



**GreenDataNet**

**D3.12 – Summary of  
deliverable Aggregated  
Energy Management System**

Final Version - Public

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## REVISION SHEET

Revision Number	Date	Brief summary of changes
Rev 0.1	02/12/2015	Draft for presentation to partners
Rev 1.0	16/12/2015	Integration of internal reviewing comments

## SUMMARY

The AEMS (Aggregated Energy Management System) software aims to optimize the energy management at the level of a network of Data Centers (DC) in order to increase the use of renewable energy and to minimize the energy consumption of the data center network. The main objective of the AEMS is to avoid buying electricity from the Grid at high electricity prices (peak shaving application) and to reach the highest share of electricity from renewables by migrating IT loads (virtual machines) between DCs.

The energy management optimization at the level of a single DC is detailed in Deliverable 3.7 (Smart Energy Management System – SEMS). This optimization takes into account the IT load optimization detailed in Deliverables 3.2 and 3.3 within the electricity consumption forecasting tool. The main role of the AEMS is to add an optimization layer taking into account the constraints of DC network. The AEMS communicates through XML file (weak interaction) with the SEMS layer. It takes into account the analytical models of the DCs' components and receives through XML files the results of the optimization delivered by the SEMS layer presented in the deliverable 3.7, the IT load and associated cooling load consumption forecast (Deliverables 3.2 and 3.1), the PV production forecast on each DC site (Deliverable 3.4), and the electricity price forecast.

The AEMS layer is developed by using the C++ programming language. The software architecture and communication strategies adopted for the AEMS are the same than for the SEMS level in order to:

- Facilitate the integration and the communication between the two parts (SEMS, AEMS) of the GreenDataNet prototype.
- Reuse the analytical models of different components of DCs (Li-ion storage system, UPS, electrical grid, photovoltaic system, IT loads) coded initially in C++ for the SEMS optimization part.
- Ease the deployment and the configuration of the prototype due to the need of a similar technical installation environment (operating system, software to execute the prototype...).
- Standardize the communication interface between the two layers

A User Interface (UI) has been designed in order to ease the users' understanding of the optimization for the next time steps. The optimization results, generated by the AEMS, are sent by XML files to the SEMS layer of each DC composing the GreenDataNet prototype.

## 2. INTRODUCTION

The model predictive control (MPC), same as for Smart Energy Management System (SEMS) level, is the core of the AEMS (Aggregated Energy Management System) for optimizing the global energy management at the level of a network of Data Centers (DCs). The working of AEMS is based on the possibility to handle the upcoming energy status of the GreenDataNet prototype in order to find its optimal energy management for the next time steps taking into account the constraints at the level of DC network. The AEMS has the possibility to handle the distribution of the DCs' loads and to shift an amount of load from a DC to another in order to increase the use of renewable energy and to minimize the energy consumption of the data center network. Hence the forecast information of photovoltaic production (Deliverable 3.4), IT loads consumption forecasting (Deliverable 3.2), and the results of the SEMS optimization (Deliverable 3.7) are taken into account (Figure 1).

### 2.1 DOCUMENT PURPOSE

This deliverable presents the design and implementation of the Aggregated Energy Management System layer developed within the GreenDataNet project (Figure 1). The AEMS layer is developed by using the C++ programming language. The software architecture and communication strategies adopted for the AEMS are the same as for the SEMS level in order to:

- Facilitate the integration and the communication between the two energy management components (SEMS and AEMS) of the GreenDataNet prototype.
- Reuse the most of the analytical models of the DCs systems coded initially in C++ for the SEMS optimization part.
- Ease the deployment and the configuration of the prototype due to the need of a similar technical installation environment (operating system, software to execute the prototype...).
- Standardize the communication interface between the two layers

The communication between the SEMS level and the AEMS level is a weak communication method by using XML.

At the AEMS level, the models of the different components (Li-ion storage system, UPS, electrical grid, photovoltaic system, IT loads) of the GreenDataNet prototype for the network of DCs, detailed in Deliverable 3.6 and formulated in mixed linear integer programming (MILP), are reused. The set of the models at the level of each Data Center are considered by the AEMS and then taken into account in the optimization.

Then AEMS software, developed for GreenDataNet project, receives the system configuration and the results of each SEMS optimization, handles the formulation of the problem, solves the optimization problem and sends back the optimal solution to the SEMS level.

