energy cost
COST _CHANGE	Change in energy cost
EFF _CHANGE	Change in the efficiency of production
FORECAST_CONS_ACCURACY	Change in consumption forecast accuracy
FORECAST_PROD_ACCURACY	Change in production forecast accuracy
OPER_COST _CHANGE	Change in operational cost
EV _CHANGE	Change in overall state of charge (SOC) of EV

Table 8 - KPI Type

The Complex Event Processing engine is the main innovation of BESOS project, as developers are able to set additional formula settings (not only related to Energy Domain). This engine, along with the respective API for the development process is provided in WP3 (internal method of OTESP platform).

Document Types

This module includes new concepts examined in BESOS project for capturing information related to the business – strategic impact. More specifically, it models concepts related to high level SLAs and low level business strategies to achieve them. The outcomes from modelling SLAs and business strategies in a modular way are summarized in the following:

- Who: the **users/organizations** involved in SLAs and business strategies
- When: the **time period** for SLAs and business strategies
- Where did it take place: the **assets** involved in SLAs and business strategies
- Why: the specific **SLA/Strategy enumeration**
- What: the **KPI and metric values** associated with the selected SLA/ business strategies

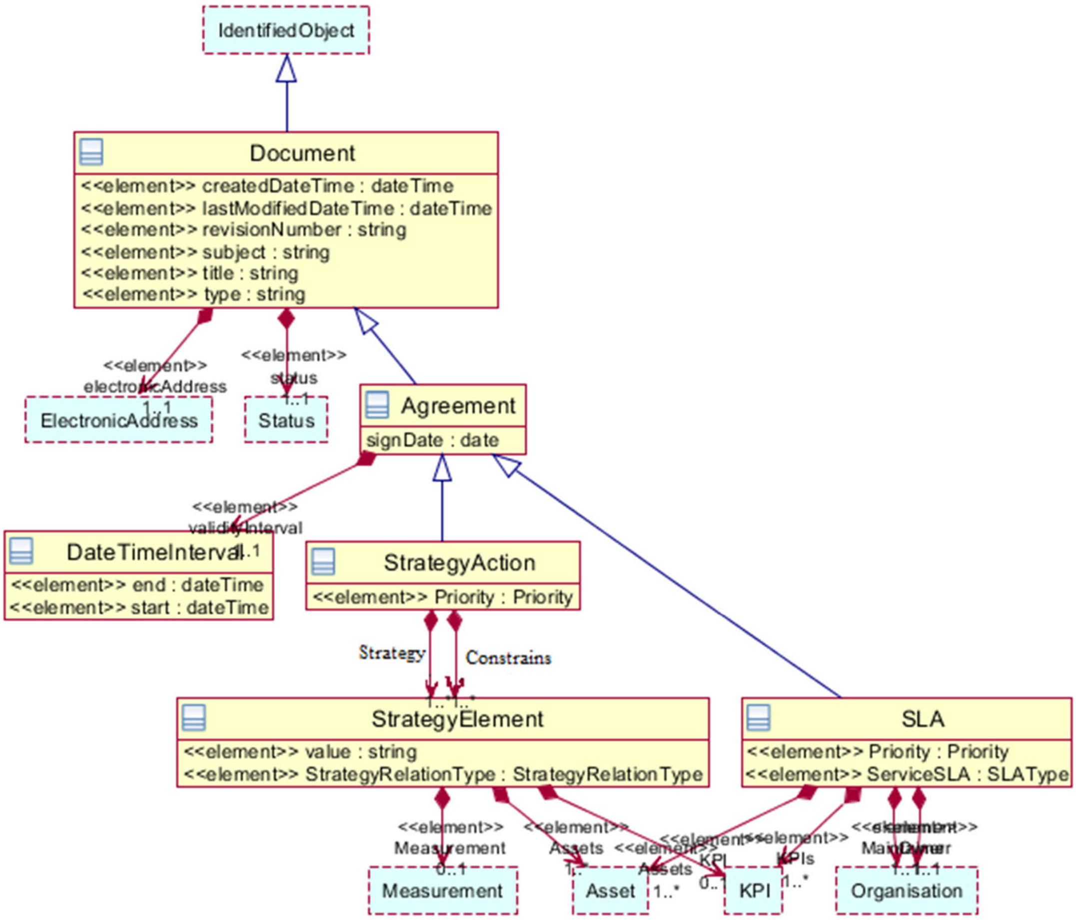

Figure 9 - Document Types Module Overview

As the total number of Service Layer Agreements examined in BESOS project is predefined (Deliverable D1.2), an enumeration type is considered for the details of each scenario examined in application level.

Control Structure

This is the last module of the BESOS CIM modular approach and includes concepts capturing information related to control commands as delivered from the Application level to the EMS level to proceed with the implementation of the control strategies.

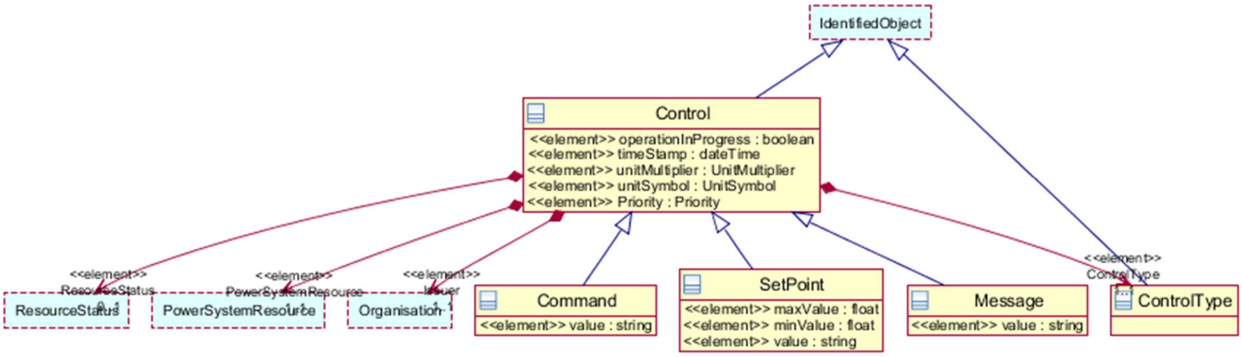

Figure 10 - Control Module Overview

A generic control class is used for supervisory/device control. It represents control outputs that are used to change the state in a process, e.g. close or open breaker, a set point value or a raise lower command.

Furthermore, a Control Type enumeration which specifies the type of Control is defined, e.g. Breaker On/Off, Generator Voltage Set Point etc. The ControlType name shall be unique among all specified types and describe the type.

DYSON_EXCEPTION	Used for error messages
COMMAND	Specific command for control process
MESSAGE	A Message type to be translated in EMS level
SETPOINT	Defines the level for control operation

Table 9 - Control structure

The goal of BESOS project is to support both monitoring and control operations, and thus we have defined this extra module for managing control activities. By decoupling this control module from the monitoring functionalities of asset types, we promote a modular and dynamic approach on the management of the different data types (different asset types are associated with different control capabilities). This modelling approach further promotes the transferability of the solution to other case studies and domains.

3.2. CONCLUSIONS

The goal of this section was to provide the updated and final version of BESOS CIM, considering the integration of additional asset types during the 3rd project period. The goal of this report is not to extensively present the details of the concepts and structures defined in BESOS CIM (as the modelling details have been presented in the previous versions of the deliverables) but to present the overall framework, further ensuring the transferability of this approach in different case studies.

The main modelling principles considered for the provision of BESOS CIM are:

- **Standards Integration:** The goal of BESOS project was to adopt existing standards to further support the ease adaptation of BESOS platform in existing infrastructures. IEC

CIM is a mature and widely adopted standard, setting the base for the provision of BESOS CIM.

