Appendix C: Requirements

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Brief introduction

The following tables present the requirements collected from an end user and a technical point of view. Every table has been defined in order to capture the requirements related to a specific aspect of the BaaS system, for example data management, APO modules, and so on. These requirements have been divided in functional and non-functional requirements. Functional ones present the main functionality expected by the BaaS platform users, and the non-functional ones complement the functional requirement in order to assure the performance and security of the system.

So as to measure the relevance of the requirements for the behaviour of the system, an "Importance" field has been defined with three levels of importance: *critical, high,* and *standard*:

- Critical – These requirements are indispensable for the operation of the BaaS system.
- High – Without these requirements, only limited functionality can be achieved.
- Standard – These requirements have an impact on the quality of service but are not crucial for the operation of the BaaS system itself, i.e. they add value to the overall system.

Table 1: Human-Machine Interaction Requirements (functional)

Name	**FR-01:** Human-Machine Interaction Requirements
WPs affected	WP 3 & WP 5
Description	The system should be able to allow the communication with the users through several graphical-user-interfaces in order to manage and operate the system. • The system should offer different access to the content and views of the BaaS system, according to the privileges of a user: o Administrators (e.g. technical staff) should have control over the configuration of the system related to both user management and specific system configuration (alarm configuration, scheduler configuration, KPI calculation configuration, etc.). o BaaS users should be able to access to the whole functionality of the system, execute optimization (in case of being manually or at any moment even if the optimization has been scheduled) and control orders and view the results of the operation executed. o External users should be able to access monitoring values and results of optimization calculations executed over the BaaS buildings (only monitoring, and without privileges for the execution of any control or optimization tasks). • User access should be controlled by managing permissions. • The system should provide a user-friendly human-computer interface (HCI). The HCI should be intuitive and easy to use. • The HCI should reflect the users' role (i.e. privileges). This includes different screens for administration of the system, monitoring values, control and optimisation, etc. • The functionality offered by the system should be available from any device via a web browser. So the system should guarantee ubiquity in the access to its functionality. • The user interface should be refreshed automatically in order to show the latest data collected by the system (live data). The update interval should be defined in the design phase.
Importance	High
Rationale	Providing structured access to the system and its functionality

Table 2: System Management Requirements: System Configuration (functional)

Name	**FR-02.1:** System Configuration
WPs affected	WP3
Description	The system should allow the **configuration of the main parameters for the proper behaviour of the system**. • The system should provide the administrator with the privileges to manage (create, delete, modify) users and their privileges. This configuration should be stored in a persistent storage medium (file, DB, DWH …). • The system should allow the BaaS users (possibly automatically through the APO service modules) to configure the needed parameters for the schedulers: start time, finish time, timer, etc. for all the activities which need a planning. • The system should allow alarm configuration: ○ The BaaS user should be able to configure the set-points below/above which an alarm must be triggered. ○ The administrator should be able to configure customised system alarms. ○ The BaaS user should be able to configure the mailing list, phone number list, etc. to which must alarms are sent.
Importance	Standard
Rationale	The configuration is an added value in order to increase the functionalities of the system.

Table 3: System Management Requirements: Interoperability (functional)

Name	**FR-02.2:** Interoperability
WPs affected	WP 2 & WP 3 & WP 5
Description	The system **should interwork in heterogeneous networks**. • The BaaS system should guarantee an appropriate interconnection among all their internal pieces of software (APO services, modules, components) as well as with external data sources and tools (BMS/BACN (Building Automation and Control Network), BIM server, DWH, external systems and services, and external tools). The whole distributed "eco"-system (regardless of being deployed locally, in a cloud, or a mix thereof) should communicate transparently and maintain coherence and consistency of data transferred. • The BaaS system should be able, if necessary, to communicate (read & write access) with the existing BMS and/or BACN at the BaaS testbeds and demonstration buildings. The interface (connector) implementing the protocols provided by the aforementioned BMSs and/or BACNs should be developed. • The BaaS system should be able, if necessary, to communicate (read & write access) with existing Data Warehouse(s), maintaining the consistency of data. The interface (connector) implementing the protocols provided by the DWH should be developed. In case that more than one DWH will be used by the BaaS system, the BaaS

	system should be able to communicate in a homogeneous and coherent way with all of them. The BaaS system should maintain the coherency of data. • The BaaS system should be able to communicate (read & write access) with existing building information model (BIM) repositor(y/ies). The interface (connector) implementing the protocols provided by the BIM repositories should be developed. In case that more than one BIM repository will be used by the BaaS system, the BaaS system should be able to communicate in a homogeneous and coherent way with all of them. The BaaS system should maintain the coherency of data. • The BaaS system should be able to retrieve data from external (third-party) service(s) (i.e. weather forecast service, occupancy forecast service, etc.). The interface (connector) implementing the protocols provided by the aforementioned external services should be developed. • The BaaS system should be able to communicate with external tools (Matlab, E+, etc.) providing data and getting results. The interface (connector) implementing the protocols provided by the aforementioned external tools should be developed. • The BaaS system should be able to communicate (read & write access) with existing ICT (external to the BMS/BACN such as metering system, access control, weather station and so on) systems used at BaaS testbeds and demonstration buildings. The interface (connector) implementing the protocols provided by the aforementioned ICT external systems should be developed. • The BaaS system should be able to communicate (read & write access) with the APO Services, providing this layer with all the data needed from the Data Layer (BMS, BIM, DWH, etc.). • The BaaS system should be cloud-enabled. The BaaS system should implement (or use from external servers/providers) those *Platform*, *Infrastructure*, and *Software as a Service* (PaaS, IaaS, SaaS) models needed in a "cloud environment" in order to guarantee the interoperability among all the components which make up the BaaS system.
Importance	Critical
Rationale	The communication amongst all the components is necessary for the properly behaviour of the whole system.

