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Abstract:

This document provides the Technical Dissemination and Exploitation of BESOS project outcomes, focusing on the technical evaluation of the components that consist of the project framework and further on the business evaluation of BESOS platform

Keywords:

BESOS Evaluation framework, Technical evaluation, Cost benefit Analysis, SWOT Analysis

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Executive Summary

The scope of this document is to proceed with the evaluation of technical and business perspective of BESOS project. While D7.2 is focusing mainly on impact assessment analysis and user experience evaluation, this deliverable provides the evaluation of technical components that consist of BESOS platform and further the business perspective of the tool. Therefore the document starts from the functional evaluation BESOS and extends this to address technical and business aspects.

The 1st part of the work is the technical evaluation of the system components. The analysis covers all the layers of reference architecture by evaluating business applications, EMS gateway but most important the OTESP platform. The role of the platform is fundamental for BESOS framework and thus an extensive evaluation is performed. Along with the technical evaluation, issues related to interoperability and security are covered during the evaluation process.

The 2nd part of the work is the evaluation of the business potential of the project. We first start with the cost benefit analysis of the main BESOS components that stand as standalone applications and we further proceed with the cost benefit analysis of the "BESOS System as a Service". Along with the cost benefit analysis, cost effectiveness analysis is performed, taking into account also the valuable feedback from active stakeholders. A limited group of users is selected to evaluate the platform on specific criteria, setting the framework for this analysis. As a last step on business evaluation, a SWOT analysis is performed in order to highlight the strengths and weaknesses of BESOS framework.

The technical and business analysis performed complements the overall evaluation process and further provides valuable feedback on the final version of BESOS project exploitation plan as documented in D8.2.2

1 Introduction

1.1 Purpose and Scope of the Document

The scope of this document is to proceed with the evaluation of the technical and business perspective of BESOS project [1]. While D7.2 [3] is focusing mainly on impact assessment analysis and user experience evaluation, this deliverable provides the evaluation of technical components that consist of BESOS platform and further the business perspective of the tool.

The 1st section highlights the technical evaluation of main technical components that consist of BESOS framework. The list of components that are evaluated are the following: BESOS BBSC, BESOS DSS, BMA Application, OTESP, and EMS Gateway covering that way the end to end BESOS management framework. Special focus is delivered on the evaluation of OTESP platform as this is the cornerstone layer of the system that enables aggregation and management of heterogeneous assets types. Different criteria have been selected for the technical evaluation, with special focus on security and interoperability aspects towards the transferability of BESOS solution in different mass scale smart-cities applications.

The evaluation process also includes the business-oriented perspective of BESOS platform in terms of cost-benefit and cost-effectiveness, within the context of business models defined at the early stage of the project. The cost-benefit analysis (CBA) incorporates a set of business-specific indicators, such as Internal Rate of Return (IRR), Pay Back Period (PBP), Net Present Value (NPV), etc. A similar approach is considered for cost-effectiveness analysis (CEA) of BESOS, on the basis of the methodology defined as part of the evaluation plan, further associated with SWOT analysis of the project reporting strengths and weaknesses of BESOS platform. The results from technical and business evaluation are part of overall evaluation framework, complementing the work documented in D7.2.

1.2 Relation to other Deliverables

As mentioned above, this document complements impact assessment evaluation of BESOS platform performed in D7.2 - Evaluation and Assessment. In addition, this part of evaluation is in line with the evaluation plan and ex-ante analysis as documented in D7.1 [2]. Furthermore, a tight association with the work performed in WP6 towards deployment and demonstration of BESOS activities is considered. Finally, the business evaluation is performed by taking into account BESOS Business models as defined in D1.2 [6].

On the other hand, the technical and business evaluation of BESOS platform will highlight the main strengths and business opportunities of BESOS platform. Therefore, this document, and especially cost benefit analysis, will screen the landscape for the final version of BESOS exploitation plan in D8.2.2 [4].

1.3 BESOS Technical Dissemination and Exploitation - Document Structure

The BESOS Technical Dissemination and Exploitation document is organised in the following sections. The current chapter introduces the main aspects and the structure of the document. Then the structure of the document is presented:

- Chapter 2 provides a **summary of the evaluation plan**, focusing mainly on the business perspective and the evaluation criteria considered for this process. The brief analysis will facilitate the implementation of BESOS business analysis towards the exploitation of project outcomes.
- In Chapter 3 the **technical evaluation** of BESOS project is performed, focusing on the different components that consist of the overall framework. The technical evaluation of system components will highlight the potential of exploitation for the respective BESOS components.

- Chapter 4 provides the **business evaluation of BESOS project.** Starting from the results of impact assessment analysis performed in D7.2, we proceed with the business oriented view of BESOS through cost benefit, cost effectiveness and SWOT analysis.
- The last Chapter (Chapter 5) presents the outcomes of this evaluation process, linking technical dissemination and exploitation with the exploitation plan to be provided in WP8.

2 BESOS Business Evaluation Plan

The BESOS evaluation framework includes the business-oriented evaluation of BESOS platform in terms of cost-benefit and cost-effectiveness, within the context of BESOS business models as defined at the very early stage of the project and validated during the demonstration period. A **cost-benefit analysis** (CBA) incorporates a set of business-specific indicators, such as Internal Rate of Return (IRR), Pay Back Period (PBP) and Net Present Value (NPV), in order to establish a fully-fledged business evaluation framework.

A similar approach will be followed for the **cost-effectiveness analysis** (CEA) towards the evaluation of BESOS framework on the basis of socio-economic impact of the platform. Furthermore a **SWOT analysis** will be performed, thus allowing for continuous updates and optimization of BESOS results (technical, scientific and business ones).

The goal of this section is to provide a high level definition of the business oriented evaluation framework in a way to define the scenarios examined as part of the evaluation process.

2.1 Cost Benefit Analysis

Cost Benefit Analysis (CBA) is the process of quantifying costs and benefits of a decision, program, or project (over a certain period), and those of its alternatives (within the same period), in order to have a single scale of comparison for unbiased evaluation. The CBA aims to estimate first of all the Net Present Value (NPV) of the decision by discounting the investment and returns. Though employed mainly in financial analysis, a full CBA is not limited to monetary considerations. It often includes environmental and social costs and benefits that can be reasonably quantified.

The Cost Benefit Analysis is used, widely, for decision support, planning, program evaluation and other purposes, in organisations of all kinds, even though the term itself has no precise definition beyond the implication that both positive and negative impacts are going to be summarized and weighed against each other. The main purpose of CBA is to provide a preliminary-though clear- idea of the investments needed for producing commercial and user acceptable products. Market penetration forecast and associated cost items of different BESOS products will be estimated by the consortium members (corresponding financial departments of their companies), who have, in turn, consider the competitive market environment.

The financial analysis is performed by: **BESOS consortium members** for the possible industrialization and market circulation of their individual products through a five-year evaluation period and **business stakeholders** for demonstration of BESOS platform. The "development costs" which are contained at the "initial investment costs" are cost for modification and commercialization of BESOS outcomes. In order to provide a concrete Cost Benefit Analysis, the "willingness to have" data, expressing the willingness of persons to use or obtain a system or product, will be extracted and further quantified through questionnaires analysis. In addition, the "willingness to pay" term expresses the maximum amount a person willing to pay, sacrifice or exchange in order to receive a product or service.

Taking into account the evaluation of inflows and outflows of BESOS platform, as well as the estimation of initial investment costs, a list of CBA indicators is provided, namely: Net Present Value (NPV), Internal Rate of Return (IRR) and Pay-Back. A brief analysis of the above mentioned indices is provided.

2.1.1 Net Present Value

The Net Present Value (NPV) of an investment project is determined by calculating the present values of the future cash flows generated by this investment, summing them up and finally subtracting this sum of from the initial outlay for the investment. The future cash flows are discounted using a discount rate considering time and risk. If the calculated NPV is positive, the investment should be undertaken. An investment with a negative NPV should not be accepted. When comparing several exclusive investment projects, the projects with the highest positive NPV should be accepted.

From a purely financial viewpoint, the NPV rule is consistent with the shareholder's objective of wealth maximisation, because it exclusively uses cash flows in the calculations as well as considers the time value of money. It evaluates investment projects in the way as investors do. The NPV has several strengths and weaknesses. The main strengths are considered:

- Its consideration of the time value of money
- The NPV considers all expected cash flows irrespective of the timing when the anticipated cash flows are generated
- It permits comparisons between different investment projects with the same pre-determined discount rate
- The NPV of an investment considers risk by applying a discount rate reflecting the minimal acceptable rate of return on projects with similar risk.

The NPV's shortcomings are mainly concerned with the understanding of the concept and its components:

- The concept may be hardly understood due to its complexity
- Selecting a suitable discount rate based on assumptions about a potential investment and considering an investment's risk may be difficult to comprehend for individuals without any financial training, background or experience
- The model gives a false sense of accuracy, since the computed present value is based on estimated and uncertain cash flows

The calculation of the NPV is given by the formula:

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+\mathrm{r})^t} - I$$

where:

t= the time of the cash flow
T= the total time of the project
r= the discount rate
C_t = the net cash flow at time t
I= the (single initial) investment outlay

2.1.2 Internal Rate of Return (IRR)

Besides the NPV, the Internal Rate of Return (IRR) concept is the second procedure employed for the financial evaluation of investment projects, which uses discounted cash flows and present values. The IRR determines the discount rate for an investment where the sum of the present values of the expected future cash flows and the initial investment outlay equals zero. It basically means that the IRR is the discount rate that equates an investment project's NPV to zero.

The internal rate of return rule is to accept an investment project if the opportunity cost of capital is less than the internal rate of return. The rationale behind this statement is that an investment project yielding more than its opportunity cost of capital has a positive NPV, thus it is worthwhile investing. The equation estimation of IRR is considered as:

$$\sum_{n=1}^{N} \frac{C_n}{(1+IRR)^n} - I = 0$$

Where:

n= the time of the cash flow
N= the total time of the project
IRR= the internal rate of return
C_n= the net cash flow at time t
I= the (single initial) investment outlay

Following the equation estimation:

- If IRR> b then the product is financially justifiable.
- If IRR< b then the product is not financially justifiable.
- If IRR= b then the conclusion is neutral, neither positive, nor negative.

The evaluation of the IRR model will take place in the actual pilot evaluation approach.

2.1.3 Pay-Back Period

The payback period is defined as the length of time required by an investment project to equal the initial investment outlay with the expected future cash flows. The shorter the payback period of an investment project the better for the project to be accepted. This index is considered as a simple one in order to quickly evaluate a product or a service and should be taken into account on the holistic evaluation process.

The overall cost benefit analysis is delivered taking into account the monetary input-output flows. In order to provide a concrete analysis, the following parameters are required:

- Equipment and installation cost (Investment Cost)
- Software development cost and estimation of the expected final product cost (Investment Cost)
- Discount rate and Inflation rate
- Cash flows and operational costs (including equipment replacement due to aging)

Within BESOS, a list of input parameters is defined for Cost Benefit Analysis evaluation. An abstract presentation of information required in order to provide the CBA analysis is summarized in Table 1:

Cost-Benefit Analysis	
Initial Investment	Software (License) Costs
	Hardware Costs
Operational Costs	Software Maintenance & Operational Costs
	Hardware Maintenance & Operational Costs
Operational Benefits	Reduction of Energy Costs
	Reduction of CO2 emissions Costs
	Reduction of personnel Costs

Table 1 CBA input parameters

The main goal of BESOS project is to ensure the establishment of a sustainable environment that lead to significant energy savings. We are evaluating the impact of different factors to estimate the aggregated reduction of energy cost. These factors are summarized:

- Reduction of energy consumption: through the optimal management of sheddable loads taking into account contextual parameters (environmental and operational conditions)
- Shifting of energy consumption: We examine demand shifting scenarios through the exploitation of shiftable loads (electric vehicles etc.…)
- Optimal market participation: through the evaluation of dynamic pricing schemas (ToU optimization) in building premises.

The results from these intertwined control strategies will be considered during CBA analysis towards the accurate evaluation of BESOS platform.

2.2 Cost-Effectiveness Analysis

The cost benefit analysis is mainly focusing in the monetary analysis of a product or service. In BESOS case, social impact must be also addressed during the evaluation process. The cost-effectiveness evaluation methodology takes into account different social and economic criteria towards a multi-criteria evaluation of BESOS framework.

Cost-effectiveness analysis (CEA) is a form of economic analysis that compares the relative costs and outcomes (effects) of two or more courses of action. Cost-effectiveness analysis is distinct from cost-benefit analysis, which assigns a monetary value to the measure of effect. Cost-effectiveness analysis is often used in the field of services, where it may be inappropriate to monetize the impact effect. Typically the CEA is expressed in terms of a ratio where the denominator is a gain in services from a measure (years of life, sight-years gained) and the numerator is the cost associated with the health gain. The most commonly used measure outcome is **quality-adjusted life years** (QALY). Cost-effectiveness is often visualized on a “cost-effectiveness plane” consisting of four-quadrants. Outcomes plotted in Quadrant I are more effective and more expensive, those in Quadrant II are more effective and less expensive, those in Quadrant III are less effective and less expensive, and those in Quadrant IV are less effective and more expensive.

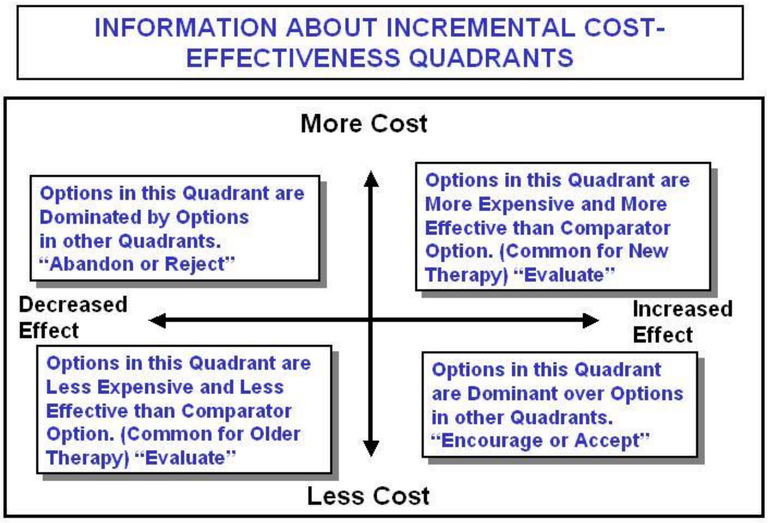

Figure 1 Cost effectiveness analysis template

The concept of cost effectiveness is applied to the planning and management of different types of organized activity. Within BESOS platform, a list of social and economic parameters are defined to assess this analysis, further presented:

- Reduction of Energy Consumption
- Reduction of Energy Cost
- Reduction of CO2 emissions
- Quality of energy
- RES penetration
- Installation Costs
- OEM Costs

We have already defined these factors as part of impact assessment analysis and we further incorporate them for cost effectiveness evaluation analysis. While we are examining the role of different business stakeholders in the project different evaluation viewpoint are considered taking into account the role of each stakeholder and the results of evaluation process. It is clear that a multi parametric analysis will be performed toward cost effectiveness evaluation of BESOS platform.

2.3 SWOT Analysis

In order to provide a holistic evaluation framework, a complementary SWOT analysis will be performed for BESOS. SWOT analysis (alternatively SWOT Matrix) is a structured planning method used to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project or in a business venture. A SWOT involves specifying the objective of the project and identifying the internal and external factors that are favorable and unfavorable to achieving that objective. Settings on the business objective are delivered the SWOT analysis. SWOT will also result achievable goals or objectives to be set for the organization. The main factors of SWOT analysis are:

- Strengths: characteristics of the business or project that give it an advantage over others
- Weaknesses: are characteristics that place the team at a disadvantage relative to others
- Opportunities: elements that the project could exploit to its advantage
- Threats: elements in the environment that could cause trouble for the business or project

A typical format for SWOT analysis is presented in Figure 2.

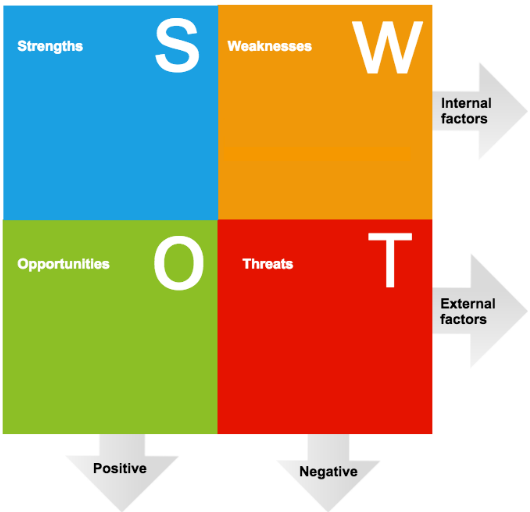

Figure 2 SWOT Analysis representation

As mentioned above, SWOT analysis aims to identify the key internal and external factors seen as important for achieving an objective. SWOT analysis groups key pieces of information into two categories:

- internal factors – the strengths and weaknesses internal to the organization
- external factors – the opportunities and threats presented by the environment external to the organization

The users of SWOT analysis need to ask and answer questions that generate meaningful information for each category (strengths, opportunities, weaknesses, and threats) in order to maximize the benefits of this evaluation and find their competitive advantage. Adopting the UCD approach considered for BESOS project, the main stakeholders of the ESOS platform were requested to evaluate the different tool on the way of conducting a concrete SWOT analysis.

The specification of BESOS business evaluation framework, as presented in this section, will further enable the implementation of BESOS business evaluation in Chapter 4. The business analysis is performed for each system component of the platform and the BESOS platform as a service, towards further dissemination and exploitation of project outcomes.

3 Technical assessment of BESOS applications

The BESOS platform consists of different layers: the EMS Gateway layer responsible for integration of heterogeneous assets types, the Middleware responsible for aggregation and routing of information and the Application layer for the different business services. The approach we follow is in line with the general approach for integrating different types of networked devices with enterprise systems. Energy Management devices (in our case EMSs & Gateways) are composed from hardware and software components that enable their low level programmability. On top layer we have various services and applications developed to support the different business stakeholders. Between these two, there is a middleware layer responsible for the management and communication of the whole information.

In order to test the performance of the platform, it is mandatory to test first each system component separately:

- EMS/Gateways Adaptation
- Open Trustworthy Energy Service Platform
- Decision Support System Cockpit
- Behavioural Mobile App assessment
- Business Balanced Score Card
- BESOS Forecasting Engine

The overall analysis is provide in accordance with the evaluation plan which defines the different criteria for technical evaluation and depicted in the following Table:

Criteria	Gateway	OTESP	BBSC	DSSC	BMApp	Forecasting Engine
Scalability		x	x	x		x
Reliability	x	x	x	x	x	x
Interoperability	x	x	x	x		
Speed of Communication	x	x	x	x	x	x
Ease on Deployment	x	x			x	x
Affordability		x	x	x		x

Table 2 Technical evaluation of BESOS Components

For each BESOS component, the respective stress tests are performed and the results are presented along with a list of outcomes from evaluation process.

3.1 EMS/Gateways Assessment Analysis

EMS/Gateways have been used in the project as the underlying software for interfacing with existing hardware infrastructures. Since it is needed to be tightly integrated with middleware, several tests relevant to EMS/Gateways has been conducted as integrated EMS/Gateways - OTESP tests. As this is part of the evaluation of OTESP platform, detailed evaluation of EMS adaptation is performed in the following section. We have to point out that the reliability of the different EMSs was presented as part of impact assessment analysis in D7.2.

A main innovation of BESOS framework is the adoption of existing standards (e.g. IEC CIM for data modelling) towards the delivery of a solution that is easily transferable to other case studies. As different asset types are integrated in BESOS platform, the main objective of the technical evaluation is to examine the different approaches considered for the incorporation of heterogeneous assets. A high level taxonomy of evaluation analysis is performed per pilot site.