- **Modularity:** towards the provision of a dynamic modelling framework that can be easily expanded in different case studies. By decoupling the different data classes of BESOS CIM to the hierarchical data modules, we promote a fully dynamic and adaptive framework that can be easily transferred to different business domains and case scenarios.
- **Common ground modelling**: The overall modelling was performed following standards based principles (UML and XML) and thus BESOS CIM is available in a way that can be easily consumed and further adapted/ extended by third parties. This was the development decision to support the transferability of BESOS CIM in other case studies.

The main innovation of the proposed BESOS CIM is that acts as a meta model that combines information from different standards towards the provision of an end to end modelling framework for smart cities. The proposed model covers both management layers: **asset management layer** responsible for the management of assets and device types (monitoring and control functionalities are supported) and the **business management layer** through the provision of a flexible modelling framework for the management of new business strategies, models and business roles.

The aforementioned modelling principles were adopted at the definition of BESOS CIM, to support project activities and enable further exploitation of BESOS outcomes, considering the requirements for transferability of BESOS solution as one of the main objectives of the project. A detailed view on how BESOS CIM can be further exploited as a guideline for similar projects is presented in Section 4.

4. Transferability to other cities

4.1. INTEGRATION WITH LISBON SMART CITY PLATFORM

The City of Lisbon is playing a central role in aggregating a large consortium of partners in this big-scale real open-innovation project called COI (Integrated Operation Centre), where all the smart city intelligence will be gathered for municipal management and to be shared and made available for citizens, entrepreneurs, universities and research centres.

The Municipality has been developing this project since 2014. The COI is the place where all the local city operational management teams will be gathered, with access to a video-wall/dashboards for city management, and an ICT platform that will deliver city-wide management information and intelligence regarding resource allocation and operations management. The operations centre technological architecture and components will be fully compliant with open standards and a platform for city information systems interoperability, both internal from the municipality and external, will be deployed creating an open innovation digital ecosystem.

The European Commission (EC) has identified the socio-ecological transition as a major challenge for the future roadmap of development, and the “Quintuple Helix” innovation model fully supports the EC vision, creating, through the interplay between the innovation, **knowledge** and **ecology** dimensions, the necessary synergies between **economy**, **society** and **democracy**.

Moreover, Lisbon is a Lighthouse City through the SCC1-2015 SHARING CITIES project, funded under the H2020 Programme. Through this project, Lisbon and PT Inovação is developing an Urban Sharing Platform (USP). The USP is a logical collection of technical components, capabilities and processes which provides functions and services that enable a Smart City. Its purpose is to aggregate **energy data** and control functions from a wide variety of devices and sensors, store, process, correlate the data and present information to the city and citizens which enables better use of the city resources and may provide support for innovative service verticals. In that sense, the integrations done in BESOS project will be reused enabling applications to access to municipality buildings information related with energy consumption and production.. The USP is being built following the EIP-SCC Urban Platforms cluster, which support the development and spread of interoperable platforms. This cluster’s goal is to give the guidelines for the development of a core building block by which cities better manage the big volumes of city data and more easily share this data between city services in order to improve outcomes for society.

The interoperability between the COI and the USP will be achieved through a data communication broker, which is being developed by PT Inovação. This broker will allow the COI to access energy data from the USP and to integrate with operational information (e.g. mobility).

The City as a large scale open innovation laboratory is Lisbon’s ambition. First within the prototype districts in the city of Lisbon, but after testing and iteration with our pan-European partners and cities from the consortium, sustainable business models will allow for the solutions and models to be scaled up and replicated at city wide and international level.

By establishing a constant cooperation and knowledge exchange platform between research institutes, other key actors and the citizenship, the city could gain support in regard to the many challenges that require high levels of expertise. To prove this, Lisbon will host ta Web Summit for the next 3 years.

The Web Summit is centred on internet technology and attendees range from Fortune 500 companies to the world’s most exciting tech companies. This contains a mix of CEOs and founders of tech start-ups together with a range of people from across the global technology industry, as well as related industries. Web Summit has grown from 400 attendees to over 50,000 attendees from more than 150 countries. No technology conference has ever grown so large so fast. Web Summit has become “Europe’s largest and most important technology marketplace”. An unrivalled global meeting place for the world’s most disruptive technology companies and those interested in how that disruption can transform their businesses and their lives.[2]

The Web summit and the USP are related once the first will have specific areas dedicated to urban management and smart cities, and the second corresponds to an innovative platform, which will promote the use and re-use of energy data, in an open innovation ecosystem. Business opportunities and transferability is clear with the development of solutions, tools and applications, using the information available in the open urban platform.

4.2. INTEGRATION WITH BARCELONA SMART CITY PLATFORM

Barcelona City Council has been developing during the last five years an ICT architecture designed to support the so called Smart City Projects. These projects have common characteristics that require special attention:

1. High use of ICT.
2. Most of the projects are open to extending/reviewing their scope considering the ongoing results.
3. The evolution of these projects is continuously reviewed.
4. The technologies used are not mature. Innovation is high, but so are risks.
5. In some cases the technology does not exist yet and, somehow, the development of the required technology is one of the goals of the project.

For all these reasons, flexibility is a must. It is also a must to both control the evolution of the development and to adapt it to the requirements of the project, which are often updated during its life-time.

Moreover, when dealing with continuously changing needs and requirements, the model of project development where one starts with the requirements and then defines the ICT to support them, is no longer valid. Therefore, the paradigm has to be turned around: we have to define a common ICT infrastructure for all the Smart City projects running in Barcelona, so that it is capable of supporting all the needs that may arise, both now and in the future.

As one of the common key aspects in smart projects deals with the harvesting and processing of the huge amount of data generated in the city, Barcelona's bet was to define an ICT platform to support all urban smart projects based not on final requirements, but on what is common to all projects: **the life cycle of the data**.

Hence, in Barcelona, we understand data life cycle is as follows:

1. Data gathering.
2. Data storage and security.
3. Data homogenization and cataloguing → Ontology.
4. Data processing: analytics, simulation, prediction, etc. → Big Data.
5. Data sharing: open data, open API → Semantics.

[2] https://websummit.net/

6. Data availability to operational IT systems.
7. Data consolidation.
8. Optional: Data deletion.

Data deletion is marked as optional, as we believe that the trending will be to preserve all data and erase none.

What we have conceptualized is an ICT architecture that supports this data cycle. This allows us to count on a framework that allows providing common functionalities to all present and future projects while dropping cost dramatically. The platform and data life cycle is summarized in the following schema:

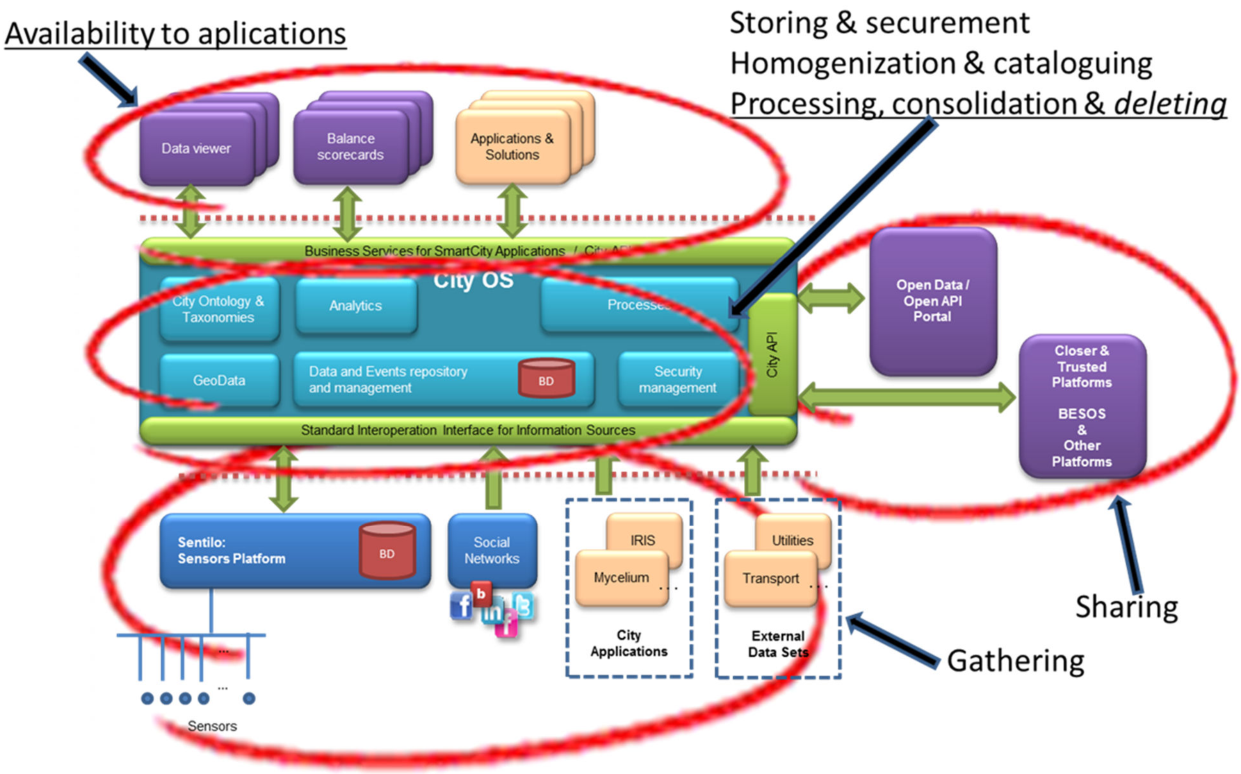

Figure 11 - Barcelona Smart City Platform

BESOS adapted EMS and applications (cockpits) connect with the Urban Platform through City API (Application Program Interface) and are certified as Closer & Trusted Platforms. Unfortunately, the central piece of the architecture of Barcelona, CityOS, has suffered some delays and is not yet available. Thus, within the project, the connection of BESOS platform to the Barcelona City Council information systems has been made directly to Sentilo, the sensor manager platform that, acting as a broker, receives data from the systems deployed in the city (in this case, lighting and energy monitoring in municipal buildings) and sends them immediately to the applications that consume them. Once CityOS is again available, migration will be trivial, since the same API Sentilo provides will be offered for CityOS.

For now, the development of BESOS in Barcelona, which is fully integrated with the Barcelona Smart City platform, follows the schema below:

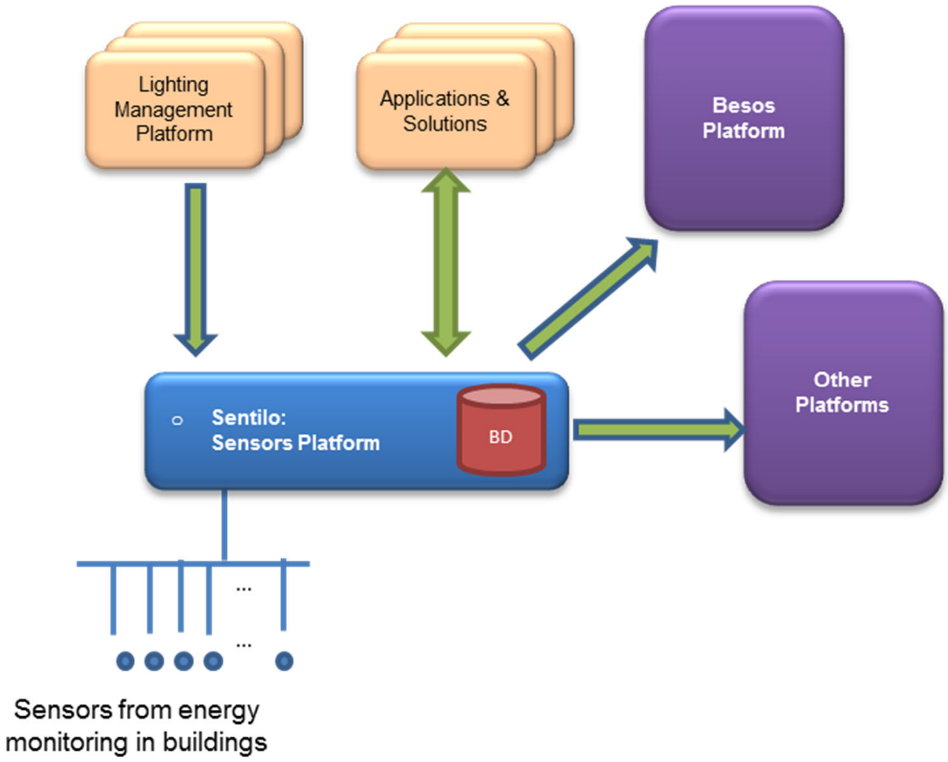

Figure 12 - BESOS integration with Barcelona Smart City Platform

Any other application that needs data exchanging with Barcelona City Council information systems will follow this second schema –tested and demonstrated in BESOS–, and will be migrated to the schema in Figure 11 as soon as CityOS is available again (expected September 2017).

4.3. TOWARDS OPEN URBAN PLATFORMS FOR SMART CITIES AND COMMUNITIES

In addition to the active participation of Lisbon and PT at the Urban Platform Initiative, ETRA has been playing a leading role as one of the first signatories of the MoU sitting together cities and industry in this initiative – actually ETRA is chairing two of the three working groups of the industrial cluster.

The "Urban Platform" sits within the European Innovation Partnership (EIP) and seeks to accelerate the adoption of urban platforms across EU cities. Specifically that by 2025 300 million EU citizens are served by platforms within their cities.

The initiative comprises three core elements:

- Demand-Side – to define common requirements and speed adoption.
- Supply-Side – to bring together EU Industry to adopt common open solutions.
- Standardisation – to formalise the capture of the core content as international standards[3].

[3] https://eu-smartcities.eu/content/urban-platforms

Whilst Lisbon is one of the 25 cities part of the Demand-Side, ETRA is involved at the Supply-side, which enables the easy transition of the BESOS approach towards specific contribution in the definition of an open common reference architecture for Urban Platforms.

