SEMIAH

Data Models

Document ID:	SEMIAH-WP4-D4.2-v0.09
Document version:	Rev 1.0
Document status:	Final
Dissemination level:	PU
Deliverable number:	D4.2
Deliverable title:	Data Models
WP number:	WP4
Lead beneficiary:	Fraunhofer IWES
Main author(s):	Stefan Siegl (IWES), Jan Ringelstein (IWES), Dominique Gabioud (HES-SO), Alain Woeffray (HES-SO)
Nature of deliverable:	O
Delivery date from Annex 1:	M18
Actual delivery date:	2015-10-05
Funding scheme / call:	STREP-FP7-ICT-2013-11
Project / GA number:	619560
Project full title:	Scalable Energy Management Infrastructure for Aggregation of Households
Project start date:	01/03/2014
Project duration:	36 months

Funded by the
European Union

This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement no 619560.

Executive Summary

This deliverable is the result of joint efforts of SEMIAH project partners working in WP4 from July 2014 to August 2015 on “development of system infrastructure” for the task 4.3 “*Definition of Object Models*”. It provides a short documentation in addition to the UML model files which were generated using the Enterprise Architect software suite.

Section 1 provides a general overview of the data models used in the project for different technical components and business actors. Section 2 focuses on data modelling used for forecasting of flexibility in the system. Section 3 introduces the data model used at the frontend level. Section 4 summarizes the data model on the backend level. Section 5 concludes the document.

Abbreviations

D	Deliverable
EC	European Commission
WP	Work Package
WT	Work Task

Contents

List of Tables

List of Figures

1 Overview of data models in SEMIAH

1.1 Role of data models in SEMIAH

The SEMIAH framework links appliances distributed in thousands of households, energy markets, distribution grid control systems and prosumers. Exchanged information between these elements requires not only commonly agreed syntaxes but also a commonly agreed semantics.

The Task 4.3 (Definition of Object Models) and Deliverable D4.2 (Data Models) deal with the definition of a commonly agreed semantics.

SEMIAH consortium members teamed up to elaborate a common understanding of data models between the SEMIAH subsystems. The elaboration process is dynamic: the data models contained in D4.2 reflect our current view of the SEMIAH system. As the SEMIAH development need for new concepts (expressed by new data model element can arise). Conversely, current data model elements could be removed if they are unused in practice.

1.2 Constraints on the SEMIAH data models

SEMIAH is built on pre-existing components and should interact with external systems. These two facts constrain the definition of data models. Concretely:

- The SEMIAH front-end is based on the OGEMA framework [1]. OGEMA has already its own data model (OGEMA data model elements are called “resources”). OGEMA resources can be extended to cover SEMIAH needs but existing resources should be used whenever possible.
- Grid transport, distribution systems and energy management systems like IWES.VPP have their own data model called CIM (Common Information model) [2]. CIM is an IEC standard (IEC 61970, IEC 61968). When relevant, SEMIAH data models have been based on the CIM semantics, to ease integration into grid operation and energy markets.

1.3 Format for data models

UML [3] has been selected as a language for the expression of the SEMIAH data models, because UML class diagrams allow the definition of data models and also because CIM is expressed in UML. The class diagrams holding the SEMIAH model are delivered in graphical representation of the UML.

1.4 SEMIAH Architecture – Overview

An abstract view of the SEMIAH technical architecture is shown in Figure 1. The heart of the architecture is the Generic Virtual Power Plant (GVPP). The GVPP has a number of consumer and provider interfaces to be listed below.

Consumer Interfaces:

- *iGridConstraint*

  Used to deliver grid constraints information.
- *iFlexForecast*
  Used to deliver the flexibility forecast for all households in SEMIAH.

Provider interfaces:

- *iAlgorithms:*
  The GVPP has an open interface for 3rd party components to interface to virtual power plant (VPP) operations. For instance, this may be new algorithms for electricity load aggregation, load forecasting and load scheduling. The interface is also a pivot point for integration of components developed and used in SEMIAH e.g., a module for interfacing to modules that can adapt to energy trading markets in relevant countries.
- *iVppControl:*
  Used for operation and maintenance of the IWES.vpp components planned for use in the SEMIAH pilot.
- *iHousehold:*
  Used for connecting and controlling the household appliances through the HEMG.
- *iHouseholdCollection:*
  The interface is similar to iHousehold except that is operates of collections of e.g., households and/or appliances.