Lisbon City Pilot Site

For Lisbon Pilot site, it was integrated assets from different hardware vendors, having different capabilities, supporting different types of metrics. Data from energy consumptions and energy productions were provided as well as alarms from specific energy management systems. In particular, in the city of Lisbon it was incorporated in the BESOS architecture the following systems:

- ISA Vendor
  - Electrical Vehicles
  - Campo Grande 25 Building
  - Olivais School
  - Mechanical and Electrical Department Building

- LMIT Vendor
  - Social Services Building

- Philips Vendor
  - Public Lighting Systems

The integration was deeply dependent on the EMS characteristics. The web interface provided by ISA makes available to authorized entities energy data related to the municipality buildings, including electrical vehicles plugs. LMIT has a different approach, it sends information each 15 minutes related with Social Services Building consumptions to agreed end points. Finally, the public lighting from Philips deployed in Lisbon provide an interface that allows the gathering of alarms information. Therefore different types of integration activities where performed, considering "web services" as the mechanism for integration in BESOS platform. This is a current trend on hardware EMS vendors to provide cloud based solutions with an API (mainly REST) for easy integration. But the main drawback of commercial solutions is still the lack of a common data model that facilitates the easy integration of any hardware solution to a common platform. This is the point where the BESOS EMS Gateway component stands, as it provides the wrappers that ensure the easy transformation of any proprietary data model to the CIM data model, enabling that way the rapid integration in standards based energy management platforms.

Figure 3 presents the approach followed in Lisbon Pilot site. A common framework, according to BESOS functional architecture defined in WP2, was applied enabling a smooth integration of the different EMSs. The BESOS Common Information Model was deployed on top of each vendor specific data model in order to let cockpit applications to have a similar view of the data gathered. Moreover it was done the "translation" of ISA, LMIT and Philips primitives towards BESOS specific services. This common framework allows therefore an easy integration of new vendors and new sources of energy data into applications facilitating the promotion of a sustainable city.

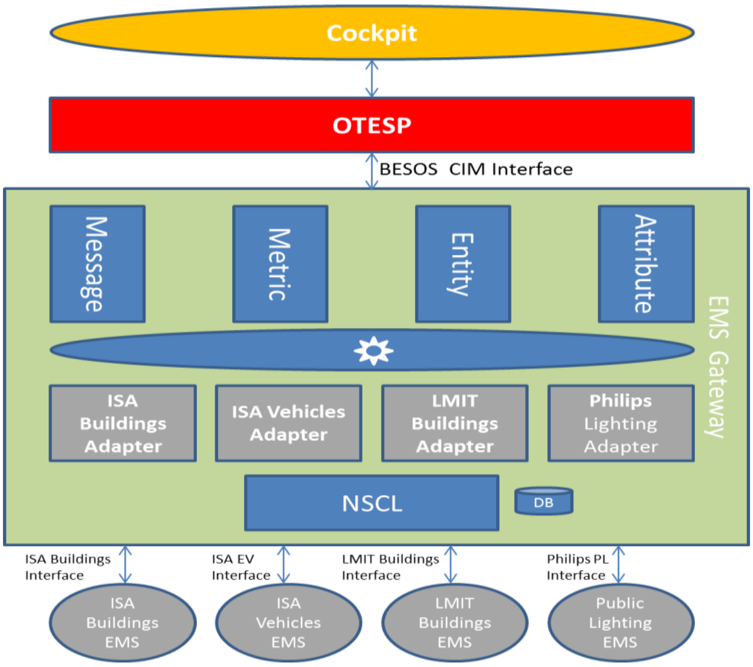

Figure 3 - Common framework for Lisbon site

Barcelona City Pilot Site

As in the case of Lisbon, for the Barcelona pilot site several systems from different vendors were adapted to the BESOS data model. Although each EMS involved a specific process to retrieve and analyse both its metadata and its measurements, in the end they all had to implement the same set of services to communicate with the next layer of the BESOS architecture, i.e. OTESP. For this reason, besides the specific adaption of each underlying system, all EMS GWs developed by ETRA shared a common core module that encapsulated the necessary functionality to deal with the OTESP communication protocol, among others:

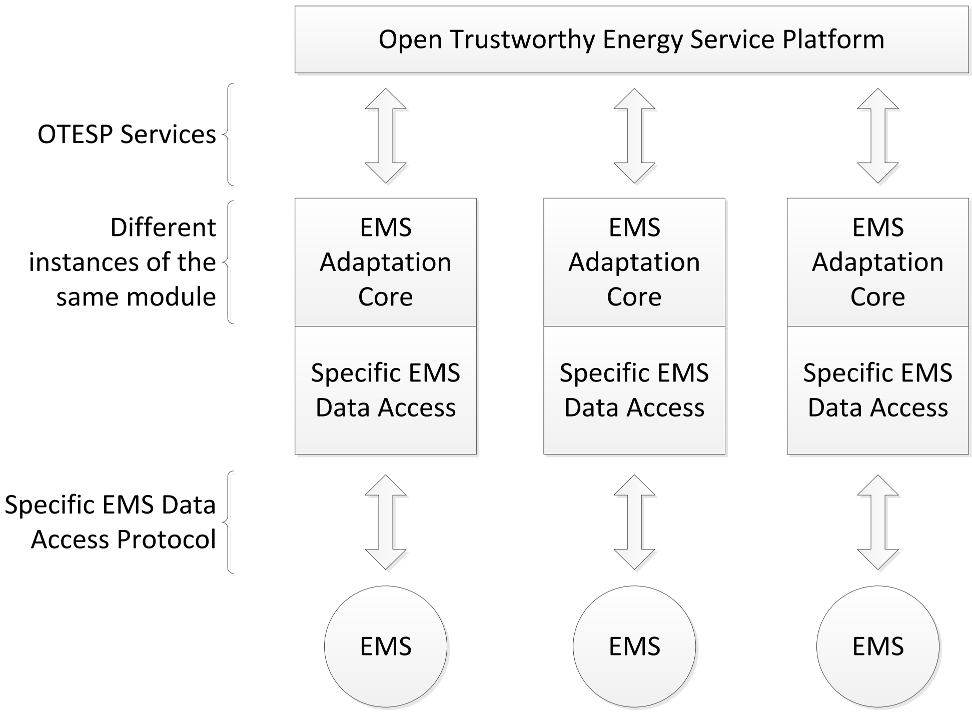

Figure 4 – ETRA EMS GWs architecture

The main functionalities of the EMS Adaptation Core included:

- Implementing the BESOS Common Information Model, including the communication protocol with the OTESP.
- Maintaining a list of entities of the EMS and their properties in a local data base.
- Integrating the metrics to comply with the requirements of each request.
    - Temporal integration: The frequency of the data taken could not potentially match the intervals needed in the request. Data had sometimes to be adapted and its integration depended on the type of metric (e.g. aggregation for energy consumption, arithmetic mean for temperature).
    - Spatial aggregation: Some OTESP services have the option to request the same metric from different entities and to receive it in aggregated form. While aggregation from entities in different EMS had to be carried out by the OTESP, local aggregation was an EMS responsibility. Again, the aggregation process depended on the type of metric requested.
- Assuring the quality of the data received from the EMS. This includes checking no data anomalies are returned to the OTESP or that blanks in the data are filled in a proper way.
- Querying external services in order to calculate complex metrics (CO_2 emissions, energy price, etc.) when they were requested.
- Notifying the OTESP about changes in the value of an attribute.

Regarding the specific access to data for each EMS, a brief description of the adaption performed in each case is described below:

- Barcelona Power Plant (Ficosa)
    - Measurements from both the generation assets and the weather station were retrieved through a RESTful web service. A module was developed that integrated its API and connected it to the core module.
- Barcelona Electric Vehicle system
    - Both the status of the EV charging points and the consumption of the vehicles were provided by means of a SOAP web service.
- Barcelona Public Lighting System & Municipality Buildings
    - These two EMS send their measurements to Sentilo, a software set by the Municipality of Barcelona that acts as a central hub for all the information of the city. By means of its public API, ETRA subscribed to an agreed set of sensors whose measurements were periodically received and stored in a local data base. This data base was then used as the source of measurements to attend the request from the OTESP.
- Barcelona Sodexo Buildings & Traffic Consumption System
    - ETRA developed a small circuit board (BETRA) that reads measurements from a network analyser using the MODBUS protocol and sends them to a remote server. A dedicated service reads these measurements and stores them in a local data base, which is used by the EMS GW to retrieve this data and serve it to the OTESP.
- Barcelona Traffic Information System
    - Information from the status of the traffic in Barcelona was uploaded every 15 minutes to a dedicated FTP. ETRA would read this information with the same frequency and store it locally in a data base that the EMS GW would eventually use as its source of data.
- Lisbon Traffic Consumption System
    - A RESTful web service was set, which once a day provided all consumption measurements from the day before in 15-minute granularity. From ETRA's side, a separate service from the EMS GW was in charge of retrieving these records

every day and store them in a local data base, which was then accessed by the EMS GW to serve the data to the OTESP.

The approach taken for the EMSs adapted by ETRA proved to be successful as it provided an easy and efficient way of integrating diverse sources of information gathered in several different forms, while fulfilling the requirements of the project. Thus, this will ensure the easy integration into the BESOS architecture of future systems and vendors, regardless of their nature or limitations.

As a summary, we highlight the lack of interoperability on existing hardware solutions that mandates us to the incorporation of different software framework for the adaptation of different asset types. This is a main innovation of BESOS platform, providing the harmonization of existing data models to CIM model which defines a common data framework for smart grids management.

3.2 OTESP Assessment Analysis

The OTESP middleware has been tested both in the trials integrated with other components and individually in lab experiments. The following section is dedicated to the analysis in an emulated WAN environment as the main innovation of the proposed framework is to easily adapt huge number of assets under a common platform.

3.2.1 Component testing process and indicators

As the OTESP platform, stands as the middle layer of the whole BESOS platform, multiple tests have been delivered in order to evaluate the overall performance. The main factors tested for OTESP adaptation are related to scalability, reliability, interoperability, speed of communication and ease on deployment. To obtain reproducible and controlled results, we conducted several lab tests with the OTESP to evaluate its performance under various settings.

3.2.2 Setup

For the setup, 7 year old desktop PCs with quad core CPUs (Intel® Core™ i7-860 Processor, 2.80 GHz, launch date Q3'09) and 8 GB of RAM are used. Since the connection quality between the systems can have a significant impact on the performance, a dual network setup is chosen: each PC is equipped with two network adapters. One adapter is connected to the normal LAN, the other adapter are connected to an isolated switch just connecting the evaluation systems. The normal LAN connection is used for controlling and evaluating the experiments, while the second connection is used to perform the actual exchange among the systems.

To limit the impact of the EMS on the measurements, a simulated EMS running on the same system as the OTESP is used. On the one hand, this increases the CPU load of the system. On the other hand, it reduces the effect of network communication. The simulated EMS consists of 10111 entities in 3 hierarchy levels. To reduce the overhead of the client, the request content of a normal web service client was recorded and is used with a pure http client for the tests. The response is read and then discarded without any parsing and further processing that would usually occur. This allows isolating the performance of the OTESP to a large degree.

Unless otherwise noted, each request was conducted 40 times – possibly distributed over several concurrent clients – and the average was taken for the results. On the one hand, isolated requests are noticeably slower due to initialization cost with ephemeral results (routing tables, DNS lookups, CPU caches, etc.). On the other hand, a client issuing multiple requests in succession is considered to be the common access pattern. Therefore it was concentrated on these for the evaluation.

3.2.3 Factors

The following factors are varied:

- *Networking Delay:* the Linux netem capabilities have been used to provide an artificial delay between the client systems and the OTESP system with the following values emulating various environments:
    - No delay: corporate connection
    - 10ms: good national connection
    - 50ms: international connection
    - 100ms: bad international connection
- *Web service protocol:* to evaluate the impact of recent standards, the protocol and the encoding are varied
    - HTTP/1.1 via TLS (HTTPS 1.1): the usual deployment option for trusted communication including encrypted transmissions
    - HTTP/2 via TLS (HTTPS 2): the new standard includes further compression methods and binary coded transmissions
- *Encoding/compression:*
    - JSON, no compression (REST nogz)
    - JSON, gzip compression (REST gzip)
    - XML, no compression (SOAP nogz)
    - XML, gzip compression (SOAP gzip)
- *Concurrent clients:* the number of concurrent clients requesting the information
    - 1, 4, 8

3.2.4 Metrics

The following information is measured directly:

- *Duration:* the duration for the complete test (involving several request/response cycles)
- *Amount of data:* the number of bytes sent/received by the client machine

To record the bandwidth information, the low level facilities provided by Linux in the /proc/net/dev file are utilized. Among others, this includes statistics for the complete number of bytes received and sent. Therefore, the measured size will be slightly larger. However, this approach makes sure to capture all effects, for example, due to SSL encryption while reducing the impact of the measurement itself as much as possible. Additionally, since a dedicated network interface is used as described above, the background traffic incurred by the OS should be minimal.

The main metrics are then computed:

- *Latency:* how long does a complete request/response cycle take on average (in milliseconds)
- *Amortized Latency:* the averaged latency when considering multiple concurrent clients (in milliseconds)
- *Throughput:* how many kilobytes per second are transferred
- *Effective Throughput:* for gzip compressed data, the number of bytes transferred by the analogous non-gzip compressed request divided by the time of the gzip request (in KB/seconds; 1 KB=1024 Bytes)

3.2.5 Request types

The following request types are used that cover the most common use cases encountered during the project and envisioned also for future use.

- *ListToplevelEntities (tle):* request the top level entities of the EMS. This is an example for a very small request.
- *FindEntities (fe):* request the complete list of entities. This very large request should occur rarely in deployments, e.g., once per day to initialize the list on the cockpits.
- *GetAllMetrics (am):* request the energy consumption of the last 15 minutes of all entities. This corresponds to the most common request of the Decision Support System Cockpit, which periodically request this information and stores it for local caching and further processing.
- *Week (w):* request the hourly energy consumption of 100 entities for a week. This represents a common use case for a cockpit that requests online information on demand.
- *Week Aggregated (wa):* request the hourly aggregated energy consumption of 100 entities for a week. Similar request as above but highlights in-network processing of the platform.

3.2.6 Results

3.2.6.1 Amount of data

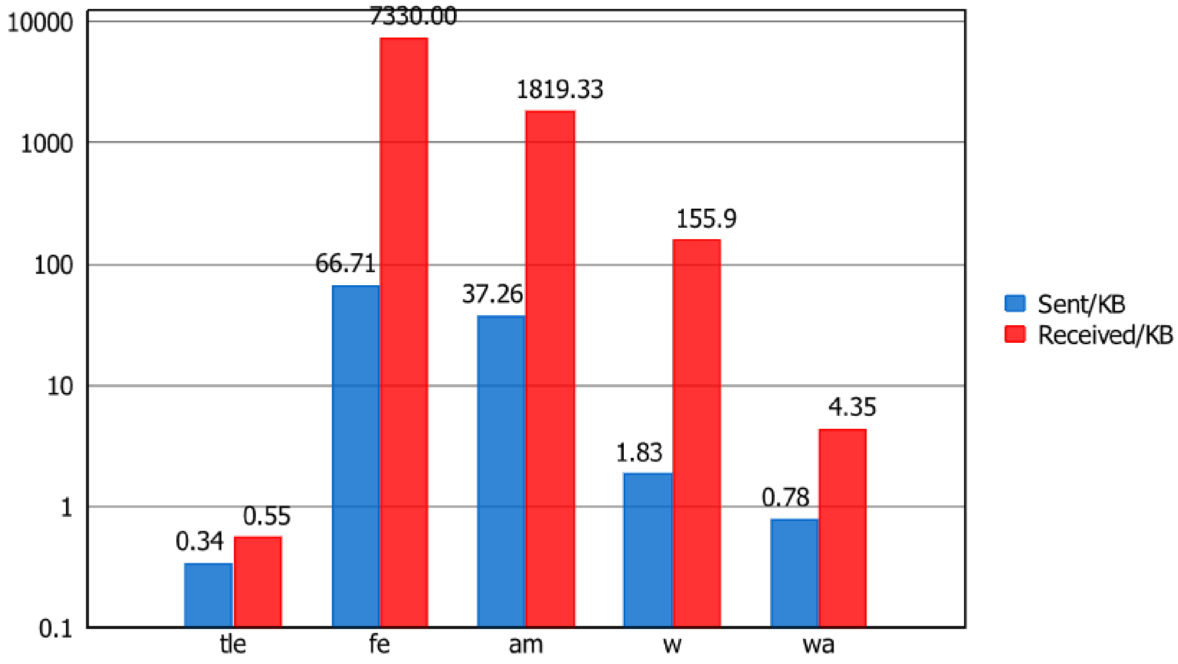

Figure 5 Amount of data sent/received in KB (logarithmic scale)

In Figure 5, the required amount of data for the different request types is compared. The results are taken from a test using the "national" environment, HTTPS 1.1 with REST without compression, averaged over the sum of 40 runs with one client.

Noteworthy is the number of sent bytes: while the net size of the requests is comparably small and the difference between "w" and "wa" is exactly one byte ("true" vs. "false"), the total overhead incurred also includes, for example, TCP acknowledgements for the response, which significantly increase the total number of bytes.

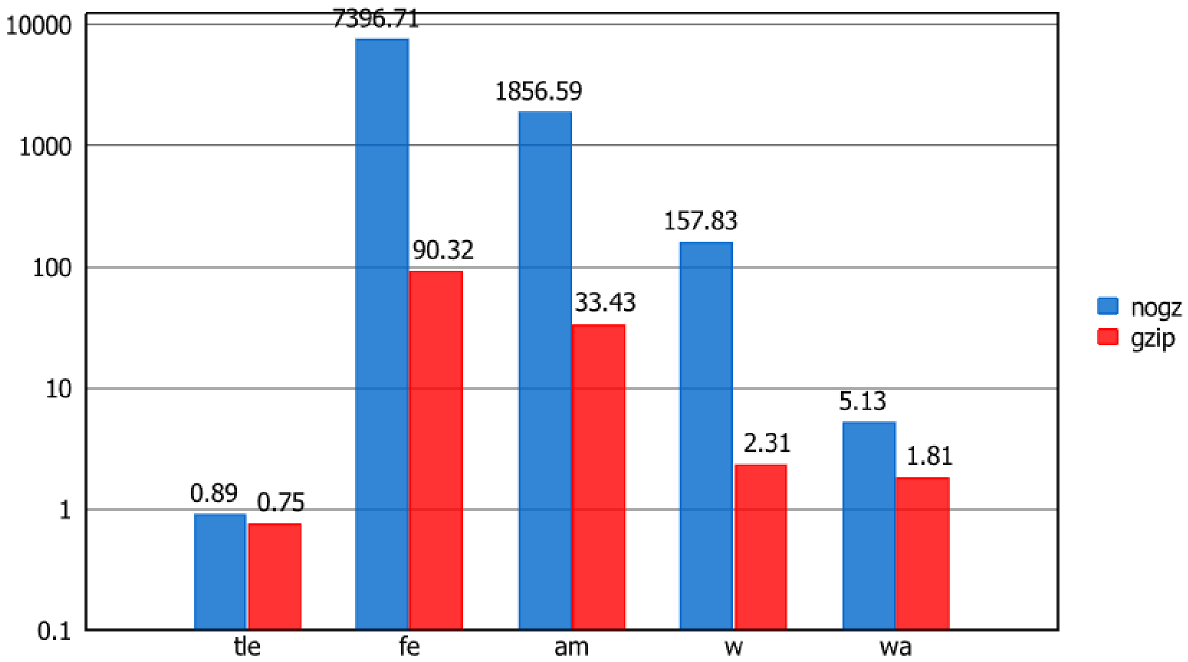

Figure 6 Amount of data in KB for gzip (logarithmic scale)

In Figure 6, the total amount of data (sent + received) from requests with and without gzip compression is compared for the same scenario as mentioned before. For large requests gzip can achieve an improvement up to two orders of magnitude. It is, however, important to note that the compression ratio varies with the data and is higher in the lab tests due to the artificial data and homogeneity of the entities. For this reason, the following test is also conducted that includes evaluating the impact on a more realistic scenario.