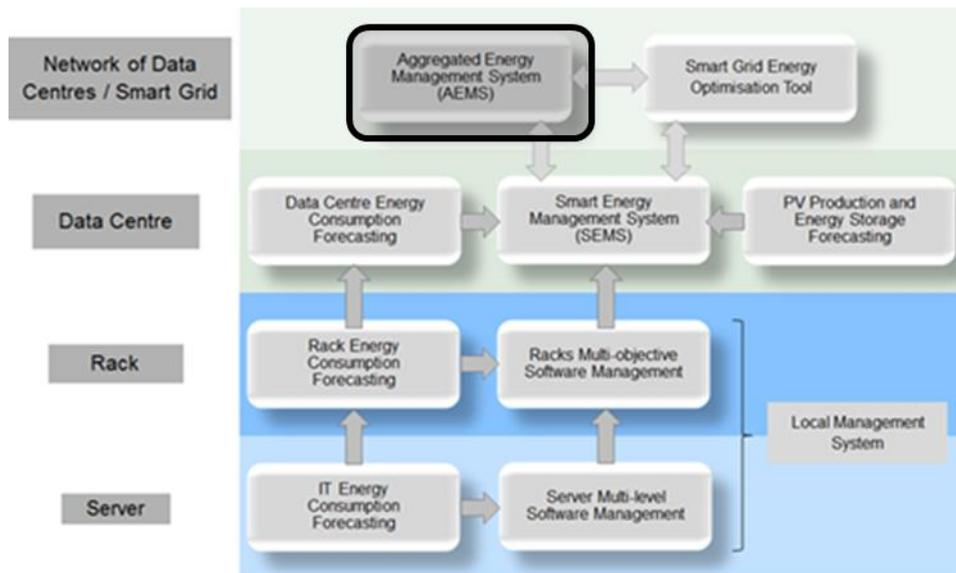


Figure 1- The AEMS placement in the GDN project framework

## 2.2 KEY ACRONYMS AND ABBREVIATIONS

AEMS	Aggregated Energy Management System
DCs	Data centers
ECFT	Electricity Consumption Forecasting Tool
ESS	Energy Storage System
INES	National Solar Energy Institute
IT	Information Technology
GDN	Green Data Net
MILP	Mixed Linear Integer Programming
MPC	Model Predictive Control
PV	Photovoltaic
SDCEC	Smart Data Center Energy Controller
SEMS	Smart Energy Management System
SGCT	Smart Grid Configuration Tool
SOC	State of Charge
SW	Software
UI	User Interface
UPS	Uninterruptible Power Supply
XML	eXtensible Markup Language

## 2.3 DOCUMENT OVERVIEW

Section 3 describes the integration of the AEMS in the GreenDataNet framework. This section not only presents the internal components of the AEMS layer, but also the interaction between the AEMS, the SEMS, and the Smart Grid Energy Optimization Tool. Section 4 concludes the work.

## 3. AEMS GREENDATANET FRAMEWORK INTEGRATION

The software (SW) for energy management of the GreenDataNet (GDN) prototype is detailed in Figure 2. This figure focuses on the AEMS components of the energy management SW for GDN project and includes interactions between the components of the AEMS and the required data exchange between SEMS and AEMS.