The SEMIAH backend system can be used in two different ways. It can be used as a mediator, which collect all information of the households, forecasts and grid constraints and provide that information to 3rd party components via the interface iAlgorithm. Those components can use the information and calculate the schedules for each household and send it to the GVPP which forward the schedules to the households. On the other way it can be used as energy management system itself. In this case, the GVPP collects also the necessary information and calculate the schedules internally. These schedules are also transmitted to the households.
Each household is also connected to the component "Flexibility Forecast", which calculates the amount of flexibility what an household can provide to the SEMIAH system.

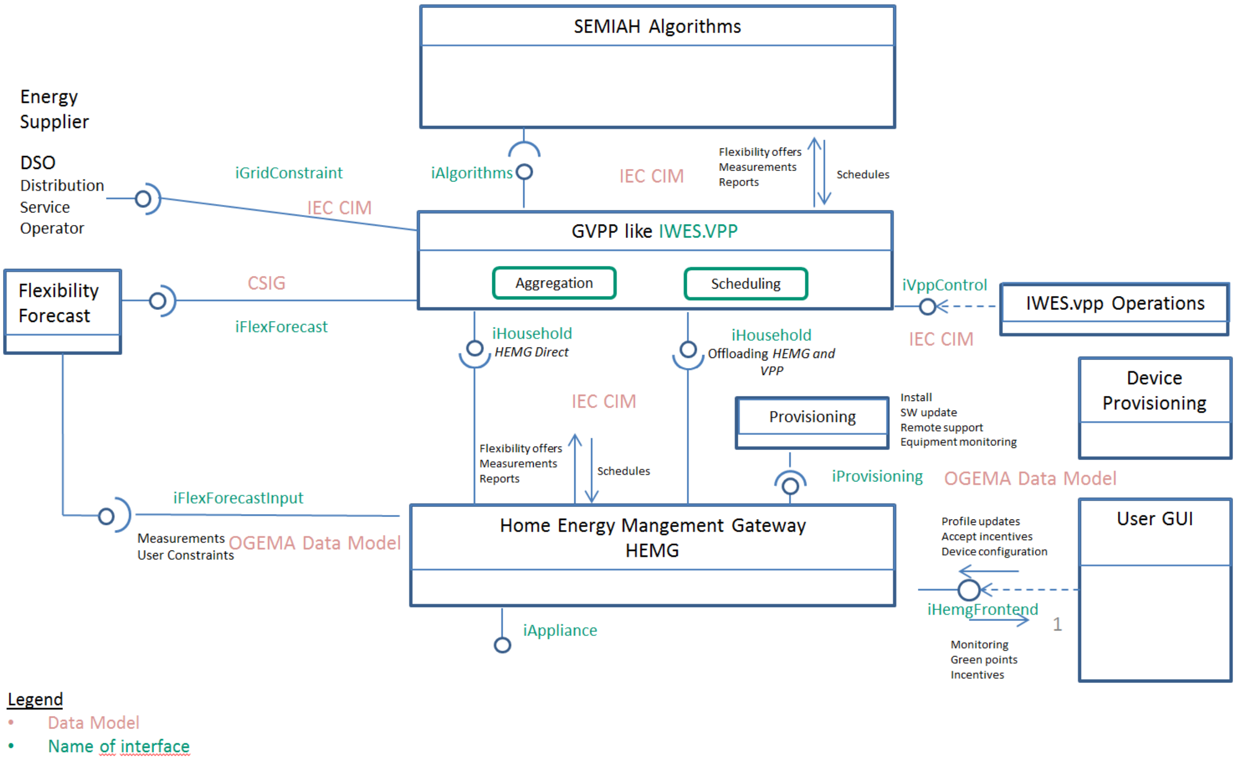

Figure 1: SEMIAH technical architecture. In the figure the letter "i" is used as a prefix for the naming of SEMIAH system interfaces

2 Flexibility Forecast data model

The Flexibility Data Model consists of three main elements: Converter, Storages and Inflow forecasts. The Inflow forecasts models external energy production or (consumption). The energy is produced or consumed to / from energy storage, which may be a zero capacity storage. The converter models an electrical connected engine, which consumes energy from the input storages and produces energy to the output storages under consideration of the efficiencies. With the power steps attribute all possible operation modes in terms of electrical active power output can be modelled.