3.2.6.2 Heterogeneous EMS

To provide an utter contrast to the mostly homogeneous EMS and to some extent worst-case scenario for compression, we consider an EMS with significant randomness. The structure and number of entities is the same as for the default EMS (10111 entities, 3 hierarchy levels).

- The number of metrics per EMS is randomly chosen (normal distribution, mean: 10)
- The metric types are randomly chosen by using a normal distribution over the complete range of metrics (110)
- For the following fields, a wordlist of 1500 commonly used English words and a uniform random value for the selection are used
  - The name of the entity (1 word)
  - The short description: normal distribution, mean 3 words
  - The long description: normal distribution, mean 11 words

For the following test, HTTPS 1.1 and REST are used with a varying number of clients, with and without gzip compression. Furthermore, the "fe" request was chosen for comparison, since the randomly chosen values mainly affect requests containing entity information.

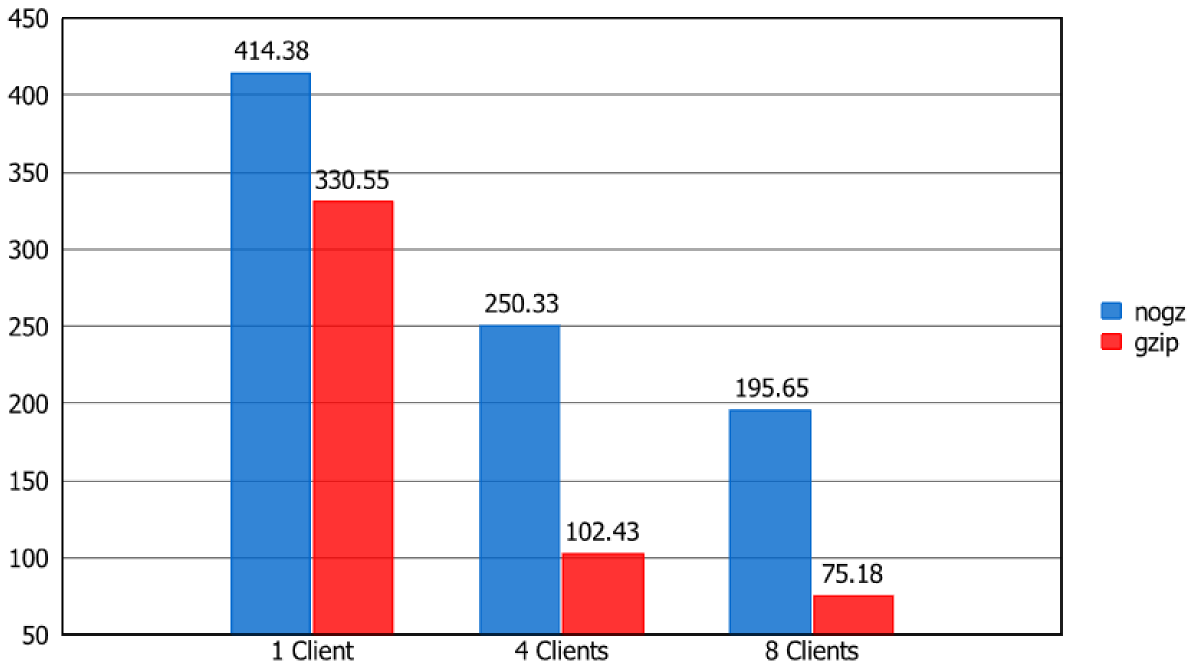

Figure 7 Amortized latencies for multiple clients using gzip and a heterogeneous EMS

Having a total request size of 11.55 MB for the “fe” request on the heterogeneous EMS, the gzip compression still reaches one order of magnitude (size reduced to 1.05 MB), resulting in the latency differences shown in Figure 7. Especially for an increasing number of concurrent requesting clients, the benefits for using data compression increase as well as the scalability of the system is highlighted. Independently of the compression method and encoding, the OTESP makes use of the multi-core system to support the requests from concurrent clients and reduces wait times introduced by the networking protocols.

3.2.6.3 Impact of communication delays

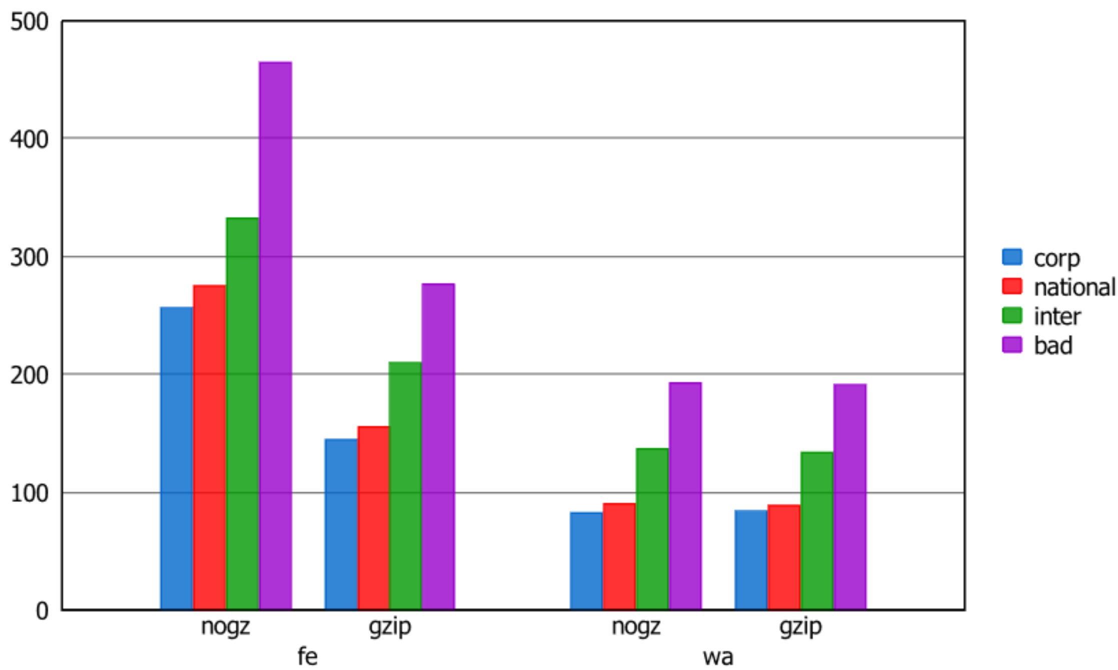

Figure 8 Latency with respect to underlying communication delay

In Figure 8, the impact of the communication delay of the underlying system is shown. The 4 settings for HTTPS 1.1 with one client are compared. The by far largest request “fe” evinces that the difference of the environments decreases with request size. When considering the “wa” request which only incurs around 10 KB of data, the bad connection performs more than 100% worse than the national connection.

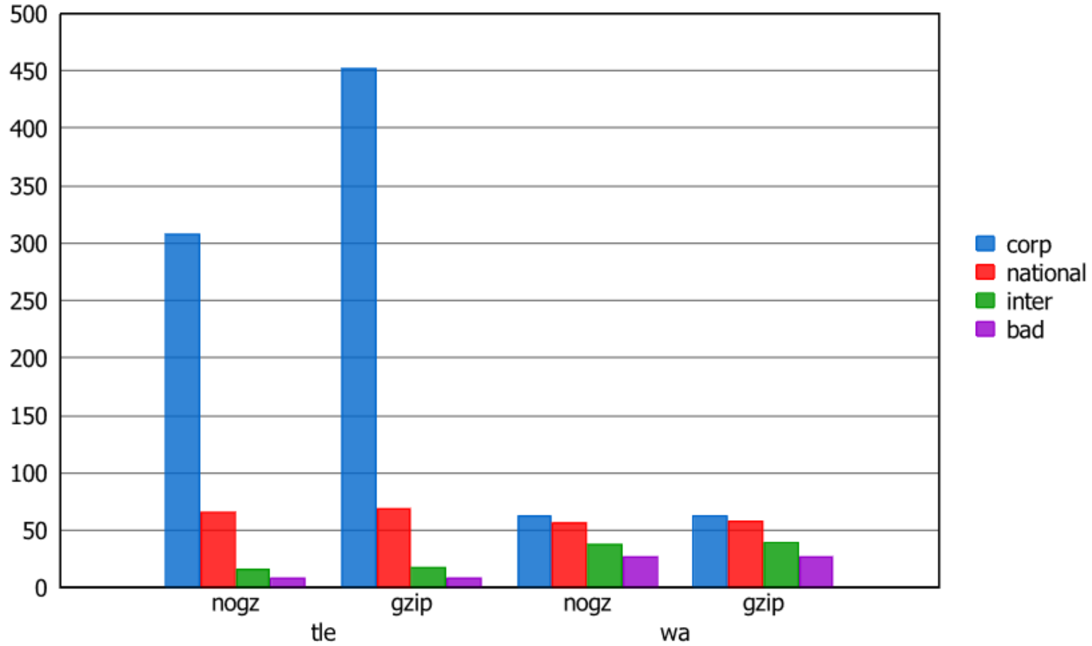

Figure 9 Effective throughput (in KB/s) with respect to underlying communication delay

The difference is even more pronounced for the smallest considered request “tle” as shown in Figure 9. It also highlights that the comparably small artificially introduced latency of 10ms for the “national” environments shows a significant impact on the smallest (“tle”) and a still noticeable impact on the small request (“wa”).

3.2.6.4 REST vs. SOAP

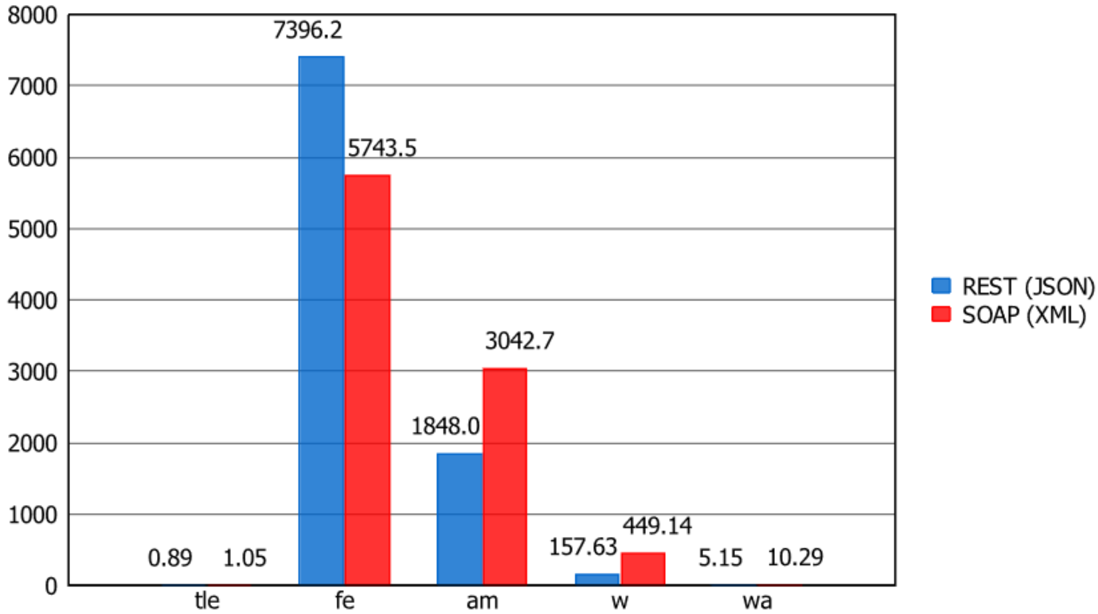

Figure 10 Amount of data for REST and SOAP in KB for each request

Since the OTESP is providing both SOAP and REST endpoints for communication and therefore accepts XML and JSON encodings, we compare both approaches and their impact on the performance. The most important aspect is the size of the encoded data. Thus in Figure 10 the total amount of data for both encodings is shown. For this test, the “national” environment with HTTPS 1.1 and without compression is used. Except for the “fe” request, all other JSON encoded requests are smaller than their XML counterparts. Since for delimiting fields of a submitted data structure XML uses opening and closing tags while JSON just uses the fieldnames once, the overhead for XML is higher in case values exist for the correspondent fields. If the respective field has no value (is null), XML allows to omit this information whereas JSON has to explicitly null the field (according to RFC4627). Therefore JSON has a disadvantage if several data fields are unset as it is the case for the “fe” request.

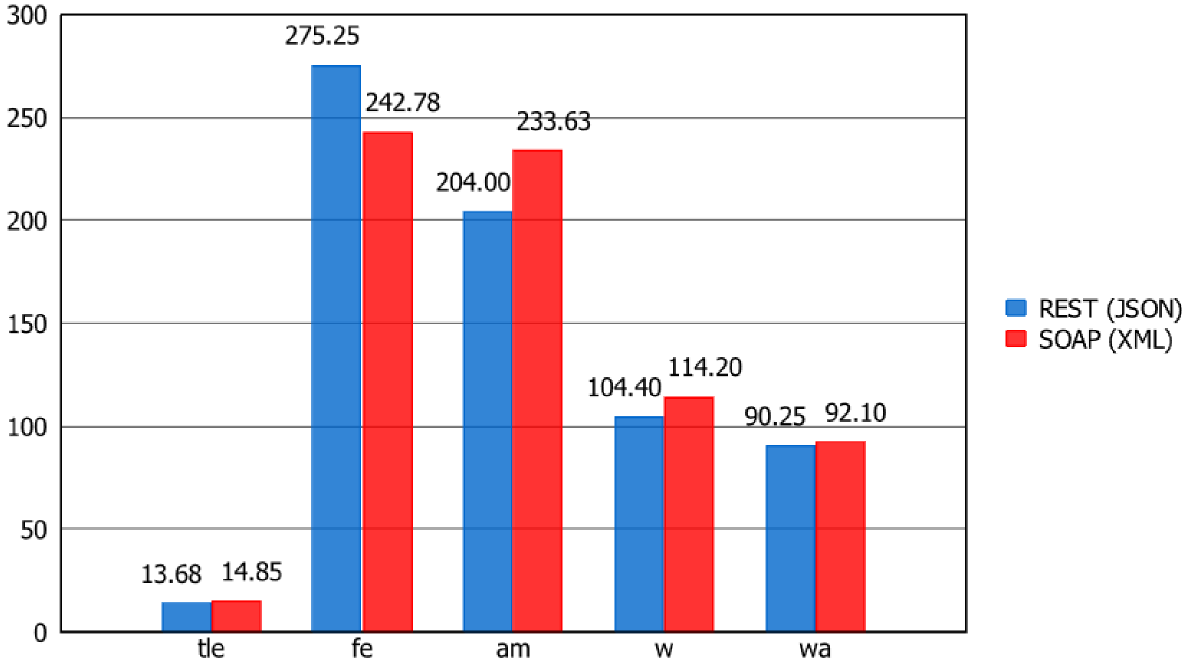

Figure 11 Latency comparison between REST and SOAP requests (latencies in ms)

The results for the latencies, shown in Figure 11 mirror the differences in the amount of data for SOAP and REST requests. All types of REST requests but the “fe” request are faster than the corresponding SOAP requests.

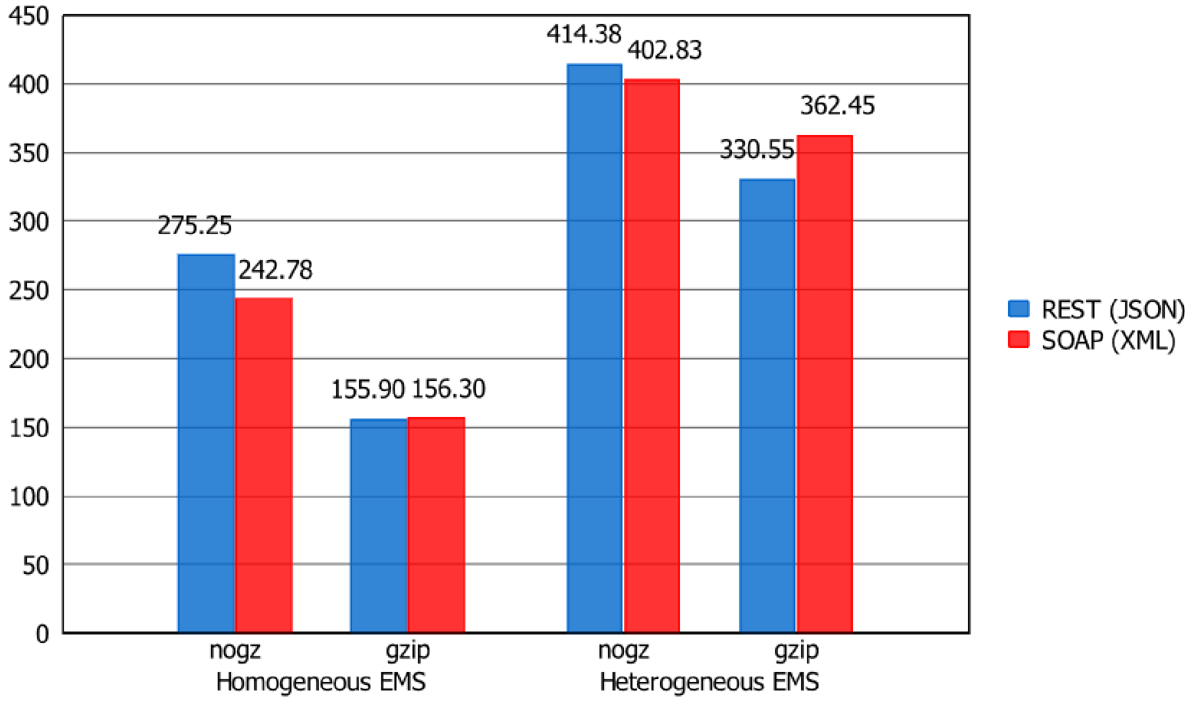

Figure 12 Latency comparison for the "fe" request with different settings

If we change the settings and again take up the homogeneous EMS described in section 3.2.6.2, we now compare the "fe" request under different circumstances. In Figure 12, the latencies for the two different types of used EMSs are shown in combination with and without data compression. Since the randomly created entities of the heterogeneous EMS contain more data than the one used for the homogeneous EMS, the weight of the overhead compared to the data decreases, resulting in more similar latencies for SOAP and REST requests. When using compression, there is almost no difference in latency between both approaches for querying the homogeneous EMS and an advantage for REST if the heterogeneous EMS is used, although the compressed size of the JSON encoded data is slightly bigger and therefore it takes more time to transmit. This indicates that also the speed of the used libraries for converting the provided data into the respective format has a noticeable impact on the response times. In general, due to the same data content, but the bigger overhead for the XML format, JSON performs better the more assigned fields the data structure contains.