Table 4: System Management Requirements: Openness (functional)

Name	**FR-02.3:** Openness
WPs affected	WP 2 & WP 3
Description	The system **should work with open systems where possible based on SOA (Service Oriented Architecture)**. • Solutions based on FLOSS (free/libre open source software) should be used. Use of FLOSS components should be encouraged and promoted (e.g. OpenBIM Server; LON- or BACnet- based BMSs; open and

	relational DWHs; M-BUS based meters). If the use of FLOSS is impossible, then the BaaS platform should use proprietary software (proprietary BIM server; proprietary BMS, etc.). • The BaaS system should implement open or standardized protocols for the communication with the BMS/BACN system (LON, BACnet, etc.). If this is not possible, we should try to include a commercial gateway mapping the proprietary protocol to BACnet, LON, or any other open or standard protocol. If it is not possible, the BMS/BACN proprietary protocol should be implemented in one connector. • The BaaS system should implement any communication with the database repositories based on SQL queries or other open database standards. Transparency between the BaaS system and these repositories should be provided (i.e. interface based on Hibernate technology in order to make the database independent of the BaaS platform). • The BaaS system should implement open or standardized protocols for the communication with the BIM Server. The system should be able to query the BIM Server using different kind of filters (site, building, storey, room, system/subsystem objects, object types, object properties). • The BaaS system should implement open or standardized protocols for the communication with the external services (SOAP, REST). • The BaaS system should implement open or standardized protocols for the communication with the external ICT system (i.e. M-BUS from energy meters). If this is not possible, proprietary protocols should be implemented in one connector.
Importance	Standard
Rationale	BaaS activities should foster openness and the adoption and use open standards

Table 5: Data Management Requirements (functional)

Name	**FR-03:** Data Management
WPs affected	**WP 2**
Description	The system should be able to maintain data consistency and to ensure high availability of the data • The system should be able to securely backup data and restore it if needed. Multi-level incremental backups are preferred. • The system should be able to keep historical records / logs of access, modification, deletion, etc. of data. • The BaaS system should be able to read/write data from/to the BMS/BACN working on the BaaS testbeds and demonstration buildings. The BaaS system should be able to read: a) live (on-line/near-real time/time response minor than predetermined time) data from devices (sensor/actuator states and values, parameters, properties, setpoints, etc.), b) temporary storage structures as data logs (for example, some BMSs are able to create a file containing data in a temporal "window" of several days), and c) other structured information like schedules, list of devices,

	etc. • The BaaS system should be able to write data to: a) Actuators (setpoints, actuation commands) b) Controllers (update parameters and control laws) • The BaaS system should be able to retrieve and store data from/to the databases/DWHs which support the data storage in the BaaS testbeds and demonstration buildings. • The BaaS system should be able to read and write information from/to the BIM repository, including: a) the entire BIM model, b) specific information (object properties, list of sensors, etc.) of the BIM repository. • The system should be able to write, update, or delete information into/from the BIM repository. For instance, sensors/actuators malfunctions could be detected by the BaaS system (*fault detection and diagnostics service*), so this new state of the sensor/actuator should be able to be updated in the BIM repository; as well as new sensors could be commissioned in the BMS/BACN system, so this new object should be added in the BIM repository. • The BaaS system should be able to retrieve data from external services and – if desired – to store these data in the DWH(s). Some examples of data served by external services are weather forecasting, historical weather data, and properties of materials. • The BaaS system should be able to retrieve and write data of external ICT system – if desired – to store these data in the DWH(s). Some examples of data served by external ICT systems could be in-building weather station, access control system, meters (gas, water, electricity).
Importance	Critical
Rationale	Good data management is crucial for the resilience and fault tolerance of the entire system.

Table 6: APO Modules General Requirements (functional)

Name	**FR-04:** APO Modules
WPs affected	WP 5
Description	APO modules are basic software modules, providing the business intelligence of the BaaS system at the APO Service Layer. A transparent and generic mechanism for development, deployment and configuration of such modules should be provided within the BaaS system. • An APO kernel service will be in charge of registering and managing modules as well as making them available to the system. • Should APO modules require parameters, they should be passed when the module is executed (by access through the middleware layer to the BIM, DW other external providers). • APO modules should propagate detected anomaly events for storing, logging, visualization, automated corrective actions, etc. to the BaaS system.