With this flexibility model each energy consumer in SEMIAH (direct heating, heat pump, etc.) can be expressed. E.g. for the direct heating system the heater could be expressed by the converter, the room and the temperature in the room by the storage element and the loss of heat in the room by the inflow forecast. The user constraints can be expressed by the borders (max, min) of the storage.

This model is shown in the file “Data Model Flexibility Forecast/iwes-vppcore-datamodel_class_flexibility_forecast.jpg”.

3 Frontend Datamodel

3.1 Overview

The data model described in this chapter refers to a representation of parameters present at the local OGEMA-based gateway level. It is most important to see that it is not intended to model any thinkable parameter present at this level. Instead, it basically only covers parameters which are exchanged between:

- The gateway local level and the virtual power plant central level
- The gateway local level and an external server providing user constraints, offering a graphic user interface (GUI)
- Drivers and applications at the gateway level, where drivers are a special type of OGEMA applications. In the SEMIAH context, the ZigBee driver is the most relevant here.
- Individual software applications at the gateway level

An example for such data exchange would be the ZigBee driver receiving a sensor value. This value is written into a data resource read by an application which provides a connector to the virtual power plant level.

For modelling components used in SEMIAH, the OGEMA standard data model is utilized as far as possible, meaning that the specific SEMIAH context is mapped onto data elements already present in the standard data model. It shall be pointed out that the model shown in this deliverable does only cover the part of the OGEMA standard data model most relevant to the projects requirements. An extensive documentation to the complete model may be found at http://www.ogema-source.net/apidocs (current version at the time of writing this document: 2.0.3).

This model has been shared by various other OGEMA related projects; hence, it is not SEMIAH specific, but defines a general, manufacturer and scenario independent data model for the gateway level. If applied to the SEMIAH requirements and scenarios, there may be drawbacks (e.g. the introduction of virtual devices might be needed). It is possible to extend or replace data elements by custom ones. But since we do not want to create proprietary model, this is done only if the standard model poses too big disadvantages or data elements are totally missing.

The UML diagrams provided along with this document provide a view of the data model resource types. Different building scenarios might be modelled using the class implementations leading to a consistent object hierarchy. For example, looking at the Building UML diagram in the file “Data Models OGEMA/Building_UMLClassModel.jpg”, consider a building which comprises an office space with several rooms that contain work places. Let each work place be equipped with a ZigBee temperature sensor that measures the temperature at each work place. In order to model this scenario, the sensor would be represented by a *ZigBeeConnectionInfo* type resource associated to a Temperature*Sensor*. Using the *reading().setValue()* method, the OGEMA driver would write into the subresource of type Temperature*Resource* of that sensor if new sensor data is received. The Temperature*Sensor* resource would be part of a *WorkPlace* type resource instance. This resource type, as a *PhysicalElement*, is inheriting a *Location* type subresource. Latter subresource would again be shared by a *Room* type resource instance. This room again would be part of a *BuildingPropertyUnit* resource instance representing the office space of the building, being a subresource of the top-level *Building* type resource instance.

Along with this document, three UML class diagrams are provided:

1. A diagram specifying resource types with regards to Building, including heating appliances, various sensors and actors (“Data Models OGEMA/Building_UMLClassModel.jpg”
2. A diagram specifying resource types for Boilers providing hot water (“Data Models OGEMA/ Boiler_UMLClassModel.jpg”)
3. A diagram specifying resource types for simple local PV plants. (“Data Models OGEMA/ PV_UMLClassModel.jpg”)

3.2 User Constraints and Control

In SEMIAH, it was decided that the user of the OGEMA gateway (e.g. the Building owner) shall input user constraints using a GUI which is provided by an external server. Hence, such constraints need to be sent to the gateway level by remote access and need to be covered by the data model. Note that some constraints (e.g. the heating system nominal power) may be input by the user only once during gateway installation with help of installation staff.