3.2.6.5 HTTP/2

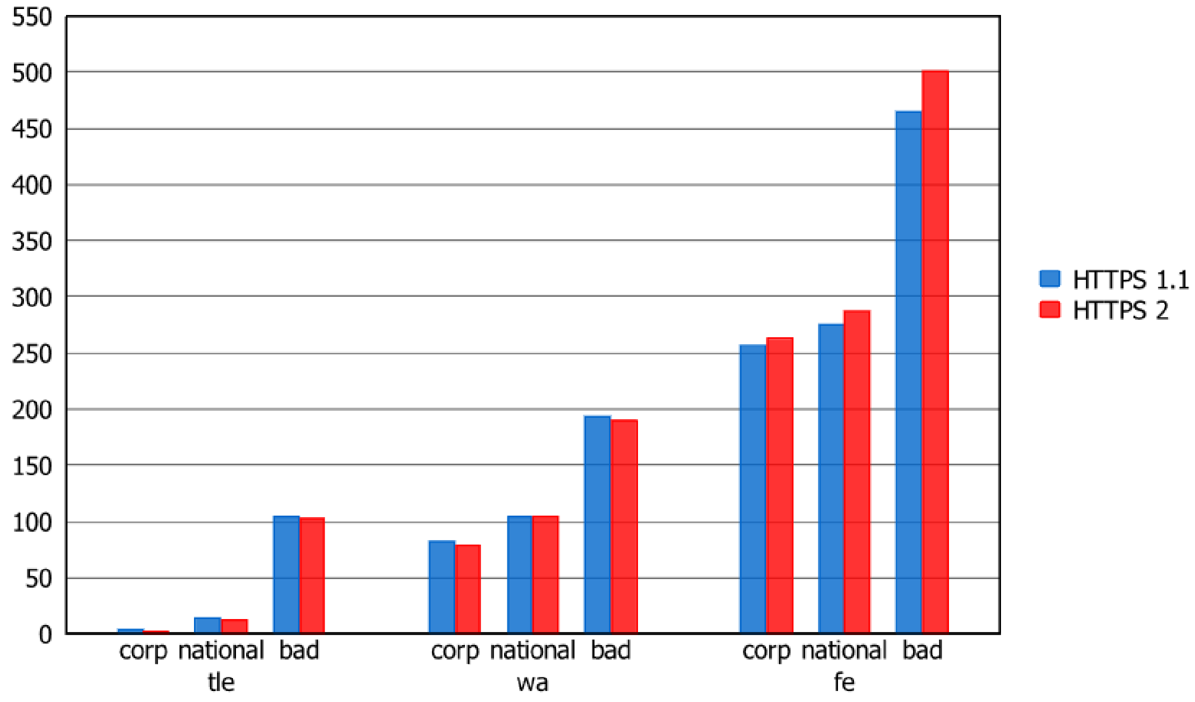

Figure 13 HTTP/2 impact (latencies in ms)

The successor of the HTTP/1.1 standard comes with new features to decrease latencies especially for small amounts of transferred data to for example allow for a faster initial webpage build-up on users' displays. The difference between the older HTTP/1.1 and the new HTTP/2 standard on the latencies are shown in Figure 13. For small requests ("tle", "wa"), there is mostly a little gain of a few milliseconds using HTTP/2, probably due to the benefits of the header compression mechanism. For large requests ("fe"), HTTP/1.1 performs noticeably better, underlining the focus of HTTP/2 optimizations on smaller request sizes.

3.2.6.6 Batching

One basic idea of the OTESP is to provide the cockpits the options to compound requests, for example by requesting data from several entities and for several metrics at the same time.

To evaluate this design, a request similar to "GetAllMetrics" is evaluated: the metric value for the last 15 minutes is requested for 5 different metrics from 100 entities. The following four approaches are distinguished:

- *Single Metric, Single Entity (SmSe):* each request obtains 1 value (i.e., 500 requests in total)
- *Single Metric, Multiple Entities (SmMe):* each request obtains the metric values for all entities, but for a single metric (i.e., 5 requests)
- *Multiple Metrics, Multiple Entities (MmMe):* one request obtaining the metric values for all entities and for all metrics. The entities are specified individually in the request.
- *Smart:* same as MmMe but uses the filtering capabilities of the request to specify the shared parent entity of the 100 children

Each sequence was performed 40 times and the results were averaged.

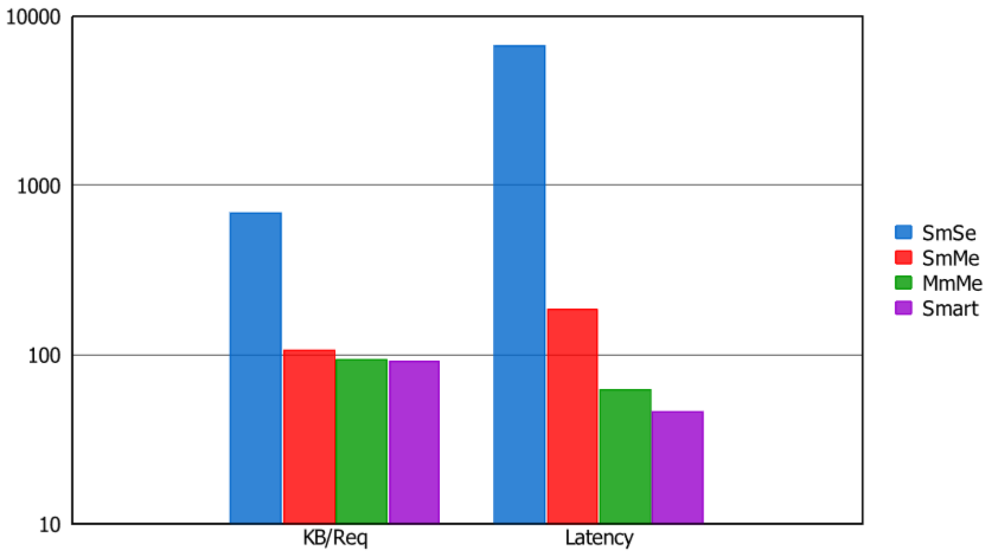

Figure 14 Comparison of batching levels (logarithmic scale)

In Figure 14, the total amount of data incurred by the different requests is shown as well as the average latency (in milliseconds). Combining the requests for 100 entities into a single one ("SmMe") decreases the amount of exchanged data by factor 4.5 and the latency by a factor of almost 38. When also including the metric types into one single request ("MmMe"), the values further decrease. If the explicit enumeration of all requested entities is replaced by the parent entity information using the filtering capabilities of the platform ("Smart") and taking advantage of the more efficient entity lookup the parent information leads to, even faster response times can be achieved.

3.2.6.7 OTESP KPI computation (CEP)

In order to evaluate the overhead and savings of computing KPIs on the platform, we chose the KPI 13 "Difference in energy exchanged" as the evaluation example. This KPI calculates the exchanged energy (production-consumption) of an entity as a time series and as a second step compares these between two time frames (for example, this year vs. the previous year). For this evaluation, the quarter-hourly numbers between two years are compared (35040 values).

Three requests are compared:

- A metric request to obtain the energy production for one year: this request contains the same number of values as the KPI request and serves as a baseline to evaluate the OTESP computation overhead
- Metric requests to obain all input values for the calculation, which allows the cockpits to calculate the KPI results itself (two requests in total - one for each time series, but for both metrics at once)
- A CEP request to obtain the KPI results

The "national" environment with HTTPS 1.1, REST and uncompressed data transmissions are used and the result is computed from the average of 40 requests. Note, as before to limit the overhead of the EMS, the simulated EMS is co-located with the OTESP.

	Relative Latency	Relative Request Size
Baseline	1	1
Metrics	2.32	4.01
CEP	1.21	1.07

Table 3 Latencies and request sizes of CEP

In the table, the relative latencies and request sizes for the results are shown. As the KPI calculation requires 4 time series (energy consumption/energy production x2 time frames), requesting all necessary values lies within the expected range and requires approximately 4 times the size and takes a bit more than 2 times as long (the increase is mostly due to the additional EMS lookup time for the second metric). The computation on the OTESP for this KPI, however, has only around 20% latency overhead compared to getting only one metric time series of equivalent length.

3.2.6.8 One million entities

As the final lab test, we evaluated the system with one million entities. Again, the "national" environment with HTTPS 1.1, REST and without compression is used.

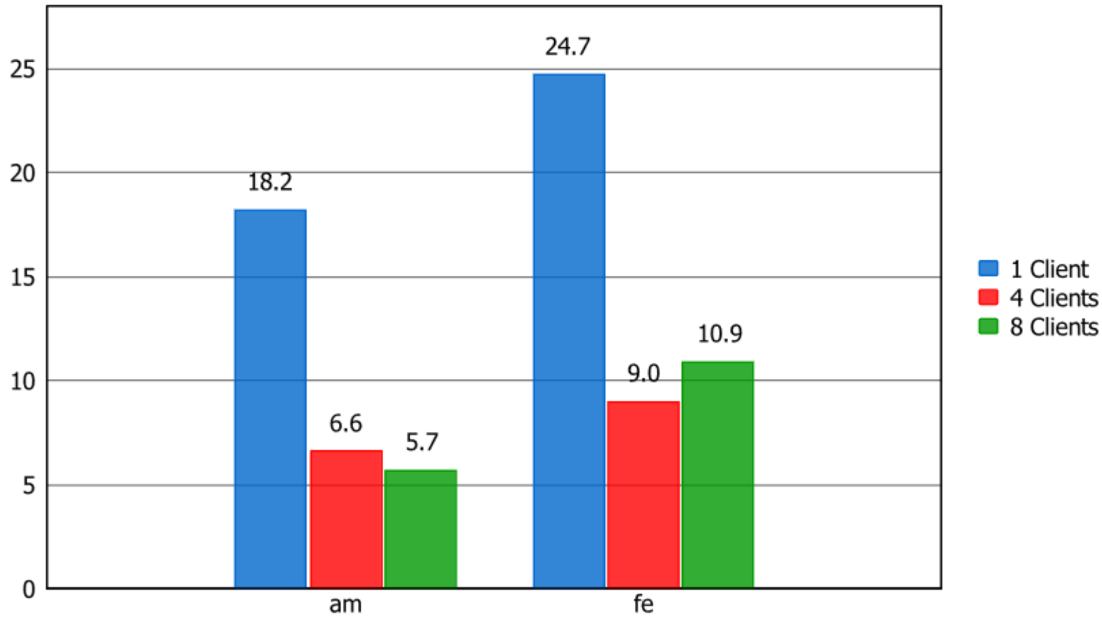

Figure 15 Amortized latencies for 1 million entities (in seconds)

In Figure 15, the latencies for the two request types involving all entities of the EMS are shown: getting a list of all entities and getting the metric values for all entities for the last 15 minutes. For easier reading, the latencies are shown in seconds for this plot. The graph highlights the scalability of the system: with 4 concurrent clients the result reflects the use of the 4 cores of the server hardware leading to around 3 times faster completions of both request types. Depending on the type of request, 8 concurrent clients show slightly better ("am") respectively worse results ("fe"). Due to the huge amount of data, the server has to send to the client, 179 MB of data for the "am" request and 718 MB for the "fe" request, the speed of the connection between client and server becomes the bottleneck of the system. For the tests, a Gigabit Ethernet connection with a theoretical maximum of 125 MB/s and an effective speed of around 100 MB/s is used. As it can be seen in Figure 16, when using 4 clients for the "fe" request, the throughput nearly hits the boundaries of the Ethernet connection. Note that during the EMS lookup time after the client request and before the platform response, no data is transferred. Thus the computed throughput decreases proportional to this time and therefore lies below the effective throughput of the Ethernet. Since more parallel clients have to share the bandwidth implying additional overhead, the throughput reduces as well as the latency increases for 8 clients. However, assuming a sufficiently fast connection for the data transfer with respect to the amount of data to be transferred, the system scales very well with the number of cores.

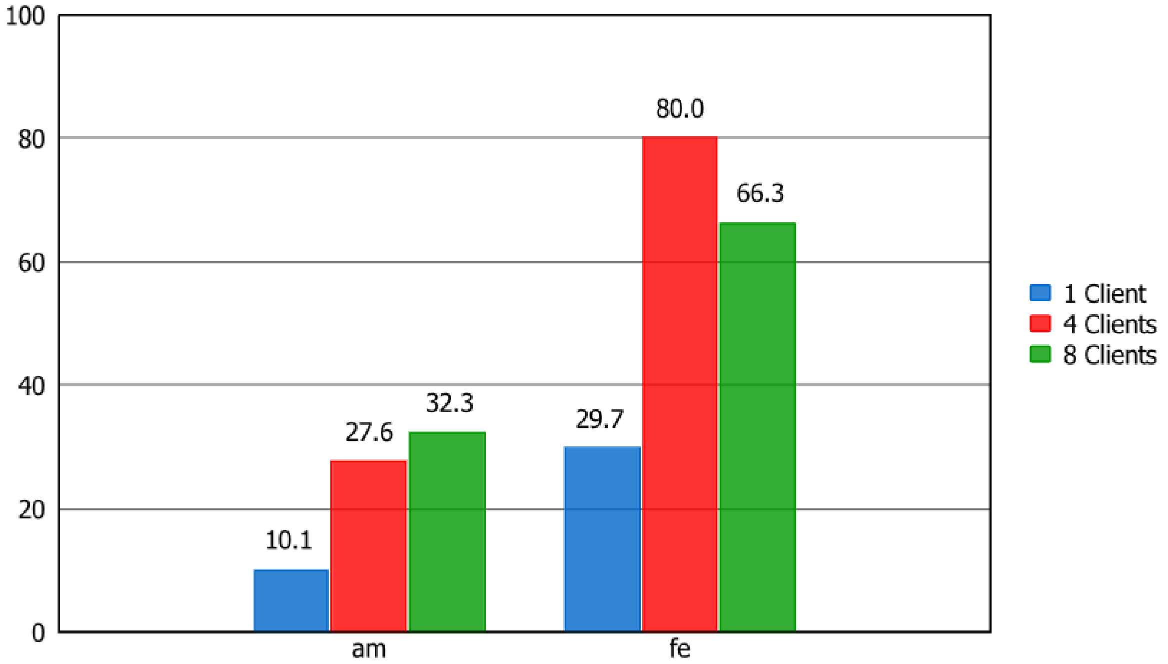

Figure 16 Throughput for 1 million entities (MB/s)

3.2.7 Reliability

Reliability is a primary concern of the design of the OTESP. Especially the failure of a single EMS should not impact requests for information from other EMS. Thus on the one hand, the OTESP analyses the request and only queries EMS that are concerned. On the other hand, a timeout value for potentially long running requests that can even be determined by the cockpits makes the OTESP return the obtained information at least up to the specified time. This handles situations if the response from an EMS is not received, for example because it is stuck in a loop or waiting for further information from subsystems. The OTESP aggressively parallelizes the requests, which also benefits the performance. Furthermore, the EMS operators have the ability to temporarily disable the EMS in the GUI – for example during maintenance time – which prevents the OTESP from even trying to reach it and further improving the answer time in case a connection is not possible at the moment. Finally, the OTESP also contains a status monitoring component, periodically querying each EMS for data in order to trace the availability and provide these statistics in the GUI as well as through a separate service on demand, helping to identify temporal interferences of the EMS services.

After deploying the OTESP prototype, the platform has been restarted 49 times in a period of approximately 18 months. There has been no crash on the platform. Instead the restarts have been necessary to accomplish configuration and model changes, updates to the platform, updates to used components and operating system updates of the server. The uptime reached over 99.9%. However, the availability was considerably smaller due to downtimes of intermediate components. Maintenance updates of firewalls and routers as well as necessary server reconfigurations due to version conflicts after updates put the availability still at around 99%.

3.2.8 Interoperability and Ease on deployment

The implementation of the OTESP, the so-called “Dyson” core which realises the web services and the platform is written in Java. Although Dyson and the underlying meta model are independent of the BESOS Common Information Model (CIM), which has been defined in WP2, it can completely be mapped to this architecture. This allows changes and extensions to the data model to be applied in a fast and easy way. Additionally, due to the support of the wide-spread and commonly used SOAP and REST technologies for information exchange on both sides, users and EMSs, the OTESP abstracts from one specific communication scheme as well as from the underlying software/programming language used by the involved components. Therefore it ensures interoperability and provides the necessary interfaces for a wide range of applications.

As already mentioned, the Dyson implementation of the OTESP has completely been realised in the Java programming language. Since today nearly every device is capable of running Java programs and there exist various runtime environments for multiple operating systems, the Dyson OTESP can be deployed on almost any computer, providing enough capabilities to act as a server. All necessary code files including all of the dependencies are assembled into one single executable jar file which can be started along with only two configuration files containing execution parameters and the available EMSs with their correspondent endpoint addresses, the OTESP shall make use of. There is no need for the installation of further programs except the Java runtime environment which most of the devices have installed today. Thus the Dyson OTESP is very easy to deploy and runs on almost every computer without requiring much technical knowledge.

3.3 BESOS BBSC Assessment Analysis

The goal of this section is to examine the technical assessment of BESOS Business Balanced Scorecard. This is a tool for facility owners and managers in order to get insights about portfolio performance and further define high level strategies, taking into account the potential of the portfolio. We have to point out that there are two different applications that comprise BESOS Business Balance Scorecard (BESOS Visual Analytics tool and BESOS Balance Scorecard) and thus we are conducting the respective stress tests per application.

3.3.1 Component testing process and indicators

In order to evaluate the performance of each application, a set of indicators has been selected for analysis. Scalability, Reliability, and Latency parameters are considered for the evaluation process. We are starting the presentation of results for Visual Analytics tool, followed by the technical evaluation of BESOS Business Balance Scorecard.

Visual Analytics tool

The goal of the Visual Analytics tool is to provide visualization and interaction mechanisms to ESCOs and FM for multidimensional analysis of the portfolio. As we are considering the integration of multiple asset types, associated with the different algorithmic techniques for analytics process, it is mandatory to evaluate the technical complexities of this application. In order to evaluate the technical implementation of Visual Analytics tool, different simulation tests were performed.

We are starting the analysis with the evaluation of BESOS VA tool reliability levels. Considering the number of assets integrated in the platform, the reliability indicator for VA tool is mainly affected by EMSs availability/adaptation in OTESP platform. As reported above, there has been no crash on the platform. The uptime reached over 99.9%. However, the availability was considerably smaller due to downtimes of intermediate components. Maintenance updates of firewalls and routers as well as necessary server reconfigurations due to version conflicts after updates put the availability still at around 99%. Similar results are reported for BESOS VA tool. The uptime of the service was over 98.0% considering reconfigurations and updates in the application to address BESOS scenarios following the integration of different asset types.

What related to EMS availability which affects the overall deployment, the detailed results are presented in D7.2. Here a summary is reported in order to define the availability of functionalities offered by BESOS VA tool.

	Lisbon Pilot Site	Barcelona Pilot Site
1st Demonstration Period	94.03%	93.80%
2nd Demonstration Period	96.04%	96.23%

Figure 17 EMS Reliability Level at Pilot Sites

The analysis is performed in the full list of assets integrated in BESOS platform.

From the aforementioned analysis, it is clear that the overall availability is affected by EMS availability levels. For both OTESP and BESOS VA, we are reporting a high level of reliability (over 97% in total) which ensures the prompt operation of the business application.

The second test is performed for the evaluation of possible latencies for each of the functionalities supported by the application. There are two main factors that affect this parameter:

- Speed of connection/interface with data management layer (queries in database for historical data and OTESP for accessing real time data) which is mainly affected by the load of requests from Visual Analytics tool and the simultaneous calls from the rest of business applications.
- Latency due to analytics process, considering the algorithmic framework that transforms raw data to meaningful knowledge.

We have to point out that the number of assets integrated in pilot cities is rather low and thus no latency is reported due to the algorithmic part of the application (analytics process is performed in a limited number of data). Considering also that the main objective of the VA app is to provide filtering and clustering of assets per scenario, a limited number of asset types is examined at each case scenario (e.g. only public building, only generation assets etc.….) On the other hand, we have to report latencies due to communication with OTESP, affected by the final deployment of the solution and the communication latency between OTESP and EMSs. Toward this direction the metrics computed are:

- *Latency:* the averaged latency when considering multiple concurrent clients (in milliseconds)
- *Throughput:* how many kilobytes per second are transferred

The results from the different tests performed during the evaluation period are reported in the following figures. The following scenarios are distinguished:

1. Single Metric, Single Entity: each request obtains 1 week value
2. Single Metric, Single Entity: each request obtains 1 month value
3. Multiple Metrics, Single Entity: each request obtains 1 week value
4. Multiple Metrics, Single Entity: each request obtains 1 month value
5. Single Metric, Multiple Entities : each request obtains the metric values for all entities, but for 1 week value
6. Single Metric, Multiple Entities : each request obtains the metric values for all entities, but for 1 month value
7. Multiple Metrics, Multiple Entities: one request obtaining the metric values for all entities and for all metrics for 1 week period
8. Multiple Metrics, Multiple Entities: one request obtaining the metric values for all entities and for all metrics for 1 month period

Each sequence was performed multiple (10) times and the results were averaged. Taking into account the list of scenarios examined in BESOS VA tool, a maximum number of 3 metrics are retrieved per business scenario, while a total group of 10 assets is also setting the max limit for demonstration. The results are presented in the following Figure starting from the raw values and further providing average data considering Scenario 1 as the baseline scenario.