	• At the kernel level, time-control mechanisms (scheduling) should be in place to allow for controlling of execution of modules at user-defined time intervals. • A user- and service-permission mechanism should control access to system resources and data. • The system should support Error- and event-handling through properly defined mechanisms and interfaces • The system should communicate events and errors with the middleware layer. • Simulation models should be available to modules. Binding to these simulation modules should be achieved with the help of the APO kernel. • The BaaS user should be able to configure what modules (performing APO tasks) must be scheduled and periodically launched. • The system must provide a bi-directional interface between the middleware and the APO layer.
Importance	Critical
Rationale	This is key BaaS functionality, a part of APO services

Table 7: FDD general requirements (functional)

Name	**FR-05:** APO services: Fault and Detection Diagnostics
WPs affected	WP 5
Description	The BaaS system should detect abrupt changes in the monitored system (building), where the changes relate to difference from expected behaviour (correct one). • Each fault definition contains its required data points. • A fault present in the system must be detected if all required data points are available and the FDD module is triggered. • FDD APO services provide actionable recommendations for the end user if appropriate.
Importance	Standard
Rationale	This is a BaaS functionality, which is a part of APO services

Table 8: Energy and Comfort Management general requirements (functional)

Name	**FR-06:** APO services: Energy and Comfort Management
WPs affected	WP 5
Description	The BaaS system should calculate KPIs describing the monitored system (i.e. building) in terms of its energy performance and user comfort. Note: calculated KPIs are listed in the deliverable 1.1 • Each KPI definition contains its required data points. • If monitored system (or its part) degrades it must be captured by deteriorating relevant KPI values. • Energy & comfort management services provide actionable recommendations for the end user if appropriate.

Importance	High
Rationale	This is key BaaS functionality, a part of APO services

Table 9: Control and Optimization general requirements (functional)

Name	**FR-07:** APO services: Control Optimization
WPs affected	WP 5
Description	The system should support supervisory control and control optimization functionalities. For design and optimization purposes access to simulation might be required. • The system should be able to automatically generate control actions to optimize selected KPIs. • Control actions should respect thermal comfort constraints. • The system should support rule-based and model-based control strategies. • The system should be able to store the optimization results and make them available upon request.
Importance	High
Rationale	This is key BaaS functionality, a part of APO services

Table 10: Modelling and Simulation general requirements (functional)

Name	**FR-08:** Modelling and Simulation
WPs affected	WP 4 & WP 5
Description	The system should be able to provide multiple simulation approaches: on the (whole) building level and, if needed, at the component level (e.g. HVAC system). These simulations should be exposed to the other system components and be made available upon request. A platform for providing "simulation as a service" to be consumed by other services is necessary. • These simulation capabilities should support multiple uses: FDD, Control Design and Optimization (CDO). • The system should be able to simulate the behaviour or the building and interface with the control algorithms. The system should be able to run simulation tasks by means of the APO Services, with the data provided by the middleware, in order to optimize the control algorithms. • The whole building simulation models should have co-simulation capabilities. • Simulation using sensed (historical) data and forecasts should be possible.
Importance	Critical
Rationale	Simulation is needed for support of APO Services

Table 11: Performance requirements (non-functional)

Name	**NFR-01:** Performance
WPs affected	WP 3
Description	The systems should provide a sufficiently high availability (--> service level agreement) and be scalable as well as fault-resilient. Scalability, replicability, reliance and robustness concepts should be taken into account. • Scalability: New functions of the BaaS system, as well as further external systems (BMSs, data sources), should be easy to add. In order to assure the BaaS system’s scalability, the documentation to code interfaces between the BaaS system and other modules should be provided, e.g.: o BMS/BACNs, o BIM repositories, o DWHs, DBs, o third-party web services o external tools, o external ICT systems/devices o new modules of the BaaS system • Reliability: A malfunction of the system should not affect the operability of the building. o The system should have a fall-back mode with reduced functionality in case of local errors (e.g. in the communication

	channels or in individual components). The building should have an emergency fall-back mode in case of total failure to maintain vital functions. • The system should be able to detect and ideally also predict internal faults. • Response time: The system should be able to respond in a limited time in order to allow a fluent activity. • Replicability: The system should be able to operate in different typologies of buildings.
Importance	Standard
Rationale	Reliable operation of the system crucial for the success of the entire project.

Table 12: Security requirements (non-functional)

Name	**NFR-02:** Security
WPs affected	WP 3
Description	The system should be able to ensure confidentiality and integrity of collected data, particularly of personally identifiable data as well as ensure privacy of people affected by the operation of the system. • Authentication and authorisation: The system should provide appropriate interfaces to support different access profiles to different users. • Integrity: The system should provide meta-information about origin and trust of the gathered data and protect the data against malicious or accidental modification. • Confidentiality: The system should ensure the confidentiality of information which might leak sensitive information about building users and tenants.
Importance	High
Rationale	Meeting legal requirements on both a local and European level is crucial for liability reasons and to achieve maximum acceptance of the BaaS system.