Most user constraints are contained in the Building UML diagram. There are also user constraints referring to the Building solar irradiation. In order to model those, a virtual PV plant may be used which is part of the standard data model. The according subresources defined in the standard data model basically allow storage of all parameters connected with this. This approach may be taken even if there is no real PV plant present at the building, leading to a virtual top-level resource. However, the same model part can be used in order to represent a real PV plant in case there is one present.

3.3 Appliances and Control

The data model considers several physical devices present as appliances inside the building, including:

- Room heating and domestic hot water
- Occupancy, temperature and light sensors attributed to the whole building, building property units (e.g. an apartment), single rooms or single work places
- Energy, current and power sensors, impulse readers
- Temperature sensors, smart thermostats attributed to heating systems
- Switching relays for active control of appliances

Sensors and Actors are also attributed to according ZigBee devices as indicated by associations in the class diagrams.

In the SEMIAH data model, thermal storages can be associated to a building or part of a building (property, room) in order to represent their thermal storage capacity on a very abstract level. For the model usage, different scenarios are possible depending on the thermal supply layout:

- If supply is given by a central heating system for both room heating and hot water, two storages and heat generators attributed with different conversion efficiencies may be used to represent the central heaters. There may also be only one central heater generating both hot water and room heating. In this case, individual storage elements for hot water tank, the room heating system storage as well as the rooms' thermal capacity may be used. A single storage for the heating might be sufficient if only the total building thermal capacity is modelled.
- If only the hot water supply is done decentrally, each supply point could be modelled by a boiler. Only a single storage would then be used at building level to represent central room heating, but multiple storages could be used to model the different thermal demand of the rooms.
- If only the room heating is done decentrally (typically by electric heaters), a storage would be associated to each heated room, eventually connected with individual electric heater resources.
- If both room heating and hot water supply is done decentrally, a room or a building property unit may be associated with up to two storages connected to individual heat generators.

In order to model these scenarios, the data model covers the following requirements:

- A storage shall always be charged by a single heat generator only.
- A single heat generator may charge (i.e. be referenced by) one or multiple storages
- A room and a building property unit may be associated to up to two storages.
- A storage may be associated to an arbitrary number of rooms or building property units or to up to one building
- A building may be directly associated to up to two storages (central hot water and room heating)

4 Backend Datamodel

The SEMIAH backend use as data model a standard that was developed by the electric power industry and that has been adopted by the International Electrotechnical Commission (IEC). The standard is called the Common Information Model (CIM). The core package of CIM is defined by the standard IEC 61970-301. For the basic understanding the most important elements are the following:

Table 1 Core classes of the Common Information Model (CIM)

Facility	A facility may contain buildings, storage facilities, switching facilities, power generation, manufacturing facilities, maintenance facilities, etc.
PowerSystemResource	A power system resource can be an item of equipment such as a switch, an equipment container containing many individual items of equipment such as a substation, or an organizational entity such as sub-control area. Power system resources can have measurements associated.
GeneratingUnit	A single or set of synchronous machines for converting mechanical power into alternating-current power. For example, individual machines within a set may be defined for scheduling purposes while a single control signal is derived for the set. In this case there would be a GeneratingUnit for each member of the set and an additional GeneratingUnit corresponding to the set.

Measurement	A Measurement represents any measured, calculated or non-measured non-calculated quantity. Any piece of equipment may contain Measurements, e.g. a substation may have temperature measurements and door open indications, a transformer may have oil temperature and tank pressure measurements, a bay may contain a number of power flow measurements and a Breaker may contain a switch status measurement.
Analog	Analog represents an analog Measurement.
Asset	Tangible resource of the utility, including power system equipment, various end devices, cabinets, buildings, etc. For electrical network equipment, the role of the asset is defined through PowerSystemResource and its subclasses.
AssetContainer	Asset that is aggregation of other assets such as conductors, transformers, switchgear, land, fences, buildings, equipment, vehicles, etc.
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.