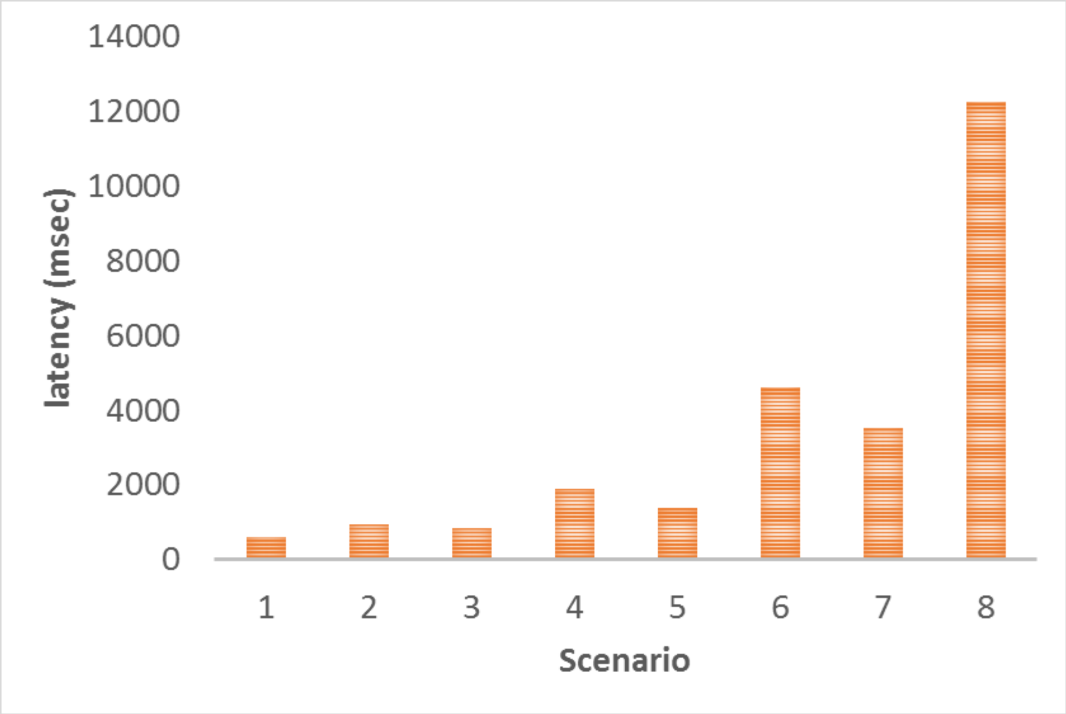

Figure 18 Latency Values for the different test scenarios

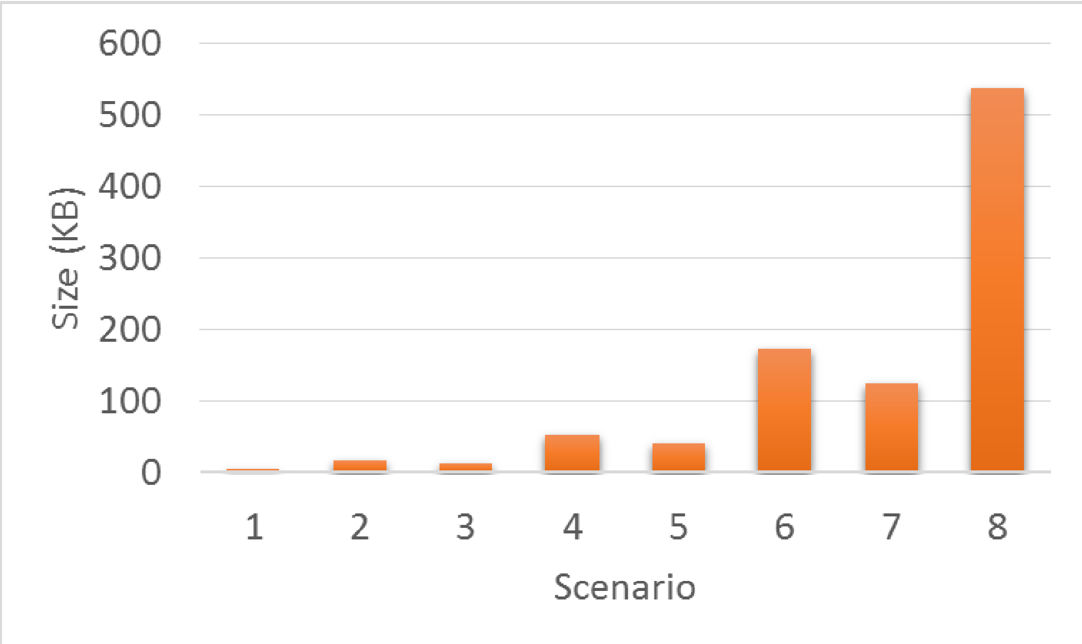

Figure 19 Message size for the different test scenarios

Then, the average values are reported in the following figures

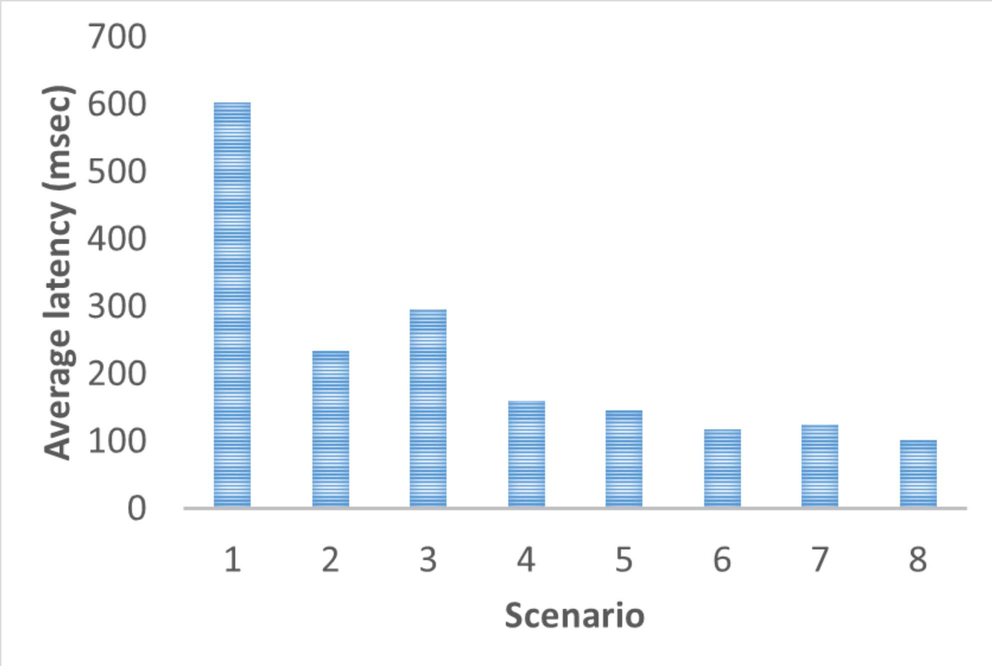

Figure 20 Average Latency for the different test scenarios

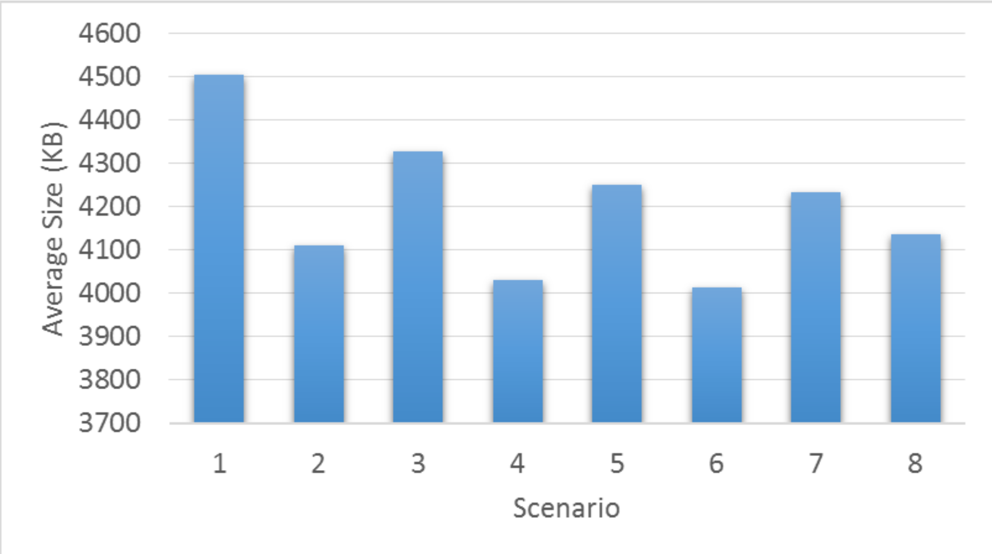

Figure 21 Average message size for the different test scenarios

The latency test is performed in the ***GetAllMetricsTimeseries*** request as this is the most common request of the BESOS VA tool, which periodically requests information and stores it for local caching and further processing.

In addition the CEP mechanism (getProcessingGraph) is also evaluated towards KPI calculation. A list of 8 test scenarios are defined as above, by replacing metric with KPI values. The results from evaluating the **latency of CEP mechanism** are presented:

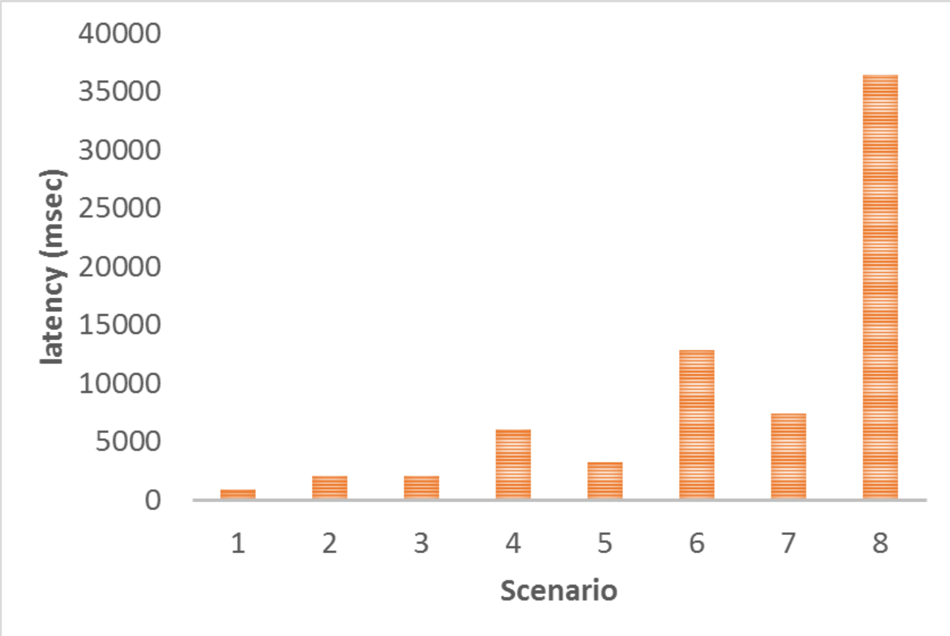

Figure 22 Latency for KPI calculation at the different test scenarios

Then the average latency considering also the size of the message is presented in the figure:

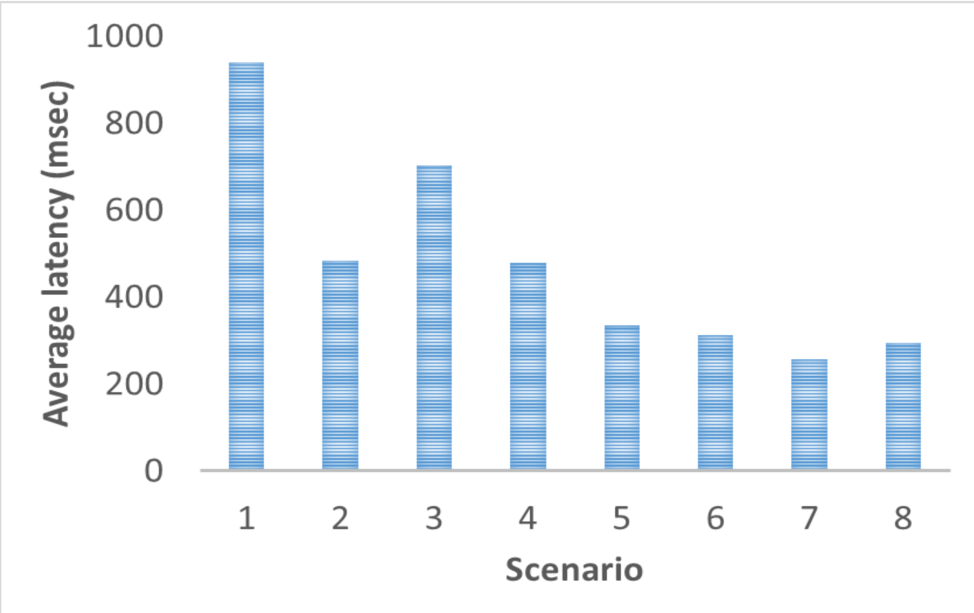

Figure 23 Average Latency for KPI calculation at the different test scenarios

The KPI calculation requires 2 time series (energy consumption x2 time frames), requesting all necessary values lies within the expected range and requires approximately 2 times the size and takes a bit more than 2 times as long. The computation on the OTESP for this KPI, and further visualization via BESOS VA tool, has a 38% latency overhead compared to getting only metric time series of equivalent length.

As a final test for Visual Analytics tool, we are examining the scalability of the application. The role of the Visual Analytics tool is to offer analytics over large volumes of data and thus we should examine the scenario of multiple assets integration and impact on VA functionality. In order to perform this test, we have extending the number of assets considered at each case scenario by multiplying the types of existing assets, setting that way a simulated portfolio. The results from this stress tests about the scalability of BESOS VA platform are presented:

The VA tool exploits the multi-thread functionality offered by OTESP towards gathering data from the different end points. This is the way to handle big data from heterogeneous asset types integrated in a common platform. The results from scalability tests are presented:

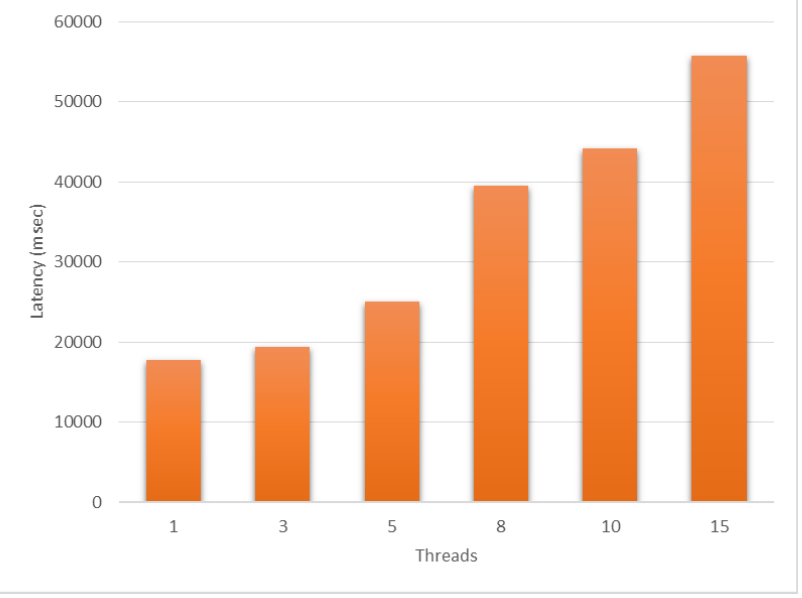

Figure 24 Latency for accessing multiple end points data

The average latency diagram considering multi thread operation towards the establishment of a scalable application is presented:

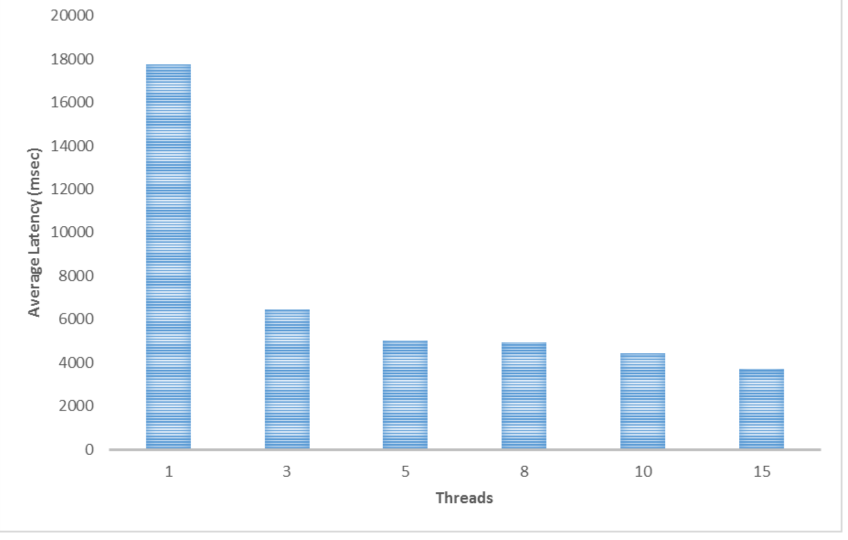

Figure 25 Average latency for accessing multiple end points data

We have to point out that for this test case, the maximum throughput is 233KB/sec which is mainly due to the remote connection with OTESP platform. Therefore the internet connection directly affects the scalability of the application, setting that way the main boundary for a distributed implementation. By hosting BESOS applications in a common infrastructure we avoid this latency, enabling that way the expandability of BESOS VA solution.

BESOS Balanced Scorecard

Following the detailed evaluation of BESOS VA tool, we further proceed with the evaluation of the complementary BESOS BBSC application, BESOS Balanced Scorecard.

Both front- and back-end of the BESOS Balanced Scorecard were deployed in a virtual machine running Windows Server® 2012 R2 Standard, with a dual-core Intel® Xeon® E5-2650 Processor @ 2.80 GHz and 10 GB of RAM. The back-end process was the part of the system in charge of communicating with the OTESP to retrieve measurements from the different EMSs in the system and feed with these data the different applications of the top-level layer of BESOS. For this reason, this will be the part of the system whose capabilities will be the main subject of the evaluation tests.

As with previous components, the performed tests for the BESOS Balanced Scorecard focused on assessing the scalability, reliability and latency of the tool. Starting with the reliability of the BESOS Balanced Scorecard, since the beginning of the 1st round of trials, the tool has been available with no substantial downtime registered. Although updates and system fixes were carried through during both testing periods, their deployments did not led to service halts longer than a few minutes, which overall resulted in an availability over 99%.

Broadening the scope of the test to the whole BESOS system, the reliability of the BESOS Balanced Scorecard depends on that of the OTESP, as it eventually is the source of all measurements managed by the application. However, as has previously been reported, the uptime of the service platform reached similar availability figures during the testing period, so even in this case the reliability of the tool has been proved to more than meet the requirements of the project.

Continuing with the assessment of the key parameters of the tool, a set of test were performed in order to assess the latencies of the tool. The following processes were evaluated:

1. **OTESP communication.** To calculate the KPIs managed by the BESOS Balanced Scorecard, measurements from the OTESP are retrieved integrated by day. The evolution of each KPI is monitored through a month, and it usually involves a set of entities, a metric type and two points in time. Although in normal functioning, only new measurements are requested to the OTESP (as previous ones are already stored in a local data base), for some tests we will consider a full-month period of data gathering.
2. **KPI calculation.** Once the data is available, an internal algorithm starts calculating the new values of the KPIs. As with the previous process, only the values for the current day are calculated, but the complete month cycle will be considered in some tests for pure evaluation purposes.