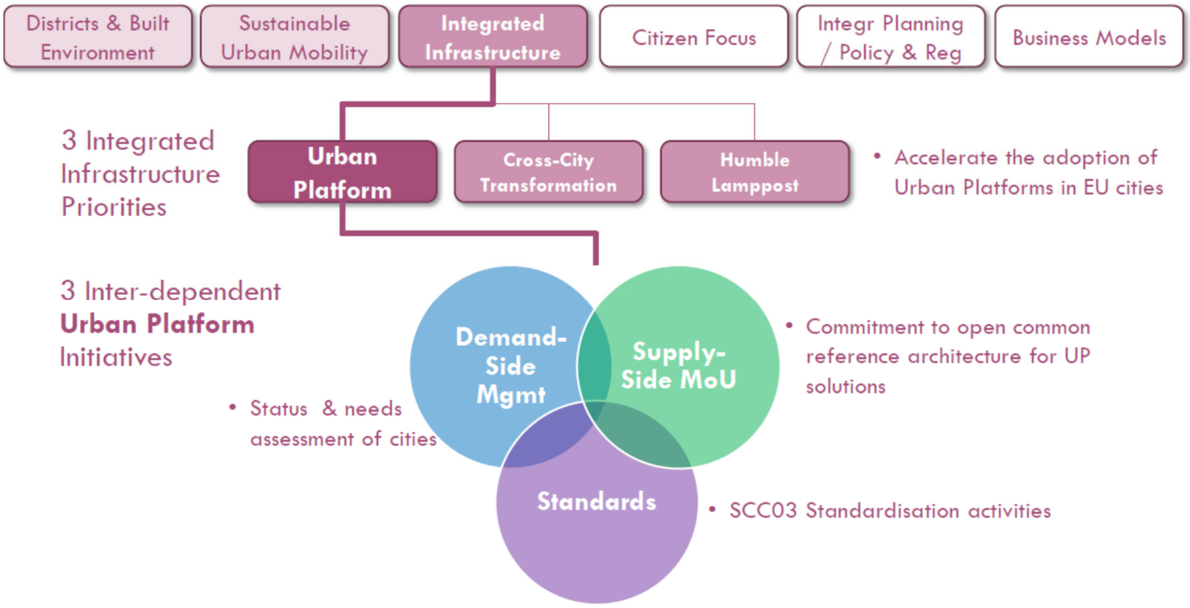

Figure 13 - Urban Platform Initiative with the overall EIP concept.

The industry group – i.e. Supply-side - has defined already the following objectives for the future, with a clear **roadmap** that includes: by 2016 to have reference templates for tenders in place to allow cities to plan in an integrated way; by 2018, to create a strong EU city market for Urban Platforms; and by 2025, to ensure that the market of 300m residents of EU cities use Urban Platform(s) to manage their business with a city and that the city in turn drives efficiencies, insight and local innovation through the platform(s).

*Strategic **Longer-Term** Objectives*	*Tactical **Shorter-Term** Objectives*
1. Accelerate the opening up of the Smart Cities Market 2. Ensure suitable industry input, and an open dialogue with cities and communities in order to take into account their **needs and concerns** 3. Develop the Urban Platform **open market** by creating competition for supply side and confidence for demand side 4. Build capacity within cities 5. Help align EC policy & funds with market needs 6. Support **longer-term competitiveness** of EU industries to export worldwide	1. Expand signatories of the MoU 2. Speed the development of a common open platform for cities 3. Demonstrate real value from **exploiting city data t**hrough use of urban platforms 4. Align capabilities across Industry sectors 5. Help **bring supply & demand** together; and find incentives / funds

Table 10 - Supply-Side next objectives

The main focus is on

- Interoperability.
- Integration / Re-use and re-purposing of data.
- Open APIs.

In this context, within the supply-side, three different working groups have been defined: Architecture; Business Models and Standards. ETRA is actively participating in all three of them, and leading the two last ones. This offers BESOS a great opportunity to affect the future definition of a common reference architecture ensuring the interoperability among smart City platforms.

The lesson learnt with the architecture defined in BESOS, as well as the CIMs, will be used in the next years at the industry group to drive the definition of a truly open architecture, accessible to any city (demand) and industry (supply) . The objective is to avoid any vendor lock-in situation, and facilitate the deployment of heterogeneous developments in any city.

4.4. BESOS PROPOSAL FOR COMMON INFORMATION MODELLING IN SMART CITIES

All the functionalities implemented in BESOS platform require an increase in information exchanges and therefore a syntactic and semantic understanding of a variety of different domains. For these reasons, the challenges that have been faced are the following:

- Heterogeneous and distributed nature of the information resources (e.g., asset data, application data, external services etc.)
- Multiple data models that have been integrated and mapped to the requirements of the involved services and tools
- Heterogeneous and distributed nature of the software tools
- Technical issues related to the information availability, especially with regard to building management systems (BMS), and
- Various legal issues related to warranties, information access, security, and so on.

To provide a solution to them, the following activities have been carried on, in particular:

- Identification of existing standards and exploitation of common data models in order to fully leverage project exploitation and replication potential.
- Definition of a common language enabling the inter-domains communication and data representation.
- Definition of physical interfaces based on the common information model identified within the scope of the project.

The CIM modelling framework defined in BESOS project has been based on widely adopted standards of the field and further integrates aspects specific for the domains of interest of BESOS framework. The global standards-based framework acts as intersection of all these local entities and it is used to facilitate reusing of concepts and mapping of local data elements. The global framework can be also understood as the skeleton of BESOS CIM which results from the union of all local common entities.

The proper definition of a semantic framework enables the identification of an "agreement" on a common definition and structuring of the identified concepts between people/actors with different skills and expertise in related domains like ICT, energy, or building management systems.

This is the core objective of BESOS CIM to the definition of a common information model that promotes the establishments of a semantic framework for smart cities management, by exploiting and further extending the existing standardization efforts on the domain.

Following the high level principles for the definition of BESOS data model, the first task is the adaptation of existing standards. The focal point for our modelling methodology and approach has been the IEC CIM.

IEC CIM defines a framework for power systems management and associated information exchange, covering communications between equipment and systems in the electric power industry – a central element in smart buildings, Smart Cities and Smart Grid projects.

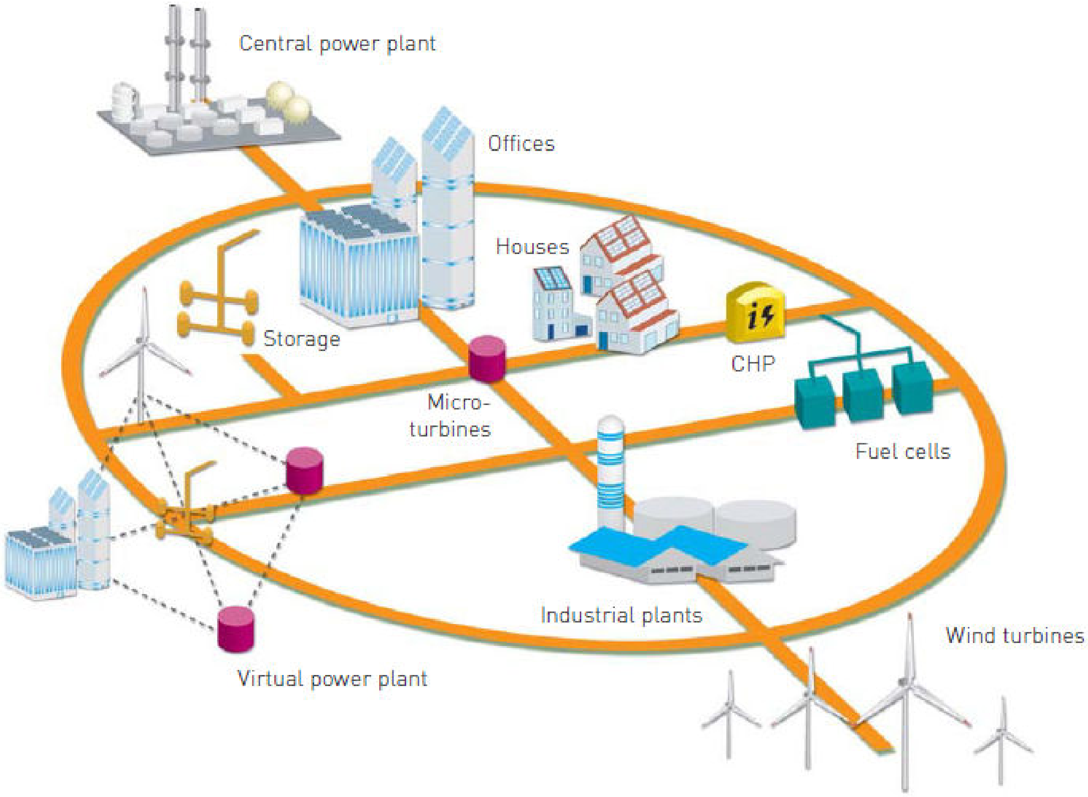

Figure 14 - Smart Grid vision of the European Technology Platform SG

The IEC CIM is a very extensive standard, one that includes 3 top-level packages addressing Transmission, Distribution and Energy Markets. More specifically, the CIM is standardized within three different IEC standard series, namely IEC 61970, IEC 61968 and IEC 62325. Each of them has a different background and covers different use cases. However, all of them consist of many sub parts which are under continuous development lead by distinct working groups. Since they all rely on the same data model strong liaisons have been established and the CIM user group was founded as a central place for discussions and cooperations. The three standard series have the following focus:

- IEC 61970: deals with "Energy Management System Application Program Interfaces (EMS-API)" and is maintained by IEC TC 57 WG 13. Against the background of providing a comprehensive integration framework, the standard series specifies various components. Beside an extensive data model defined within IEC 61970-301, it contains CIS as well as GID. One of the pursued objectives is to develop a platform independent data model using technology independent services which is continuously improved. However, mappings to specific technologies are or will be specified like RDF, XML and OWL.
- IEC 61968: is called "Application Integration at Electric Utilities - System Interfaces for Distribution Management" and contains (amongst others) the IRM for the CIM. In contrast to the CIS/GID where generic interfaces are defined within IEC 61970, the

IRM specifies detailed use cases for coupling two systems and the according exchanged XML messages. Thereby, the focus is not on the CIM objects primary needed for grid operations, but on secondary objects like billing and network extension. The CIM base data model defined in IEC 61970-301 is extended with further objects within IEC 61968-11. The addressed interfaces cover message exchange for network operations, records and asset management, operational planning and optimization, maintenance and construction, network extension planning, customer support, and meter reading and control. The standard series is maintained by the IEC TC 57 WG 14.

- IEC 62325: is maintained by IEC TC 57 WG 16 and includes a set of standards describing a "framework for energy market communications". The scope is to develop standards for electricity market communications on the premise to use the IEC TC 57 CIM. Communications between market participants and market operator as well as communication among market operators are covered by the standard series.

The amount of work required in for a good overview and understanding of its philosophy and what it covers is not trivial. Thankfully, the fact that the TC57 working group has approached the issue by not only working to unify the IEC standards, but also providing a tool (CIMTool) to promote working with the standards has provided a huge reusability boost. Instead of having to go through endless pages of documentation, the CIMTool with its navigation and search capabilities has served as a quick reference for the IEC CIM, helping modelers familiarizing themselves and promoting their knowledge of the standard.

In addition to its sheer size, the IEC CIM is not always the most straightforward of data models. As it is the result of work that has spanned a significant number of organisations and people over the years and its goal it to cover the electricity domain in a very broad perspective. Therefore, in many cases there is a multitude of modelling constructs used to represent a multitude of views and aspects. On the other hand, we had to consider that:

a. The needs of BESOS are very specific, and not every aspect that the IEC CIM covers is needed. Therefore, in many cases we were faced with the dilemma of simplicity versus compatibility: by fully adopting the IEC CIM approach, we would introduce complexity that is not really required for BESOS, as the same goal could have been achieved by a simpler modelling approach.
b. Conversely, not every aspect of the domain BESOS needs to capture is covered by the IEC CIM. Therefore, in many cases we needed to devise new concepts and properties that would have to be organically integrated with existing ones.

Therefore, the decision was to go with a high level adaptation of IEC CIM domains and aspects (global layer of BESOS data model) and further to extend the current version with project specific attributes (local level data entities).

Following this modular approach on the development of BESOS data model, the starting point of the work is the provision of the skeleton for the model, taking into account the structure of existing standards in energy domain. The data model was broken down to 7 logical modules in order to facilitate cohesion and reusability. The logical modules also correspond to physical ones, so there are 7 XSD files.

- **Location:** This module includes concepts used to capture information related to location, as well as root concepts that are used throughout the data model and have been included here for convenience. The location structure covers all attributes related to the geographical topology of assets that are part of the portfolio of an ESCO/ Manager/ Municipality.

- **Organisation & Users:** This module includes concepts capturing information about organisations as well as users. These have been adopted by the IEC CIM and enhanced with additional properties to accommodate BESOS needs.
- **Asset Structure:** This module includes concepts capturing information about Assets. It does not contain information on specific asset types or measurements (included in other modules), rather it defines the concept of an Asset and its main supporting concepts.
- **Assets Representation:** This module includes concepts capturing information about specific types of Assets. As the physical representation of Assets is used for this purpose, all concepts are associated with the Asset class and the logical representation of the whole entities system
- **Measurements & KPIs:** This module includes concepts capturing information that help keep track of dynamically evolving attributes (Measurement) used themselves to display and aggregate as well as KPIs defined utilizing these measurements.
- **DocumentTypes:** This module includes concepts capturing information related to the business – strategic aspects of BESOS. More specifically, it models concepts having to do with SLAs and Business Strategies to achieve them.
- **Control Structure:** This module includes concepts capturing information related to control commands as delivered from the Application level to the EMS level in order to proceed with the implementation of the control strategies defined.

This high level segmentation to the associated modules (global layer of data model) covers all functionalities related *to assets monitoring and control functionalities* examined in the project. The high level representation of data classes, following IEC CIM, enables the easy replication and transformation of the solution to other smart cities solutions. Concepts related to physical (Location, Asset Structure, Measurements, Control) and business (Organizations, Document Types) structure of a portfolio are identified at any smart cities management project, supporting that way the transferability of the proposed modelling framework.

On the other hand, the modular approach adopted for the data model structure enables the customization of the global structure to specific project needs (local layer of data model). More specifically, for the needs of BESOS project we highlight:

- **Organisation & Users:** where we defined additional attributes associated with the roles of ESCOs and Authorities as the main stakeholders examined in the project
- **Assets Representation:** This dynamic module was extended to cover the different types of assets examined in BESOS project:
  - Public buildings with the associated device types: HVAC, Lighting, Chillers etc…
  - RES Generation units further segmented to wind generation and photovoltaics.
  - Public Lighting and Traffic Lighting energy management systems
  - Electric Vehicles charging points integrated to the BESOS platform

  and the virtual entities:
  - Mobility structure providing traffic density data and further associated with Traffic Lighting energy management systems
  - Forecasting structure providing generation and consumption forecasting data to the platform.
- **Measurements & KPIs:** This module was customized to cover the specific metrics and KPIs examined in the project. The data model is structured in a way to enable the association of KPIs with the relevant metric types

- **DocumentTypes & Control Structure** were also defined in way that covers BESOS project specific requirements. We have to point out though, that these modules are providing in a way to cover all possible business and technical implementations at smart cities applications.

The detailed structure of BESOS data model was provided in D2.1.1 “Reference Architecture and Data Models” while in the second version of the deliverable D2.1.2 “Reference Architecture and Data Models” we documented the project specific views with final revision of this work in Section 3 of this document. This clear segmentation of work was performed taking into account the project requirement for transferability of BESOS solution to other Smart Cities. By defining the different classes and modules we can easily wrap up BESOS CIM work and exploit this in a flexible way. This approach is further addressed in the exploitation plan for BESOS project, documented in D82.2.2, where a detailed plan is provided for further exploitation of BESOS CIM.