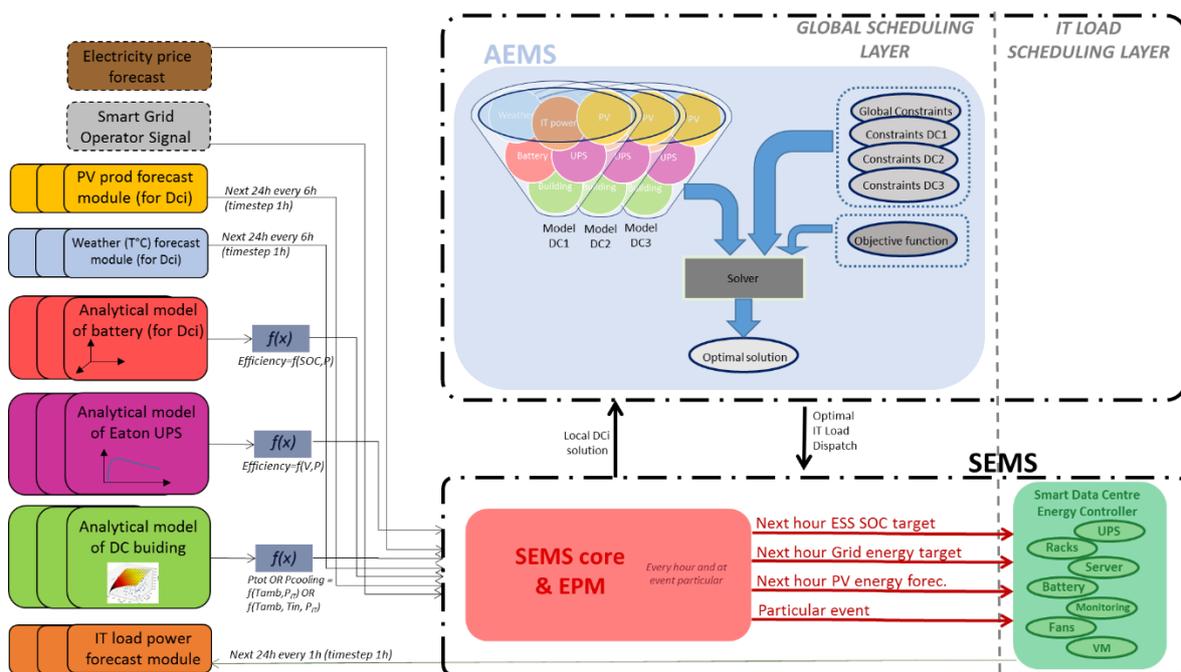


Figure 2- The components of the GreenDataNet Framework

After receiving the local DC optimization solution delivered by the set of local SEMSs, The AEMS launches a new global optimization for the whole network of DCs. The AEMS solves the optimization problem and sends back to the SEMS the optimal dispatch of IT load between the different DCs. The AEMS optimization solution could be sent to the SEMS at every AEMS calculation period (every hour for instance) or regarding a particular event. Such particular event could be the same generated for the SEMS optimization and described in Deliverable 3.7.

The AEMS can also be able to receive signals from grid operator (or smart grid actors) through the Smart Grid Configuration Tool (SGCT – Deliverable 3.13) and to adapt the energetic strategy of the network of DCs.

The AEMS can perform the optimization with a longer time step than the SEMS. As an indicative example, if the time step at the level of the SEMS is ½ hour, the time step at the level of the AEMS is 1 hour.

The SEMS forwards the local PV production forecast information, delivered by the PV production forecast module, to the AEMS. The PV forecast production module is described in Deliverable 3.4. The option of sending the information to the AEMS through the local SEMS is adopted in order to preserve only one communication interface between the local process (forecast module and SEMS) and the aggregated process (AEMS). The model predictive control (MPC) inside the AEMS starts the optimization. This AEMS block delivers an optimal distribution of the IT load between the DCs. Such optimization is provided by taking into account, for each DC localization, the PV production forecast for the next 24h (PV forecast module, Deliverable 3.2), the ambient temperature forecast from a weather forecast service (Weather forecast module), and the IT load power forecast (IT load power forecast module).

Furthermore the MPC also integrates analytical models of the components of the set of DCs component (batteries, UPS, DC building) composing the considered network. The same analytical models of battery, Eaton UPS, and DC building (Deliverable 3.1) described in deliverable 3.6 are used at the AEMS level. The Smart Grid Configuration Tool (SGCT) provides also a long term prediction of the grid operator needs to the AEMS.

Then it is necessary to formulate the optimization problem with objective and constraints functions before solving it with solvers in order to find, in a short computation time, an optimal solution for the system. The prediction delivered by the SGCT is formulated as a constraint in the AEMS optimization problem.

After each optimization cycle, the AEMS delivers the next IT load dispatch to each local SEMS. A new local optimization (SEMS) is launched if there is a load shifting from the local DC to another DC.

After this local optimization, run for each DC (by its SEMS) of the network, the new values of SOC target for the local ESS, the Grid energy target, the PV forecast for the next hour are communicated to the Smart Data Center Energy Controller (SDCEC) in order to compute the optimal planning of IT tasks. The SDCEC, detailed in Deliverables 3.2 and 3.3, is the core of the Electricity Consumption Forecasting Tool (ECFT). The communication between the SEMS and the SDCEC and the integration of the SEMS in the GreenDataNet prototype are detailed in the Deliverable 3.7.

The next hour charge/discharge powers for the Li-ion battery are communicated to the local control of the UPS. The communication of the optimal solution to the other components is illustrated in Figure 3.

In the following sections, the architecture of the AEMS and the coupling between the AEMS and SEMS are detailed. As noted before, the coupling between the AEMS and SEMS has been designed to be as simple as possible through data exchange file. The SEMS can compute and execute a local optimal plan even an AEMS layer is not connected.