Data modelling is a key aspect of SEMIAH to ensure interoperability between stakeholder's systems. In accordance with the recommendation for European smart grids, the SEMIAH project will be based on the Common Information Model (CIM). CIM is an open standard that defines how managed elements in an information technology environment are represented as a common set of objects and relationships between them. Within the energy domain CIM can be used for representing power system components and networks which has been primarily developed by the Electric Power Research Institute (EPRI) IEC61970/IEC61968. The following chapters show how CIM is adopted for the SEMIAH framework.

4.1 Households

The file “Data Models Backend/iwes-vppcore-datamodel_class_semiah_cim.jpg” shows the data model of SEMIAH based on IEC CIM. The virtual power plant has different sub elements like feeder or clusters of households. The virtual power plant, the household cluster, the households and the feeders are modelled as Facility. Each Facility has a connection to a GeneratingUnit. The GeneratingUnit has one or more Measurements to represent the characteristics of an element. The Analog-Class is derived from Measurements.

The file “Data Models Backend/iwes-vppcore-datamodel_class_facilities_DistributedEnergyResources.jpg” shows a general UML diagram about how Facilities and GeneratingUnits are modelled in CIM. How households can be modelled in SEMIAH with CIM is shown in “Data Models Backend/iwes-vppcore-datamodel_class_semiah_cim.jpg”.

4.2 Time series

4.2.1 Measurements, Forecasts and Schedules

The core object for modelling measurements, forecasts and schedules is the Analog object described above. Every measurement, forecast or schedule represents its core data in a time series of values. With an additional type of data together with UnitMultiplier and UnitSymbol it is distinguished between these different types of an Analog.

The Analog has a createdDateTime which is treated differently. In case of measurements and schedules this field can be neglected, because every AnalogValue has the complete information of the timestamp where the given value is valid for. In case of a forecast this property is used as the timestamp describing when this forecast was calculated, meaning when the associated forecast model was run. Obviously this is necessary to distinguish between older and newer forecast data to calculate the best forecast with strategies merging relevant forecasts.

The UML diagram of the Analog can be found next to this document in the file “Data Models Backend/iwes-vppcore-datamodel_class_timeseries_analog.jpg”.

4.2.2 Grid Constraints from Grid Operation

The Grid Constraints are modelled within the SEMIAH-System as a time series (Analog) which include the information about the maximum energy consumption of a cluster of households. This time series is used as constraint for the scheduling and describe the energy consumption for a collection of households. These information elements are transferred via the interface iGridConstraint.

4.3 ActivityRecord

To trigger an action in the SEMIAH-Backend an Operation is needed. The Operation is represented as the class ActivityRecord. It contains all information to perform the requested action. For example to send a schedule to a household an operation is need for that task. The operation to send a schedule for a household to the SEMIAH-Backend is shown in the file “Data Models Backend/iwes-vppcore-datamodel_class_operations_activityrecord.jpg”.

5 Conclusion

The discussion on data models within the consortium has led to a better common understanding of the SEMIAH architecture. The links between the components has been described at the semantic level, will support further development phase and will ease a seamless integration.

The data models are not “graved in stone”: they will evolve to reflect the more precise understanding of the SEMIAH framework that will be gained during infrastructure development, system integration and even pilot testing.

6 References

[1] »OGEMA Introduction of Concepts, Terminology and Framework Services,« [Online]. Available: http://www.ogema.org//wp-content/uploads/2014/12/OGEMA_2.0_introduction_v2.0.2.pdf. [Senest hentet eller vist den 14 8 2015].

[2] E. t. report, »Common Information Model Primer - Third Edition,« [Online]. Available: file:///C:/Users/gad/Downloads/000000003002006001.pdf. [Senest hentet eller vist den 14 8 2015].

[3] OMG. [Online]. Available: http://www.uml.org/. [Senest hentet eller vist den 07 2015].