5. Conclusions

Back in 2013, when the project initiated its activities, and even before, when the project started to be planned among the core partners of the BESOS consortium, the concept of a Smart City was something still under definition, without any practical implantation of any of the Smart Platforms that nowadays are being deployed in most of European cities. Thus, the project was forces to specify – with the support of Lisbon and Barcelona – its own architecture of what was going to be needed to act as an Energy-oriented smart City Platform. The outcome of this effort is what can be found in this deliverable: and architecture and CIM that has serve the project to evaluate Smart-City Applications in two pilots that were not provided yet with Smart City Platforms.

Obviously, the objective of BESOS was never the definition of a high level ICT urban platform – extensively tackled in other bigger projects – but to provide an open reference of the framework needed to attend one of the main pillars of any Smart City: the energy management. It is in this context, that the project produced back in 2014 its first reference architecture and CIM, implemented, deployed and validated later in BESOS pilot sites.

Once the main objective of the project architecture – support the validation of BESOS developments – was fulfilled, the consortium started looking at what could be the future for the architecture defined in the project. Not being a full Smart City Platform – only the energy area is covered – the options were to escalate the solution trying to become one of the many urban platforms that are competing in Europe – with some major players already marketing its property solutions – or to use the know-how gained in order to affect future standards and especially the definition of a common open reference architecture promoted by the Smart Cities EIP.

The second option has finally prevailed, much more, the project has ensure that the developments validated in Lisbon and Barcelona are seamlessly integrated with the Urban Platforms being deployed at each city.

6. References and Acronyms

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3. BESOS Consortium, D1.3 “D1.3 Key Performance Indicators”, 2014
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ACRONYMS

Acronyms List	
BBSC	Business Balanced Score Card
BMA	Mobile Applications for behavioural modification
CEP	Complex event processing
CIM	Common Information Model
CRUD	Create, read, update and delete
DoW	Description of Work
DSSC	Decision Support System Cockpit
ECF	Energy Consumption Forecasting
EMS	Energy Management Systems
EPF	Energy Production Forecasting
EPQ	Electrical Power Quality
ESCOs	Energy Service Company
EV	Electric Vehicles
FM	Facility Manager
GW	Gateway
KPIs	Key Performance Indicators
nMAE	normalized Mean Average Error
nRMSE	normalized Root Mean Square Error
NWPs	Numerical weather predictions
OTESP	Open Trustworthy Energy Services Platform
PHEV	Plug-in Hybrid Electric Vehicles
PoL	Point of Light
PPM	Parts per million
R&D	Research and Development

RES	Renewable Energy Sources
S&P	Storage and prediction
SC	Segment Controller
SLAs	Service Level Agreements
UML	Unified Modelling Language
V2G	Vehicle to Grid
VA	Visual Analytics
WD	Weather Data
WP	Work Package

ANNEX A

As part of the 1st version of the deliverable, the main concepts and attributes of BESOS data model have been defined. Here, we summarize the data classes that have not been updated but together with the ones reported on Section 4, set the overall documentation of BESOS data model. We follow the common methodological approach through the documentation of the high level modules that have been initially defined.

Location

This module includes concepts used to capture information related to location.

StreetAddress

General purpose street address information relevant to the entity examined

streetDetail	1..1	StreetDetail	Street detail.
townDetail	1..1	TownDetail	Town detail.

StreetDetail

Street details, in the context of the address associated.

addressGeneral	1..1	string	Additional address information, for example a mailstop.
buildingName	1..1	string	(if applicable) In certain cases the physical location of the place of interest does not have a direct point of entry from the street, but may be located inside a larger structure such as a building, complex, office block, apartment, etc.
code	1..1	string	(if applicable) Utilities often make use of external reference systems, such as those of the town-planner's department or surveyor general's mapping system, that allocate global reference codes to streets.
name	1..1	string	Name of the street.
number	1..1	string	Designator of the specific location on the street.
prefix	1..1	string	Prefix to the street name. For example: North, South, East, West.
suffix	1..1	string	Suffix to the street name. For example: North, South, East, West.
suiteNumber	1..1	string	Number of the apartment or suite.
type	1..1	string	Type of street. Examples include: street, circle, boulevard, avenue, road, drive, etc.
withinTownLimits	1..1	boolean	True if this street is within the legal geographical boundaries of the specified town (default).

TownDetail

Town details, in the context of address.

code	1..1	string	Town code.
country	1..1	string	Name of the country.
name	1..1	string	Town name.
section	1..1	string	Town section. For example, it is common for there to be 36 sections per township.
stateOrProvince	1..1	string	Name of the state or province.

TelephoneNumber

Telephone number, in the context of the details for premises

areaCode	1..1	string	Area or region code.
cityCode	1..1	string	(if applicable) City code.
countryCode	1..1	string	Country code.
extension	1..1	string	(if applicable) Extension for this telephone number.
localNumber	1..1	string	Main (local) part of this telephone number.

PositionPoint

Set of spatial coordinates that determine a point, defined in coordinate system specified in 'Location.CoordinateSystem'. Use a single position point instance to describe a point-oriented location. Use a sequence of position points to describe a line-oriented object (physical location of non-point oriented objects like cables or lines), or area of an object (like a substation or a geographical zone - in this case, have first and last position point with the same values).

sequenceNumber	1..1	integer	Zero-relative sequence number of this point within a series of points.
xPosition	1..1	string	X axis position.
yPosition	1..1	string	Y axis position.
zPosition	1..1	string	(if applicable) Z axis position.
Location	1..1	Location	Location described by this position point.

Location

The place, scene, or point of something where someone or something has been, is, and/or will be at a given moment in time. It can be defined with one or more position points (coordinates) in a given coordinate system.

direction	1..1	string	(if applicable) Direction that allows field crews to quickly find a given asset. For a given location, such as a street address, this is the relative direction in which to find the asset. For example, a streetlight may be located at the 'NW' (northwest) corner of the customer's site, or a usage point may be located on the second floor of an apartment building.
geoInfoReference	1..1	string	(if applicable) Reference to geographical information source, often external to the utility.
type	1..1	string	Classification by utility's corporate standards and practices, relative to the location itself (e.g., geographical, functional accounting, etc., not a given property that happens to exist at that location).
CoordinateSystem	1..1	CoordinateType	Coordinate system used to describe position points of this location.
electronicAddress	1..1	ElectronicAddress	Electronic address.
mainAddress	1..1	StreetAddress	Main address of the location.
phone1	1..1	TelephoneNumber	Phone number.
phone2	1..1	TelephoneNumber	Additional phone number.
secondaryAddress	1..1	StreetAddress	Secondary address of the location. For example, PO Box address may have different ZIP code than that in the 'mainAddress'.
status	1..1	Status	Status of this location.

Organisation & Users

This module includes concepts capturing information about organisations as well as users.

Organisation

Organisation as examined in BESOS project might have roles as utility, contractor, supplier, manufacturer, customer, etc. This class extends IdentifiedObject.

electronicAddress	1..1	ElectronicAddress	Electronic address.
phone1	1..1	TelephoneNumber	Phone number.
streetAddress	1..1	StreetAddress	Street address.
AssetsOwned	0..n	Asset	All assets this organizations owns
AssetsMaintained	0..n	Asset	All assets this organizations maintains

ElectronicAddress

Details about Electronic address information of organization.

email1	0..1	string	Primary email address.
email2	0..1	string	Alternate email address.
lan	0..1	string	Address on local area network.
mac	0..1	string	MAC (Media Access Control) address.
password	0..1	string	Password needed to log in.
radio	0..1	string	Radio address.
userID	0..1	string	User ID needed to log in, which can be for an individual person, an organisation, a location, etc.
web	0..1	string	World wide web address.

UserGroup

Users are organized in groups, in order to streamline permissions. It extends IdentifiedObject.

Priority	1..1	Priority	User group priority
creationTime	1..1	dateTime	Group time of creation.
Users	0..n	User	Users belonging to this group
Permissions	1..n	Permission	Permissions granted to users belonging to this group.