The tests defined to evaluate the latency of these processes are the same ones used in the case of the BESOS VA tool. However, the amounts of data and the integration of the measurements considered on each of them were adapted to fit the requirements of the BESOS Balanced Scorecard. Thus, the scenarios distinguished were:

1. Single metric, single entity, 1 day value (1 measurement)
2. Single metric, single entity, 1 month value (30 measurements)
3. Multiple metrics, single entity, 1 day value (1 measurement per metric)
4. Multiple metrics, single entity, 1 month value (30 measurements per metric)
5. Single metric, multiple entities, 1 day value (1 measurement per entity)
6. Single metric, multiple entities, 1 month value (30 measurements per entity)
7. Multiple metrics, multiple entities, 1 day period (1 measurement per entity and metric)
8. Multiple metrics, multiple entities, 1 month period (30 measurements per entity and metric)

To adequate the tests to the ones previously performed for the VA tool, the same amount of entities (10) and metrics (3) were considered in tests 3 to 8, when stated as such. In the same way, the metrics evaluated in each case were the latency (in seconds) and the throughput (in bytes per second), both globally and averaged per single measurement. The tests were performed over the ***GetMetricTimeseries*** service, which is the one used by the BESOS Balanced Scorecard to retrieve the data. Each test was performed 10 times and the average result was eventually considered. The results are shown in the graphs below:

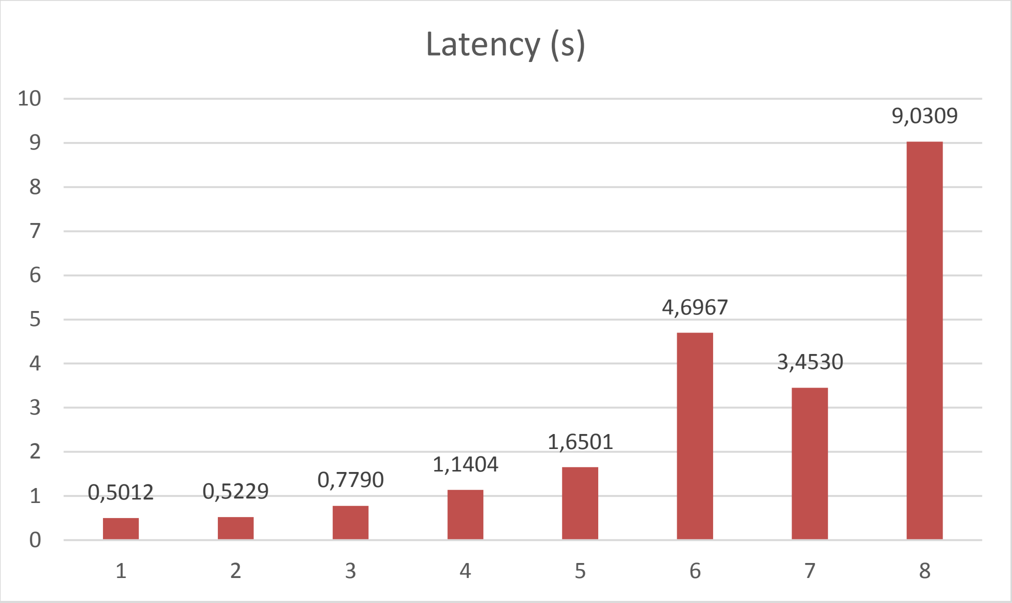

Figure 26 BBSC-OTESP communication latency

As we could expect, the latency grows when the number of entities, metrics and/or measurements is bigger; however, even in scenario number 8 –which in a normal functioning of the tool would not be executed– the latency of the gathering of data (9 seconds) is perfectly acceptable.

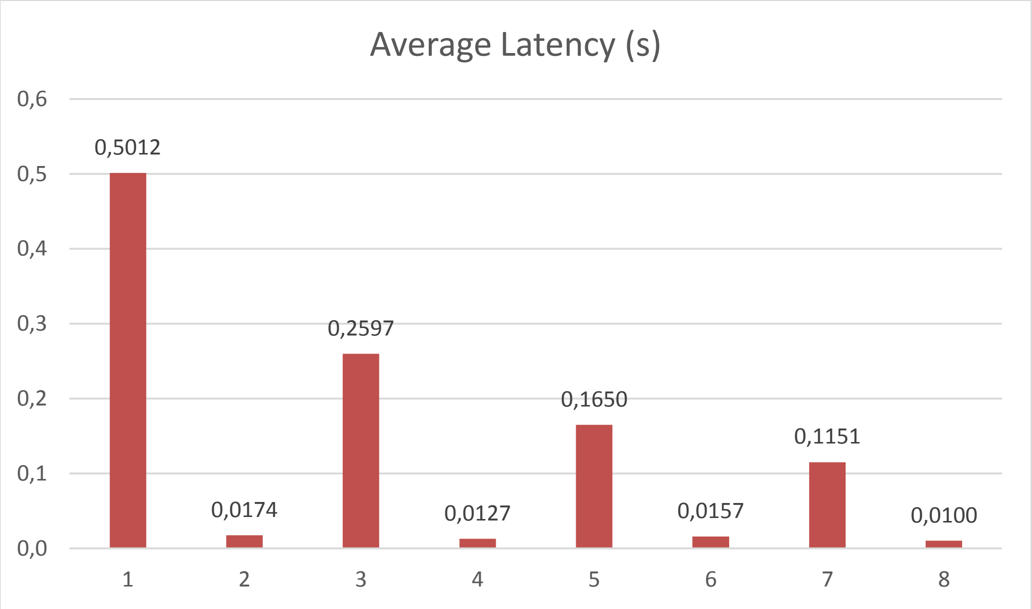

Figure 27 BBSC-OTESP communication average latency

When averaged per single measurement it is shown that retrieving a several values in a single call is 10 to almost 30 times more efficient than retrieving them in multiple calls.

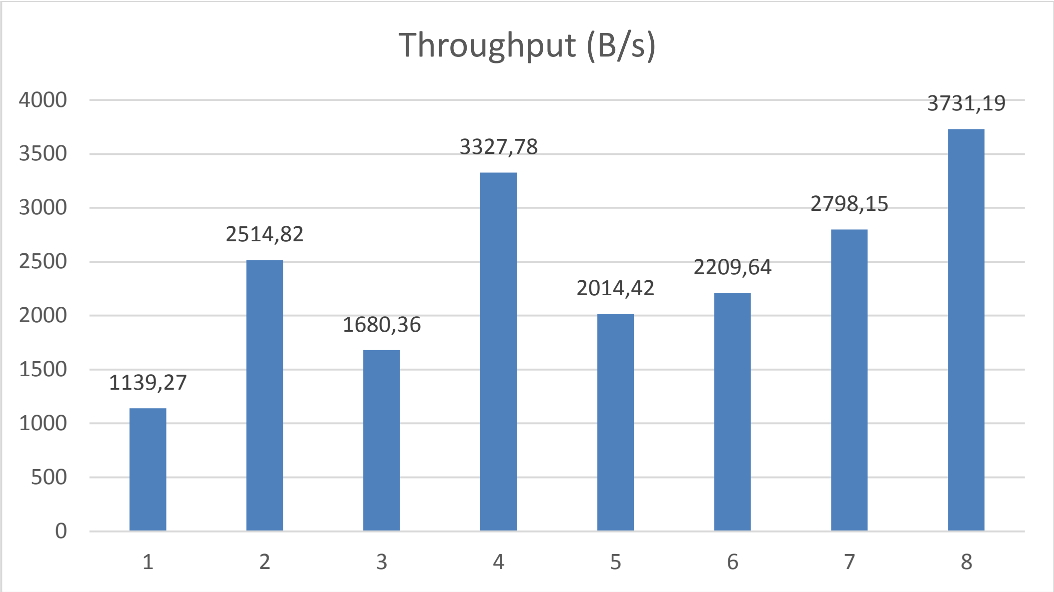

Figure 28 BBSC-OTESP communication throughput

Previous conclusions are confirmed when looking at throughput, as the amount of data received per second is always bigger in the scenarios where 30 values are requested respect to their 1-value counterparts.

It is worth to denote that, as most KPIs are based on comparison between two periods of time, in a real environment at least two calls would be required in each case to get the necessary data to continue with the process.

For the second part of the latency tests, we will be assessing the performance of the next part of the process, which is the calculation of the KPIs using the metrics retrieved from the OTESP. In this case, the number of metrics will be fixed (1), while the number of entities involved and the total number of values calculated will be altered. The scenarios considered in this case are:

1. 1 entity, 1 day value (1 KPI value calculated)
2. 10 entities, 1 day value (1 KPI value calculated)
3. 50 entities, 1 day value (1 KPI value calculated)
4. 1 entity, 1 month value (30 KPI values calculated)
5. 10 entities, 1 month value (30 KPI values calculated)
6. 50 entities, 1 month value (30 KPI values calculated)

The results were as follows:

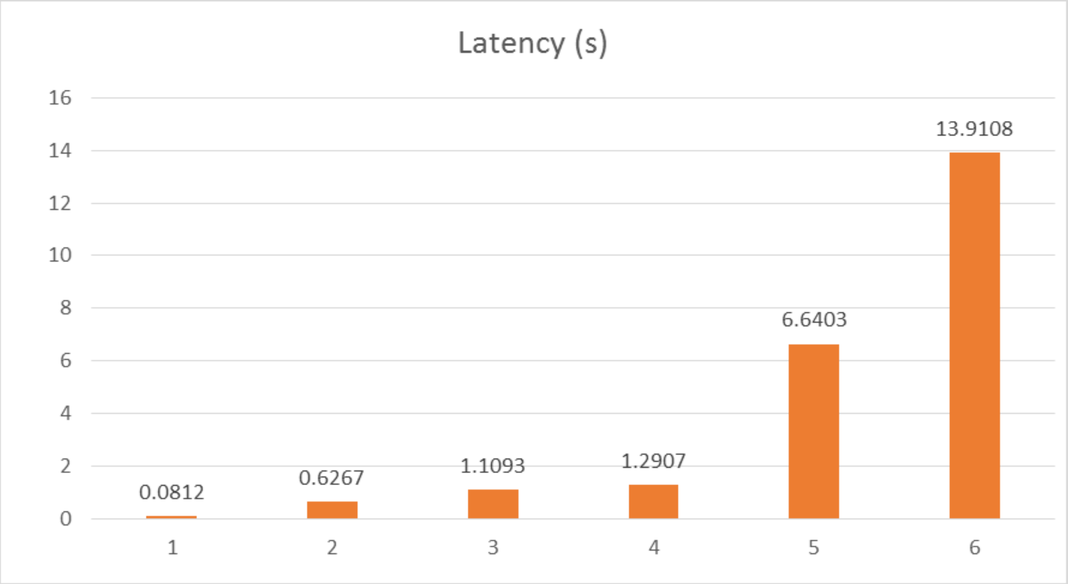

Figure 29 BBSC KPI calculation latency

It is assessed that the calculation of a single KPI value even with 50 entities (scenario 3) takes little more than one second. Having that the calculation process is launched once a day –when all measurements from the previous day are available– the number of KPIs that could be supported by this mechanism amounts to tens of thousands, working with a single thread.

When evaluated in average per KPI value calculated, it is shown that calculating just a single value (scenarios 1-3) costs about twice as much as calculating the whole month; however, we previously presented that the absolute figures do not mean a problem even with a huge amount of KPIs to be calculated.

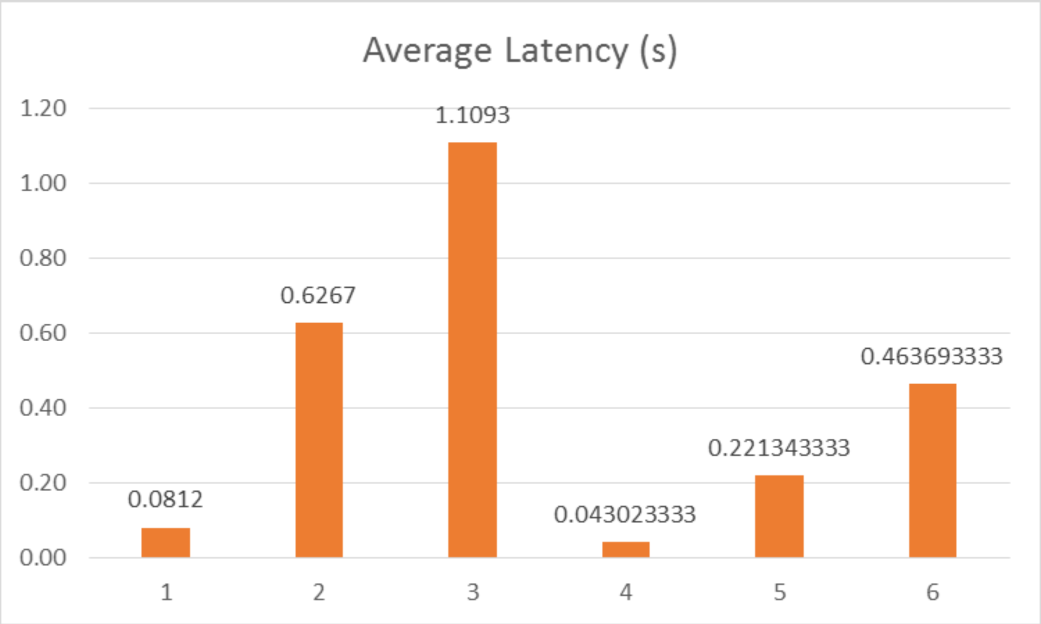

Figure 30 BBSC KPI calculation average latency

Finally, we will evaluate the scalability of the tool by increasing the number of entities whose KPIs to calculate. The BESOS Balanced Scorecard takes advantage of the multithreading capabilities of the OTESP by setting a maximum number of entities per request and parallelizing the calls. For these tests, a single value of a single metric is requested for a fixed number of entities (50), which is the most common scenario in the normal functioning of the BBSC. The total number of threads is increased to achieve up to 15 simultaneous calls. The results are shown below:

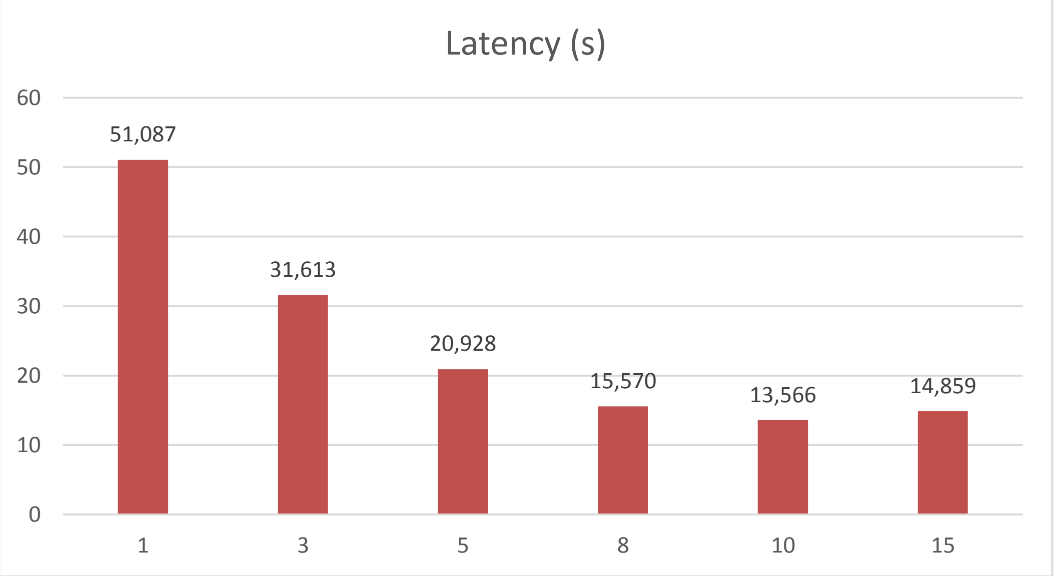

Figure 31 BSSC-OTESP multithreading latency

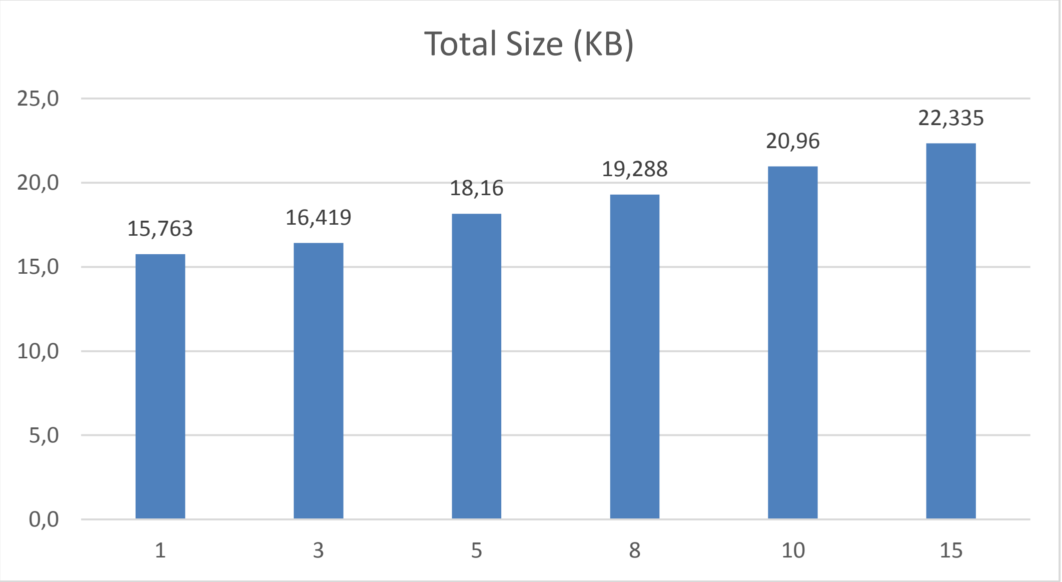

Figure 32 BSSC-OTESP multithreading total message size

One can see that increasing the number of threads reduces the total latency of the process, being around 10 threads the scenarios with best results. It is also noted that the size of the messages receives grows due to the replication of headers and other parts that are not replicated when performing a single call.

3.3.2 Interoperability and Ease on deployment

One of the main goals of the project is to provide business applications that can be easily transferred to other demonstration sites. Therefore, special focus is delivered on the interoperability and transferability of BBSC tool. Towards this direction, the best practices for the development of business applications are adopted for BSSC development.

A web services approach is considered for business applications integration in BESOS platform. As presented in D5.1.2 “DSS cockpit and Business Balanced Score Card v2”, and the schema of the architecture for the applications, there is a common software layer (back end of BBSC application) that ensures interfacing with OTESP platform. This is an abstract software layer, separate from the rest of core BBSC functionality. Therefore, this module can be easily removed and replaced by any other software component to ensure smooth interfacing with platforms or systems without affecting the application and presentation layers of BBSC. By adopting this modular approach on the development of BBSC, the business layer is communication protocol agnostic as the WSDL/REST interface layer selected for BESOS project (OTESP exposed a WSDL API and a REST API for business applications integration) can be easily replaced by any other communication protocol (e.g. MQTT).

What related to data model of BBSC for interfacing OTESP platform, this is based on IEC CIM, providing that way a solution that is easily transferable to other standards based platforms. In electric power transmission and distribution, the Common Information Model (CIM) is a standard developed by the electric power industry and has been officially adopted by the International Electrotechnical Commission (IEC), aiming to allow application software to exchange information about electrical network. This is a commonly adopted information model in applications similar to BESOS and towards this direction we are adopting this approach in the development process.

Special focus should be delivered also on the modular approach (micro services framework) adopted for the development of the application layer of BBSC. Visual Analytics & Balance Scorecard applications are two separate applications and thus any modification in one of this does not affect the overall deployment of the BBSC tool. This approach further enables the extension of BBSC with additional applications without affecting the current version of BBSC solution.

In addition, the development of BBSC applications as responsive web applications is following common web design practices, enabling that way a flexible access to BBSC tools from different working environments (smartphone, tablets, and desktops).

3.4 DSSC assessment analysis

The goal of this section is to examine the technical assessment of BESOS DSSC business application. DSSC system is the application for ESCOs and Facility managers in order to support real time optimal management of portfolio and proceed with the implementation of control strategies.

3.4.1 Component testing process and indicators

The analysis focuses on the functionalities offered by the DSSC applications from the perspective of the evaluation of scalability, reliability and speed of communication. Therefore, we follow the common framework for the performance evaluation of the respective component.