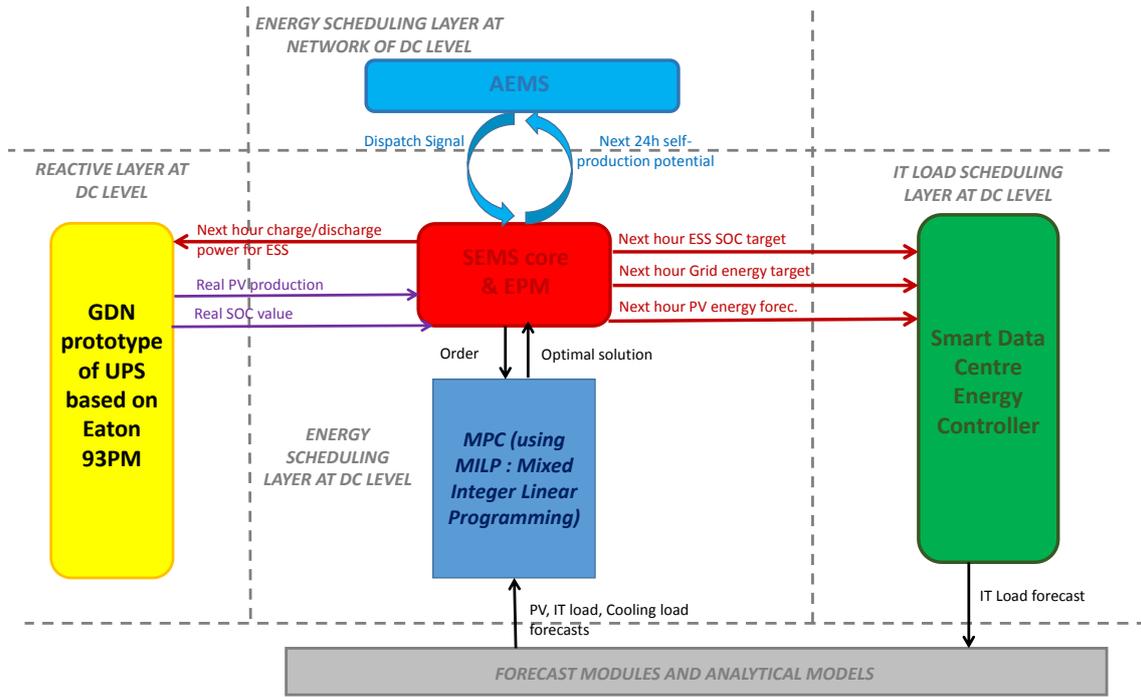


Figure 3- Interactions and data exchange between the different components of the GreenDataNet Framework

## 4. CONCLUSION

In this deliverable, the AEMS layer has been presented. The AEMS is designed in order to optimally manage the energy at the network of DCs level with local renewable production and storage. It aims to increase the self-consumption and self-production ratios (to benefit from renewable energy) at the level of every singular data center and/or decrease the global cost of energy for the network of DCs.

This report has been written in order to explain the AEMS software architecture, its interfaces and the integration of the AEMS in the GreenDataNet prototype.

The AEMS software has been developed in C++ for robustness and rapidity objectives but also for reuse of analytical models developed for the SEMS optimization at the level of a single DC optimization.

The tool can be launched every time step after receiving the results of the local optimization handled by the SEMS local layer at the set of DCs and the prediction delivered by the Smart Grid Configuration Tool.

The AEMS delivers, after solving the MILP problem, the optimal dispatch of IT loads over the DCs. The local SEMS system must compute the new local solution after receiving the new amount of IT load that will be carried by the local DC.

The granularity, the level of precision, in the internal representation of the electrical architecture of each DC is lower at the level of the AEMS than for the SEMS. The decrease of the representation granularity at the AEMS level is driven by:

- A minimization of the MILP formulation number of variable is required.
- The precision in the internal representation of each DC is not significant due to the minimal impact of such representation on the global solution at the network of DCs.

The interaction between the SEMS and the AEMS is realized through XML files, which permits to have a weak but very robust interaction.

The deployment architecture of the GreenDataNet prototype including the AEMS is also described in this document.

The architecture is composed of two main parts: the AEMS server side and the DCs side. On the DCs side the optimization is driven by the SEMS local optimizer for each DC.

The AEMS will be deployed in a specific centralized server at CEA-INES Chambéry for the validation and demonstration task.

A User Interface (UI) has been designed in order to ease the users' understanding of the optimization results.