Asset Structure

This module includes concepts capturing information about Assets.

Asset

This concept has been adopted from IEC CIM and is used to represent the logical manifestation of a piece of equipment, as opposed to the physical one for which the PowerSystemResource is used. It extends IdentifiedObject.

ActivityRecords	1..unbounded	ActivityRecord	All activity records created for this asset.
AssetContainer	1..1	AssetContainer	Container of this asset.
Lifecycle	1..1	LifecycleDate	Lifecycle dates for this asset.
Location	1..1	Location	Location of this asset.
Status	1..1	Status	Status of this asset.
TypeAsset	1..1	TypeAssetCatalogue	Type of this asset
CurrentTimeSchedule	0..n	TimeSchedule	Current schedule for the asset
HistoricTimeSchedule	0..n	TimeSchedule	Past schedule for the asset
Priority	1..1	Priority	The asset's priority

PowerSystemResource

This concept has been adopted from IEC CIM and is used to represent the physical manifestation of a piece of equipment, as opposed to the ***logical one for which the Asset*** is used. It extends IdentifiedObject.

Assets	1..unbounded	Asset	All assets represented by this power system resource. For Besos, multiple conductor assets are electrically modelled as a single AC line segment. For Besos, it is expected that a 1-1 association will always be used
Measurements	1..unbounded	Measurement	The measurements associated with this power system resource.
CurrentStatus	1..1	ResourceStatus	Current status of the resource
AllowedStatuses	1..n	ResourceStatus	Allowed statuses of the resource

AssetContainer

This is an asset that is aggregation of other assets such as conductors, transformers, switchgear, land, fences, buildings, equipment, vehicles, etc. It extends Asset.

Assets	1..unbounded	Asset	All assets within this container asset.

EMS Structure

An EMS, as a core entity in BESOS project, is modelled as an Asset Container. It extends AssetContainer. In order to define the impact of the EMS within the BESOS, the association with one or more KPIs is considered.

KPIs	0..unbounded	KPI	The KPIs associated with this EMS

TimeSchedule

This is the description of anything that changes through time. Time schedule is used to perform a single-valued function of time. Use 'type' attribute to give additional information on this schedule, such as: periodic (hourly, daily, weekly, monthly, etc.), day of the month, by date, calendar (specific times and dates).

disabled	1..1	Boolean	True if this schedule is deactivated (disabled).
type	1..1	String	Define the type of the schedule for the respective Asset
offset	1..1	Seconds	The offset from midnight (i.e., 0 h,

			0 min, 0 s) for the periodic time points to begin. For example, for an interval meter that is set up for five minute intervals ('recurrencePeriod'=300=5 min), setting 'offset'=120=2 min would result in scheduled events to read the meter executing at 2 min, 7 min, 12 min, 17 min, 22 min, 27 min, 32 min, 37 min, 42 min, 47 min, 52 min, and 57 min past each hour.
recurrencePattern	1..1	string	Interval at which the scheduled action repeats (e.g., first Monday of every month, last day of the month, etc.).
recurrencePeriod	1..1	Seconds	Duration between time points, from the beginning of one period to the beginning of the next period. Note that a device like a meter may have multiple interval periods (e.g., 1 min, 5 min, 15 min, 30 min, or 60 min).
scheduleInterval	1..1	DateTimeInterval	Schedule date and time interval.
requestingUser	1.1	User	Defines the User that requests the specific Schedule

ActivityRecord

Records activity for an entity at a point in time; activity may be for an event that has already occurred or for a planned activity. It extends IdentifiedObject

createdDateTime	1..1	dateTime	Date and time this activity record has been created (different from the 'status.dateTime', which is the time of a status change of the associated object, if applicable).
reason	1..1	string	Reason for event resulting in this activity record, typically supplied when user initiated.
severity	1..1	string	Severity level of event resulting in this activity record.
type	1..1	string	Type of event resulting in this activity record.
isAlarm	1..1	boolean	True if the ActivityRecord concerns an alarm event
Priority	1..1	Priority	The ActivityRecord's priority

LifecycleDate

This class represents the dates for lifecycle events of an asset.

installationDate	1..1	date	(if applicable) Date current installation was completed, which may not be the same as the in-service date. Asset may have been installed at other locations previously. Ignored if asset is (a) not currently installed (e.g., stored in a depot) or (b) not intended to be installed (e.g., vehicle, tool).
manufacturedDate	1..1	date	Date the asset was manufactured.
purchaseDate	1..1	date	Date the asset was purchased. Note that even though an asset may have been purchased, it may not have been received into inventory at the time of purchase.
receivedDate	1..1	date	Date the asset was received and first placed into inventory.
removalDate	1..1	date	(if applicable) Date when the asset was last removed from service. Ignored if (a) not intended to be in service, or (b) currently in service.
retiredDate	1..1	date	(if applicable) Date the asset is permanently retired from service and may be scheduled for disposal. Ignored if asset is (a) currently in service, or (b) permanently removed from service.

Assets Representation

This module includes concepts capturing information about specific types of Assets. The whole set of classes has been updated and extended.

Measurements & KPIs

This module includes concepts capturing information that help keep track of dynamically evolving attributes (Measurement) used themselves to display and aggregate as well as KPIs defined utilizing these measurements.

MeasurementValue

This class represents the current state for a measurement. A state value is an instance of a measurement from a specific source. Measurements can be associated with many state values; each representing a different source for the measurement. It extends IdentifiedObject

sensorAccuracy	1..1	PerCent	The limit, expressed as a percentage of the sensor maximum, that errors will not exceed when the sensor is used under reference conditions.
timeStamp	1..1	dateTime	The time when the value was last updated
value	1..1	string	Value at 'timeStamp'; prior values are kept in instances of Measurement Values associated with the Measurement to which this Measurement Value applies
MeasurementValueSource	1..1	MeasurementValueSource	A reference to the type of source that updates the MeasurementValue, e.g. SCADA, CCLink, manual, etc. User conventions for the names of sources are contained in the introduction to IEC 61970-301.

MeasurementValueSource

MeasurementValueSource describes the alternative sources updating a MeasurementValue. User conventions for how to use the MeasurementValueSource attributes are described in the introduction to IEC 61970-301. It also extends IdentifiedObject

PowerSystemResource	1..1	PowerSystemResource	A reference to the PowerSystemResource that has recorded a measurement

KPIValue

This class represents the current state for a KPI. A state value is an instance of a KPI from a specific source. KPIs can be associated with many state values, each representing a different instance for the KPI. It extends the IdentifiedObject class

timeStamp	1..1	dateTime	The time when the value was last updated
Value	1..1	string	Value at 'timeStamp'; prior values are kept in instances of KPI Values associated with the KPI to which this KPI Value applies
KPIValueSource	1..1	KPIValueSource	A reference to the source that updates the KPIValue - i.e. EMS

KPIValueSource

KPIValueSource has been modelled after MeasurementValueSource to describe the sources (EMSs) that update KPI values. Extends IdentifiedObject

EMS	1..1	EMS	A reference to the EMS that has calculated a KPI

TimeSeries

A TimeSeries is used to define intervals over which aggregated Measurements are calculated, including which measurement to calculate, aggregation type and step. Extends IdentifiedObject

DateTimeInterval	1..1	DateTimeInterval	Interval for the time series
description	0..1	string	Description for the time series
Measurement	1..1	Measurement	The measurement to be aggregated - returned
Measurement SeriesType	1..1	MeasurementSeries Type	How to aggregate the measurement
Step	1..1	Step	Step to aggregate the measurement

Step

This is the definition of step for time series. Extends IdentifiedObject

StepResolution	1..1	integer	The step resolution, i.e. how many units should be calculated together
StepUnit	1..1	string	Time unit of calculation
StepOrientation	1..1	StepOrientation	Step orientation of calculation

StepOrientation

This is an enumeration class that specifies the way that a time interval should be defined for calculations. The values for StepOrientation are:

UNKNOWN	The orientation of the time stamp is unknown
LEFT	The timestamp is left sided, e.g. an timestamp of “2014-06-01T08:00:00+00” means, the value is recorded in the interval of 07:45-08:00
RIGHT	The timestamp is right sided, e.g. an timestamp of “2014-06-01T08:00:00+00” means, the value is recorded in the interval of 08:00-08:15

MIDDLE	The timestamp relates to the middle of the interval, e.g. an timestamp of “2014-06-01T08:00:00+00” means, the value is relates to the middle of the interval, 08:07:30. At the moment, this orientation is only uses by the real time irradiation measurement values from the Meteosat satellite

MeasurementSeriesType

This is an enumeration class that specifies the type of calculation to be performed for a time series. This enumeration defines a limited number of time series addressed in the BESOS project based on the requirements analysis.