3.4.2 Setup

As previously stated, the back-end part of the BESOS DSSC shared some functionalities with that of the BESOS Balanced Scorecard, namely those in charge of periodically retrieving new data from the OTESP. Thus, the settings of the machine where it is deployed are the same in both cases: a virtual machine running Windows Server® 2012 R2 Standard, with a dual-core Intel® Xeon® E5-2650 Processor @ 2.80 GHz and 10 GB of RAM.

3.4.3 Results

Being the core of communications with the rest of the system and the source of complex calculations, the following set of most common functionalities of DSSC back-end were put under testing:

1. **OTESP communication.** Measurements from all EMS are periodically retrieved using the SOAP web services of the OTESP and stored locally for applications to use them.
2. **Reactive platform communication.** Besides the repository of historical data, a small window of data is maintained on a separate reactive platform whose capabilities provide the applications with a mechanism to be up-to-date with the current status of the assets. The connection with the platform is done over the Distributed Data Protocol (DDP).
3. **Historical data retrieval from local data base.** Measurements retrieved from the OTESP are collected in a local MongoDB repository that is eventually used both for visualization and analysis purposes.
4. **Strategic Control data update.** The strategic control component of the DSSC works with its own data base deployed in SQL Server. This data base is fed with the same information coming from the OTESP.
5. **Optimization processes.** Optimization processes for several parts of the system were developed during the project. These algorithms will be tested to assess their scalability in future scenarios.

Unless other specified, each test was run 10 times and the averaged results are provided below. The metrics evaluated each time were the latency (seconds) and throughput (bytes/measurements/entities per second). Due to the different nature of each component, the rest of specific settings for each test are explained on its own section, along with the obtained results.

3.4.3.1 OTESP Interfaces

Based on the most common functionalities of the BESOS DSSC that interact with the OTESP, the following services from the platform were tested:

- ***ListTopLevelEntities* (top).** Retrieves all top-level entities from the different EMSs.
- ***FindEntityDescendants* (des).** Given an entity –usually a top-level entity from the previous service–, returns all its children up to a certain level or all of them if no maximum level is specified. BESOS DSSC uses this last configuration to iterate over all top-level entities and gather the whole tree of entities of the system.
- ***GetAttributeValue* (att).** Used to gather the geo-location information of those entities that will eventually be represented in the map.
- ***GetStatusInformation* (sta).** Provides the current status of the communication of each entity in a single call.
- ***GetMetricTimeseries* (met).** The service most frequently used by the DSSC, it retrieves measurements for all entities in the system every 15 minutes, hour and day, each integrated by its corresponding time period. Depending on this integration period and the specific entities and metric types updated, the new data is distributed to certain parts of the system to be either used or stored for future utilization.

To assess both the speed of communication and the scalability of this part of the system, we will modify the number of entities involved in the process (values 1, 10, 100, and 1000) whenever possible (services **top** and **sta** do not admit any parameters). The results are available below:

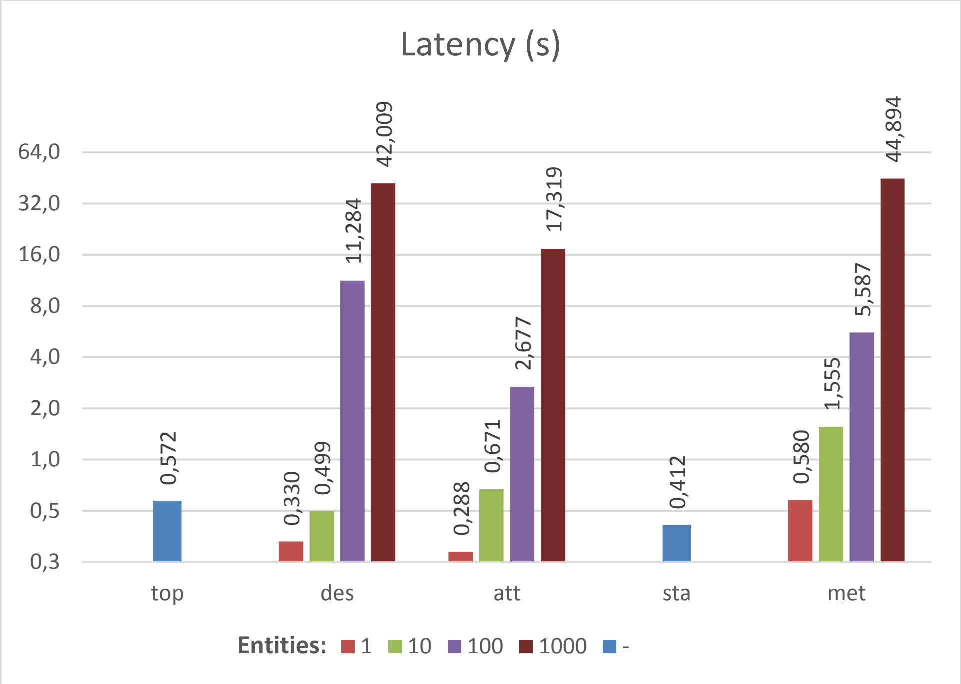

Figure 33 DDSC-OTESP communication latency (logarithmic scale)

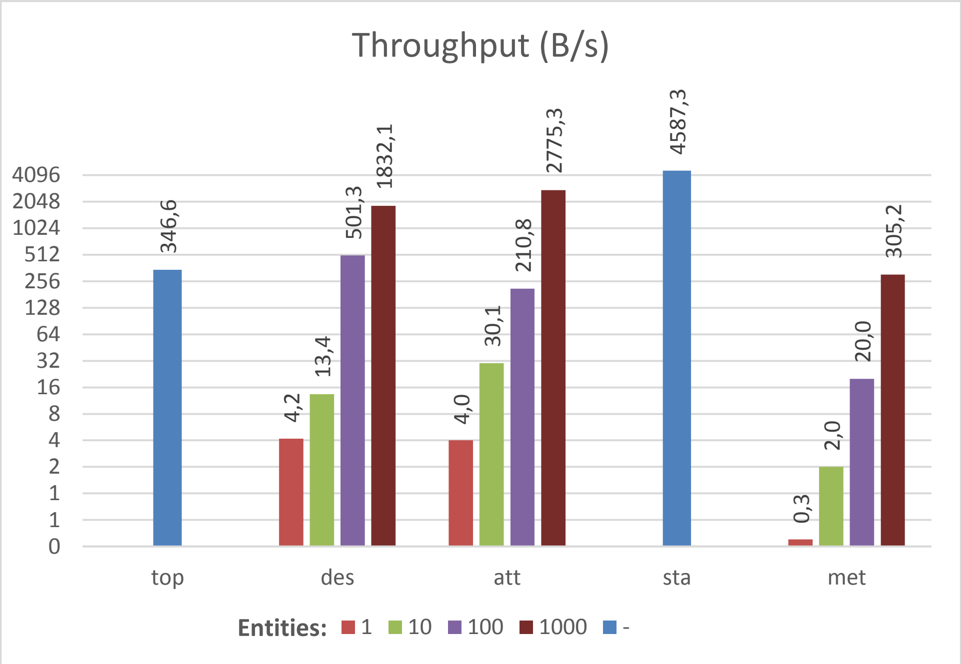

Figure 34 DDSC-OTESP communication throughput (logarithmic scale)

The results show how the scalability of the system is not restricted by an equivalent grow in the latency of the service – although the number of bytes per second does grow at a similar pace. As an example, had the **met** service not taken advantage of the multithreading capabilities of the OTESP, the latency to obtain the same results for 1000 entities would have grown up to almost 13 times (580 seconds) when compared to the single entity case.

3.4.3.2 Reactive platform

Moving to the next part of the system, the reactive platform will be put under test. This component is used by the monitoring tool to provide the user with an up-to-date view on the status of the whole system. Although the platform is involved in several other processes, the following two are the most costly in terms of time and data; thus, they will be assessed in terms of latency and scalability:

- **Dashboard measurements update (das).** The DSSC Dashboard provides an overall view of all entities in the system. It selects a group of key entities and shows two specific time windows –2 days integrated by hour and 1 month by day– for each entity that provides them. These values are updated each time new values are retrieved from the OTESP.
- **Entity status update (ent).** Based on the last measurements received from the OTESP, the status –both nominal and graphical– of each entity is calculated. For those entities that do not provide metrics, its status is calculated based on those of its children.

To test these two functionalities, we will vary the total number of entities, taking the same values as in the previous section section (1, 10, 100, and 1000). In the case of the measurement update, the number of metrics updated per entity varies randomly between 1 and 5. Regarding the amount of values updated, two scenarios are contemplated: the update of 1 value per entity-metric pair –namely the last measured value, which represents the normal functioning of the process– and 30 values per entity-metric – which corresponds to the most costly scenario for the process: filling all daily values from scratch.

The results are shown below:

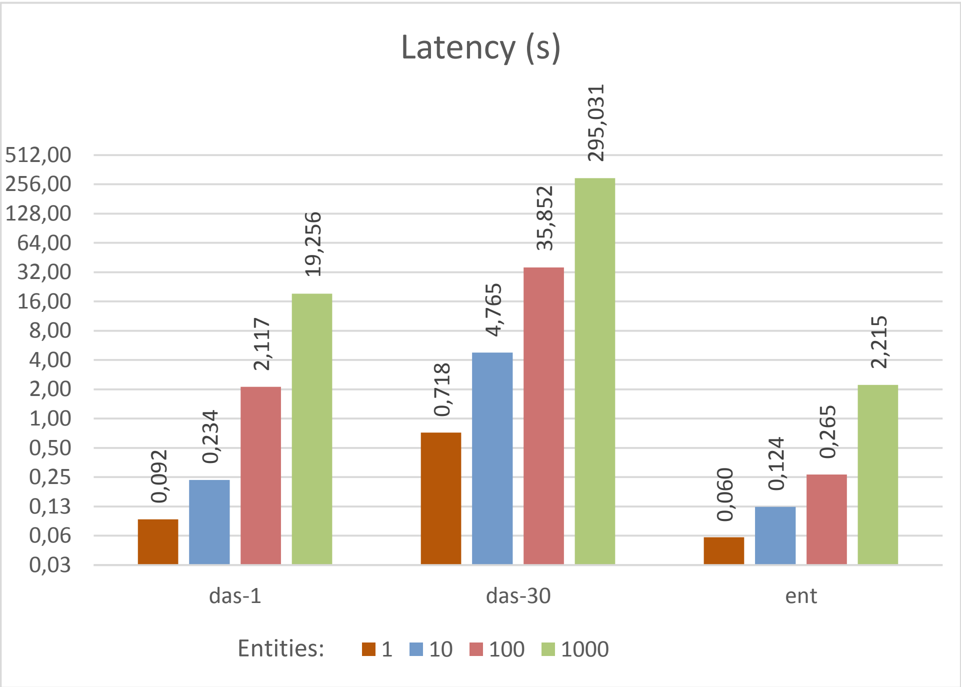

Figure 35 DDSC-Reactive platform communication latency (logarithmic scale)

The latency in the all three tests only reaches a point where it experiences a growth roughly proportional to the increase of the number of entities when moving from 100 to 1000; below those figures, the growth rate is much lower. This is confirmed by the throughput:

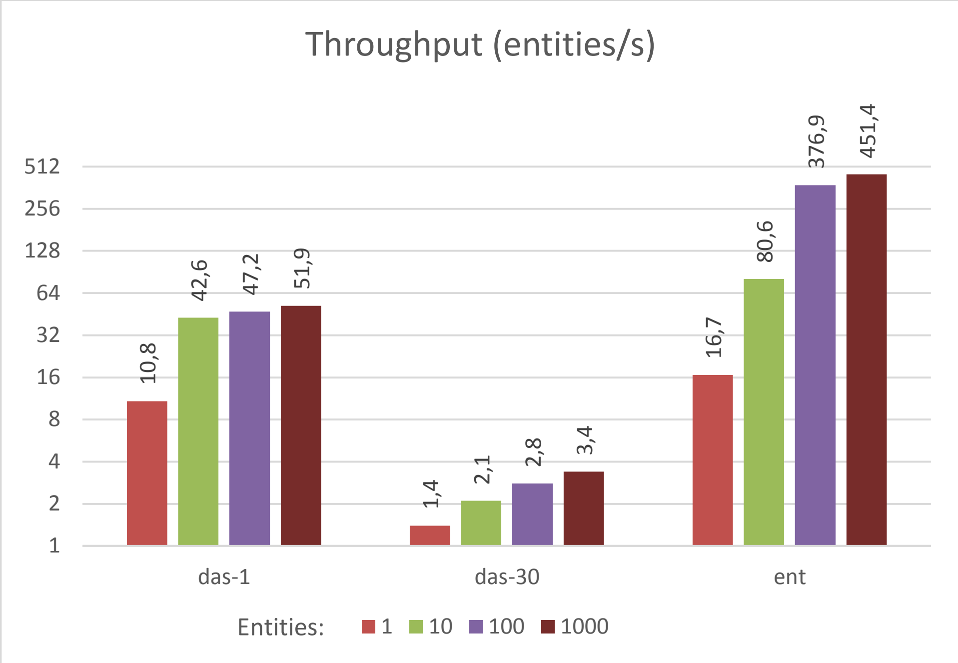

Figure 36 DDSC-Reactive platform communication throughput (logarithmic scale)

In the identified cases (from 100 to 1000 entities) the number of entities treated per second remains constant, evincing the maximum number of operations of each kind that the platform is able to manage at a time: around 40 dashboard updates (**das-1**) and 400 status updates (**ent**). A special case is the update of the whole dashboard (**das-30**), which is only performed on the set-up of the application or whenever a new entity is added to the system, so the figures related to it should not be considered a potential problem.

3.4.3.3 DSS Local data base

All measurements that are periodically retrieved from the OTESP are eventually stored in a local MongoDB repository to be used by the applications for analysis and/or visualization purposes. The initial reason to adopt this solution was to avoid requesting huge amounts of data to the OTESP or even asking more than once for the same data, thus saturating the EMS GWs.

To evaluate this part of the system, we will retrieve different sets of measurements from the local repository in order to assess how latency (in seconds) and throughput (in measurements per second) behave. The following scenarios are contemplated:

1. 1 entity, 1 measurement per entity
2. 10 entities, 1 measurement per entity
3. 100 entities, 1 measurement per entity
4. 1000 entities, 1 measurement per entity
5. 1 entity, 10 measurements per entity
6. 10 entities, 10 measurements per entity
7. 100 entities, 10 measurements per entity
8. 1000 entities, 10 measurements per entity
9. 1 entity, 100 measurements per entity
10. 10 entities, 100 measurements per entity
11. 100 entities, 100 measurements per entity
12. 1000 entities, 100 measurements per entity

The results are presented below:

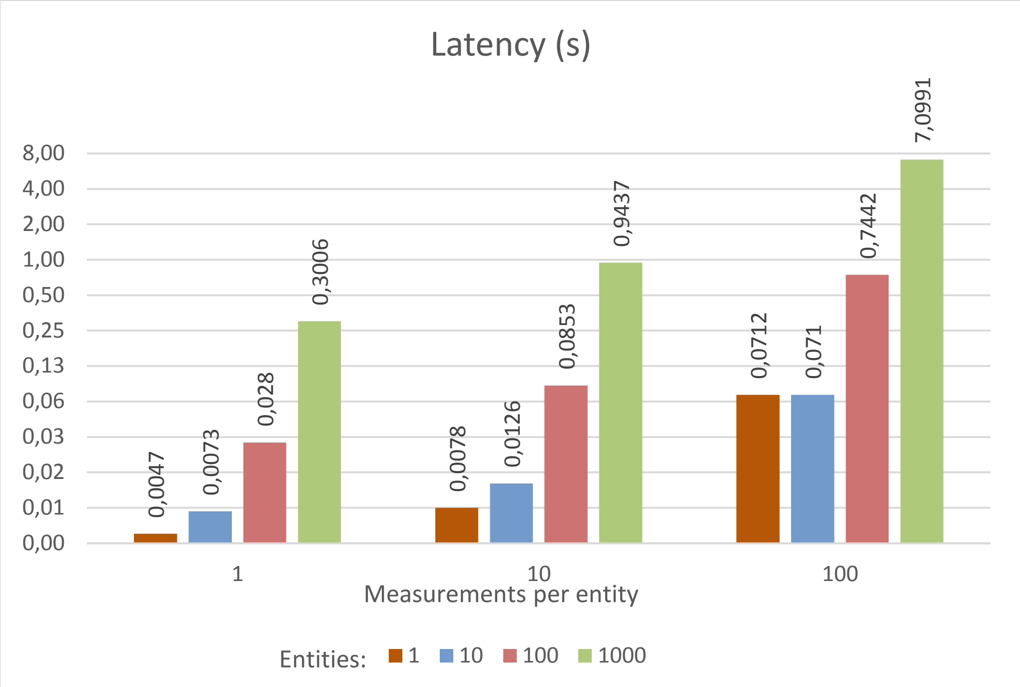

Figure 37 DDSC-DB communication latency (logarithmic scale)

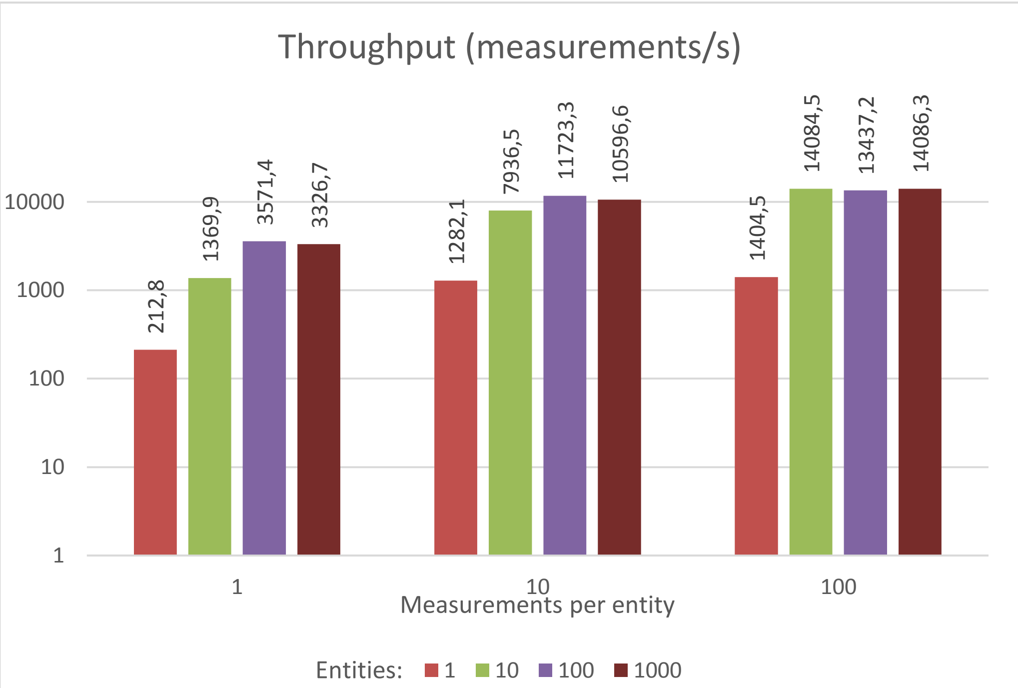

Figure 38 DDSC-DB communication throughput (logarithmic scale)

In general terms, we can see that the latency grows proportionally (in orders of magnitude) with the number of entities, while the increment in number of measurements results less costly (about 3 times when moving from 1 to 10 measurements, 7 times from 10 to 100). Regarding throughput, the growth rate slows down as the number of entities is bigger, and it becomes stagnant when moving from 100 to 1000 entities, or even before in the last tests.

In any case, the absolute figures assess the decision of using a local repository to store measurements when compared with the results in section 3.4.3.1: although latency figures for 100 entities are perfectly reasonable (less than 6 seconds) and the process has been proved to be open to parallelization, the continuous querying over historical data from different processes and applications could potentially lead to greater overheads, which are more likely to be avoided with a local data base (which latency for the same operation is more than 100 times faster).

3.4.3.4 Strategic Control

At an initial stage, the strategic control component of the DSSC is fed with historical data from the entities in the system. Entities are grouped depending on their nature –e.g. all sensors in a building– and their data is analysed to discover the most common situations for each group. At this point, new data is periodically added to the system so it can identify in which situation is currently each group and send a preventive alarm to the manager of the system if necessary.