AVERAGE	Timeseries addressing the average value within the timeperiod examined
MEDIAN	Timeseries addressing the median value within the timeperiod examined
MAXIMUM	Timeseries addressing the maximum value within the timeperiod examined
MINIMUM	Timeseries addressing the minimum value within the timeperiod examined

StepUnit

This is an enumeration class that specifies allowed time steps for the analysis

SECOND	Time interval in Seconds
MINUTE	Time interval in Minutes
HOUR	Time interval in Hours
DAY	Time interval in Days
WEEK	Time interval in Weeks
MONTH	Time interval in Months
YEAR	Time interval in Years

UnitMultiplier

This is the enumeration class for the unit multipliers defined for the CIM. The potential values of the enumeration are:

G	Giga 10**9.
M	Mega 10**6.
T	Tera 10**12.
c	Centi 10**-2.
d	Deci 10**-1.
k	Kilo 10**3.
m	Milli 10**-3.
micro	Micro 10**-6.

n	Nano 10**-9.
none	No multiplier or equivalently multiply by 1.
p	Pico 10**-12.

PhaseCode

The enumeration of phase identifiers is considered. This attribute allows designation of phases for transmission and distribution equipment, circuits and loads. Residential and small commercial loads are often served from single-phase, or split-phase, secondary circuits. For example of s12N, phases 1 and 2 refer to hot wires that are 180 degrees out of phase, while N refers to the neutral wire. Through single-phase transformer connections, these secondary circuits may be served from one or two of the primary phases A, B, and C. For three-phase loads, use the A, B, C phase codes instead of s12N.

A	Phase A.
AB	Phases A and B.
ABC	Phases A, B, and C.
ABCN	Phases A, B, C, and N.
ABN	Phases A, B, and neutral.
AC	Phases A and C.
ACN	Phases A, C and neutral.
AN	Phases A and neutral.
B	Phase B.
BC	Phases B and C.
BCN	Phases B, C, and neutral.
BN	Phases B and neutral.
C	Phase C.
CN	Phases C and neutral.
N	Neutral phase.
s1	Secondary phase 1.
s12	Secondary phase 1 and 2.
s12N	Secondary phases 1, 2, and neutral.
s1N	Secondary phase 1 and neutral.
s2	Secondary phase 2.
s2N	Secondary phase 2 and neutral.

DocumentTypes

This module includes concepts capturing information related to the business – strategic aspects of BESOS. More specifically, it models concepts having to do with SLAs and Strategies to achieve them.

Document

Parent class for different groupings of information collected and managed as a part of a business process. It will frequently contain references to other objects, such as assets, people and power system resources. It extends IdentifiedObject class.

createdDateTime	1..1	dateTime	Date and time that this document was created.
lastModified DateTime	1..1	dateTime	Date and time this document was last modified. Documents may potentially be modified many times during their lifetime.
revisionNumber	1..1	string	Revision number for this document.
subject	1..1	string	Document subject.
title	1..1	string	Document title.
type	1..1	string	Utility-specific classification of this document, according to their corporate standards, practices, and existing IT systems (e.g., for management of assets, maintenance, work, outage, customers, etc.).
electronicAddress	1..1	ElectronicAddress	Electronic address.
status	1..1	Status	Status of subject matter (e.g., Agreement, Work) this document represents. For status of the document itself, use 'docStatus' attribute.

Agreement

Formal agreement between two parties defining the terms and conditions for a set of services. The specifics of the services are, in turn, defined via one or more service agreements. It extends Document class.

signDate	1..1	date	Date this agreement was consummated among associated persons and/or organisations.
validityInterval	1..1	DateTimeInterval	Date and time interval this agreement is valid (from going into effect to termination).

StrategyAction

The StrategyAction contains one request of municipality. It is modelled as a subclass of Agreement to designate its semantics and inherit Agreement properties. It extends Agreement type.

Strategy Constraints	1..n	StrategyElement	The constraints applicable to this strategy action,, e.g. points of light should be kept on in a specific area
StrategyGoals	1..n	StrategyElement	The goals set for this strategy action,, e.g. total consumption must be less than X val-

			ue
Priority	1..1	Priority	The priority of this strategy action

StrategyElement

This concept is used to model specific strategic sub-objectives as part of the strategy actions. It extends Agreement class.

value	1..1	string	Strategy element description
Assets	1..n	Asset	The assets involved in this strategic objective
KPI	0..1	KPI	A KPI the desired value of which is within the goals of this strategy. Either a KPI or a Measurement is included; use of xsd choice elements was avoided for reasons of data model mapping to OO - UML
Measurement	0..1	Measurement	A Measurement the desired value of which is within the goals of this strategy. Either a KPI or a Measurement is included; use of xsd choice elements was avoided for reasons of data model mapping to OO - UML
StrategyRelationType	1..1	StrategyRelationType	Designates relation with specified KPI / Measurement

StrategyRelationType

This enumeration class defines types of relationships for strategy goals and constraint values set. The potential values are:

LEQ	Less or equal.
EQ	Equal.
GEQ	Greater or equal.

DateTimeInterval

This is the interval between two date and time points.

end	1..1	dateTime	End date and time of this interval.
start	1..1	dateTime	Start date and time of this interval.

Control Structure

This module includes concepts capturing information related to control commands as delivered from the Application level to the EMS level in order to proceed with the implementation of the control strategies defined. A structure of the direct control operation is defined:

Control

Control type is used for supervisory/device control.

operationIn Progress	1..1	boolean	Indicates that a client is currently sending control commands that has not completed.
timeStamp	1..1	dateTime	The last time a control output was sent.
unitMultiplier	1..1	UnitMultiplier	The unit multiplier of the controlled quantity.
unitSymbol	1..1	UnitSymbol	The unit of measure of the controlled quantity.
ControlType	1..1	ControlType	The type of control.
ResourceStatus	0..1	ResourceStatus	The status that the receiving PowerSystemResource should transition to
PowerSystemResource	1..1	PowerSystemResource	The resource this command should be applied to
Issuer	1..1	Organisation	The organisations that issued this command
Priority	1..1	Priority	The command's priority

SetPoint

A SetPoint is an analogue control used for supervisory control. This class is a generalization of the control class.

maxValue	1..1	float	Normal value range maximum for any of the Control.value. Used for scaling, e.g. in bar graphs.
minValue	1..1	float	Normal value range minimum for any of the Control.value. Used for scaling, e.g. in bar graphs.
value	1..1	float	The value representing the actuator output.

The detailed reference of the respective classes is in line with the UML representation as presented on Section 4 of the deliverable.