Having that the initial process is an offline analysis, the following tests will be focused on the periodical update of the strategic control. This process takes the new measurements gathered from the OTESP and stores them into the SQL Server data base used by the strategic control for its internal analysis. The variation in number of entities and metrics will follow the same approach as in previous sections, while 1 measurement per entity (usual functioning) will be sent.

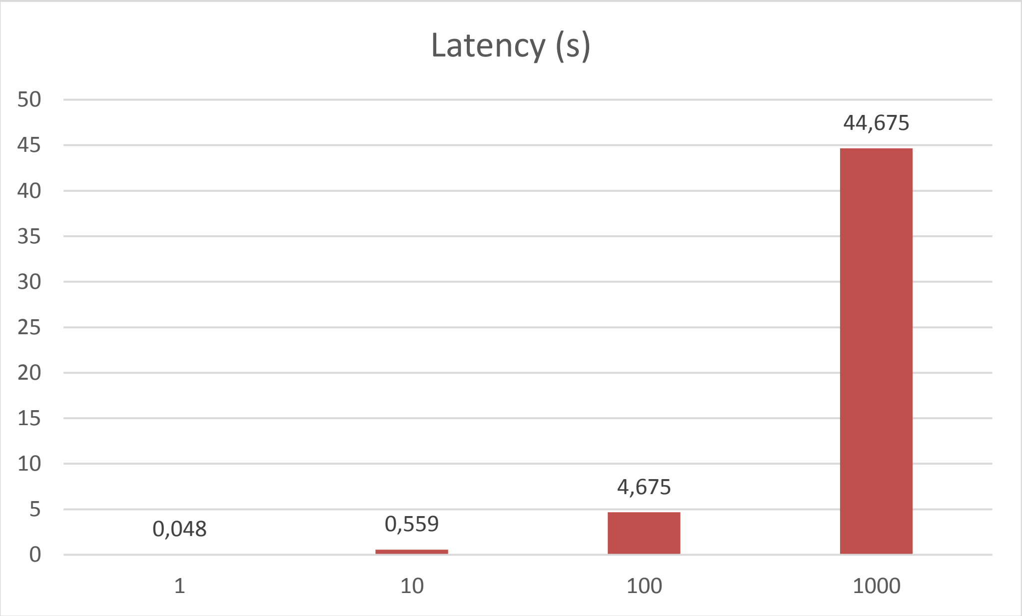

Figure 39 DDSC-SC communication latency

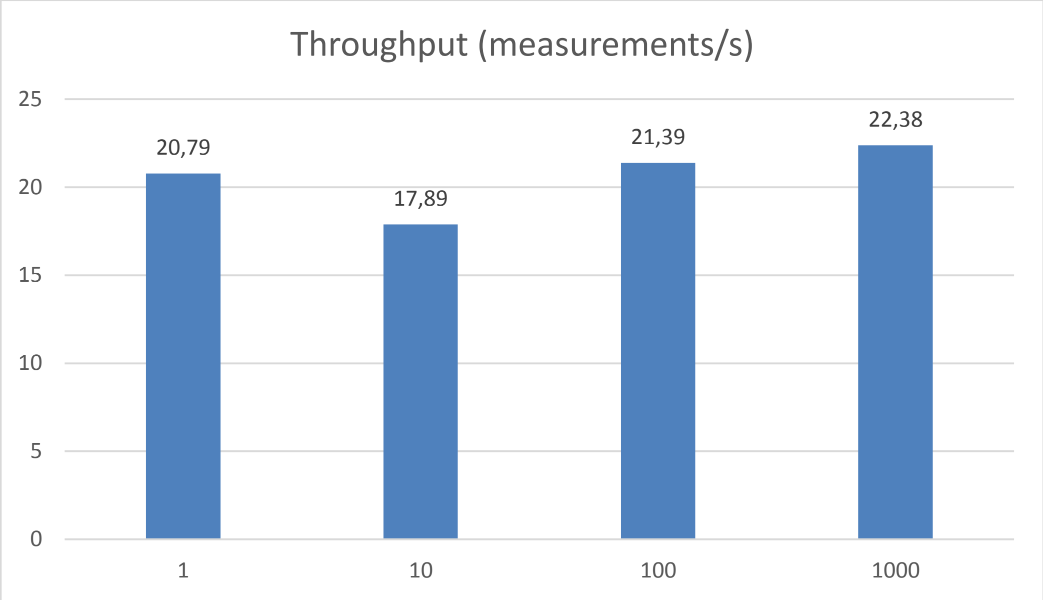

Figure 40 DDSC-SC communication throughput

Latency figures show how the process of updating 1000 entities –normally run every 15 minutes, when new measurements are available– is completed in about 20 seconds, which is perfectly manageable for the application and could be easily escalated to manage larger amounts of data. Throughput evinces that the ratio of measurements sent per second is roughly constant in all scenarios.

3.4.3.5 Public lighting optimization

Having assessed the communication among the different parts of the system, we will continue by performing similar tests to the different optimization processes implemented in the DSSC. Please note that the following tests are centred exclusively on the cost of calculating the results, not taking into account the additional efforts to obtain the data from the local repository or any other external source.

The public lighting optimization algorithm generates a 24-hour scheduling plan for each public lighting EMS, based on the user comfort set by the manager of the system and other external factors (ambient light, consumption and production forecasts, etc.).

Although the algorithm takes points of light data as an input, in a real environment the luminosity would not be adjusted on each lamp individually, but rather by groupings of points of light covering a whole street or area. The scenarios contemplated on these test vary this number of groups from 1 to 10 with the following results:

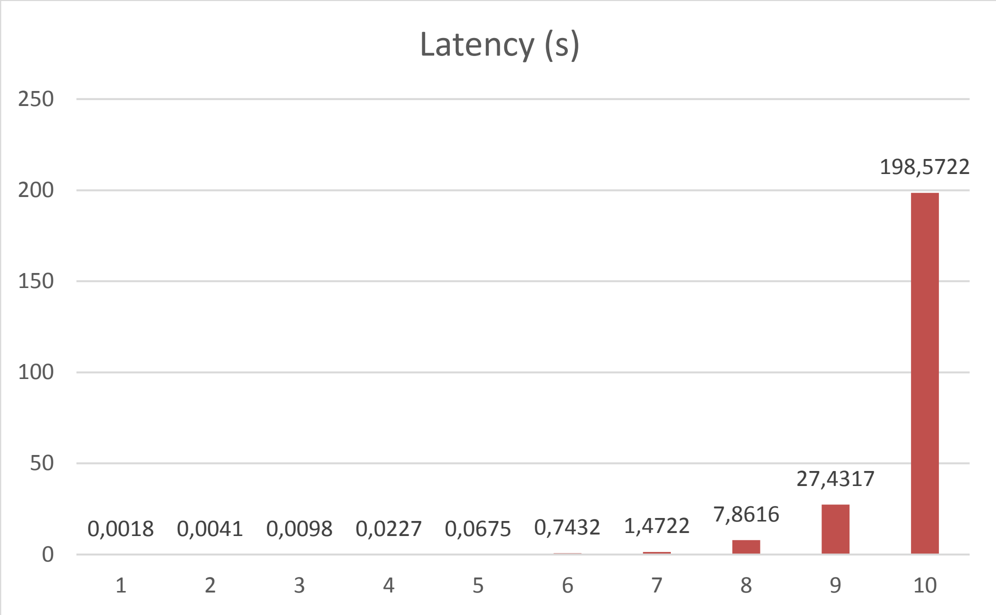

Figure 41 Public lighting optimization algorithm latency

Contrary to the results obtained in the communication tests, the previous graph showcases broader differences as the number of groups grow, following an exponential evolution: while the scenario with 9 groups takes about 3.5 times more than the one with 8, the last scenario is about 7 times most costly than its predecessor.

These results are aligned with the implementation of the algorithm, as it contemplates all possible combinations among the given groups in terms of dimming level to find the one that better satisfies the objectives (i.e. KPIs) of the system; thus, the complexity of the calculations grow exponentially. This is confirmed by the throughput values:

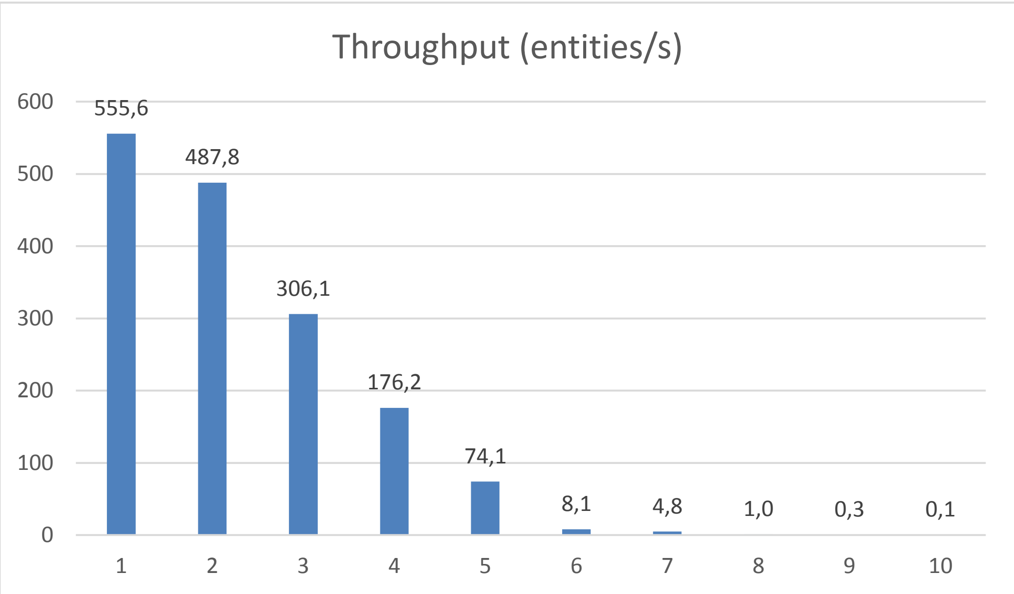

Figure 42 Public lighting optimization algorithm throughput

This behaviour predicts potential problems when launching the algorithm for great numbers of entities; however, a satisfactory solution could be achieved by running different optimizations for different sub-groups while maintaining the rest of the parameters constant.

3.4.3.6 Public lighting vs. traffic conditions optimization

Using the available information about the traffic level in Barcelona, a complementary optimization over public lighting is calculated. The number of road lanes were varied from 1 to 1000, this time adding additional steps for 5, 50, and 500 entities to obtain clearer results. Below are the results of the performed tests:

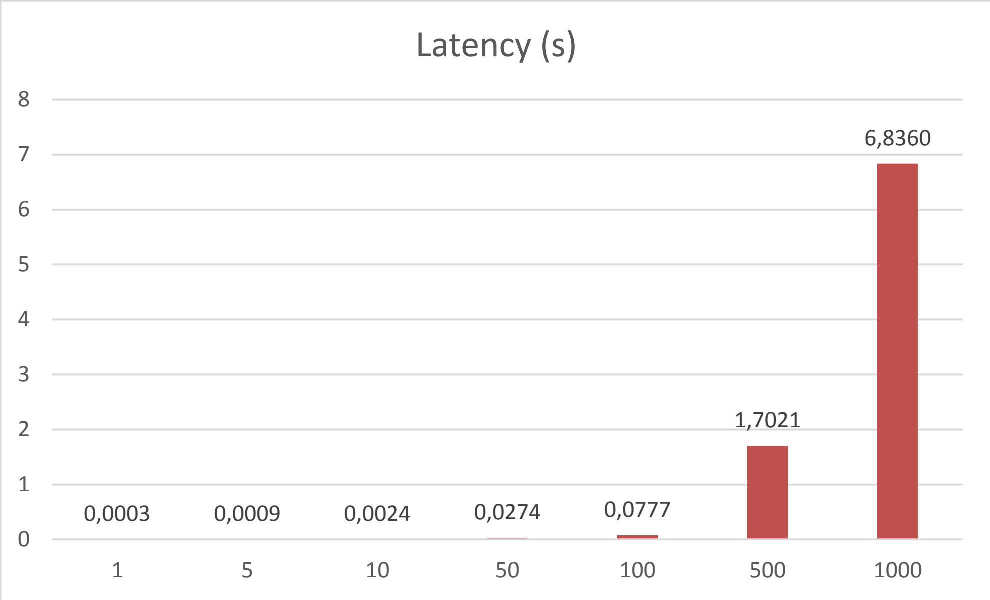

Figure 43 PL vs. traffic optimization algorithm latency

Similarly to the previous optimization process, the evolution of latency follows an exponential progression that predicts a saturation of the process with a larger amount of entities. However, the calculation of the optimization for 1000 entities is not a problem in terms of absolute time (less than 7 seconds), so the aforementioned saturation point is not likely to suppose a problem even without parallelization.

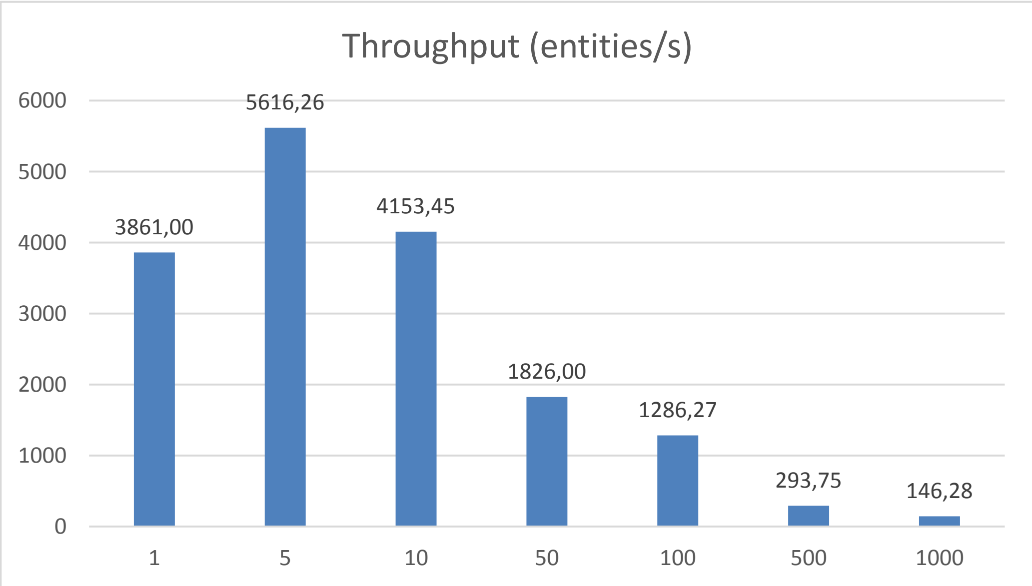

Figure 44 PL vs. traffic optimization algorithm throughput

Throughput showcases that the optimal calculation is achieved with 5 entities, but this is due to the low figures of the latency. Depending on the number of entities to be managed, performing a parallel optimization in groups of 5 may not fulfil the expectations due to the large number of threads.

3.4.3.7 Electric Vehicle optimization

The electric vehicle system of Lisbon was integrated with the DSSC in order to put into practice its optimization mechanism. Unlike the previous algorithms, this optimization was not run periodically but only triggered when vehicles were detected charging.

A set of tests were carried out to assess the capabilities of the process, with figures taking the same values as the previous section. The results are shown below:

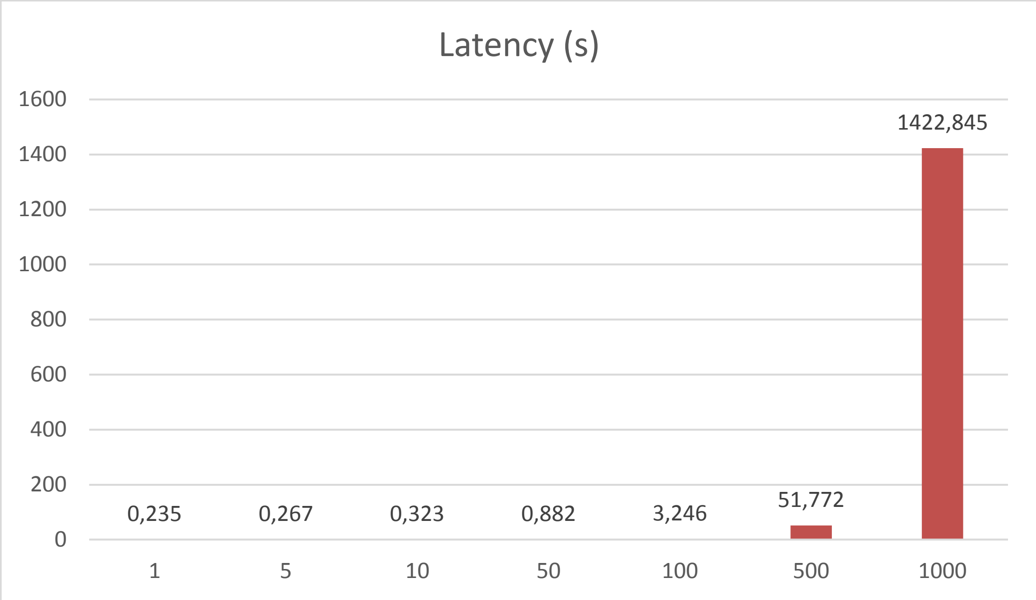

Figure 45 EV optimization algorithm latency

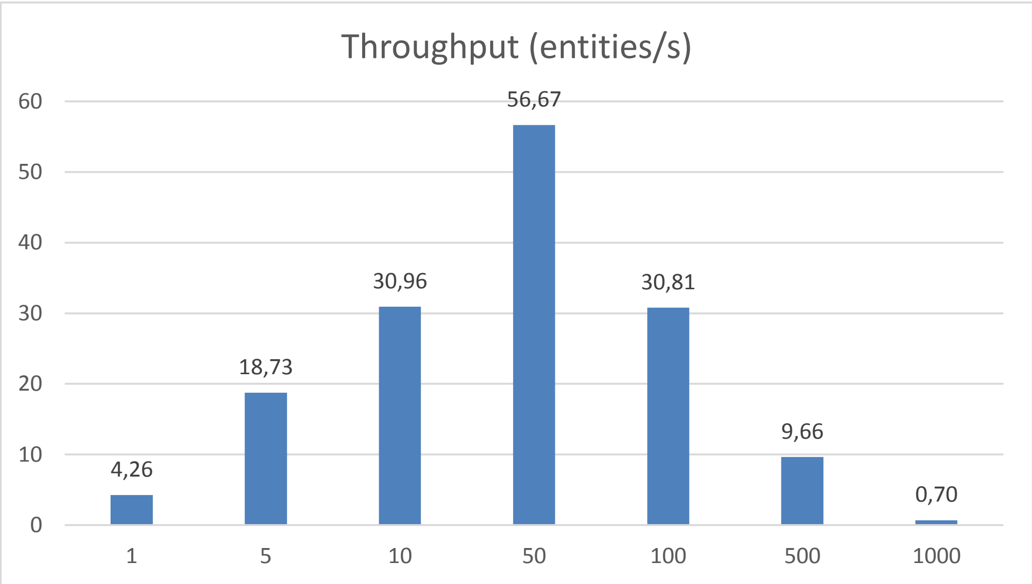

Figure 46 EV optimization algorithm throughput

As in previous cases, the growth ratio is exponential with a latency almost 30 times bigger when duplicating the number of entities in the last scenario. Absolute figures show that the calculations when dealing with 1000 entities last more than 20 minutes.

At this point, a more recommendable strategy would be to divide the charging spots into subgroups and run different instances of the algorithm while maintaining the rest of the inputs constant. This is supported by the fact that dividing them into just two groups would barely cost 2 minutes, an order of magnitude lower.

3.4.3.8 Tariff optimization

The final component from the BESOS DSSC to be evaluated is the tariff optimization process. Again, we tested the latency and scalability of the service with different ranges of entities, while maintaining a constant set of tariffs (20) and time period (a month). The results were:

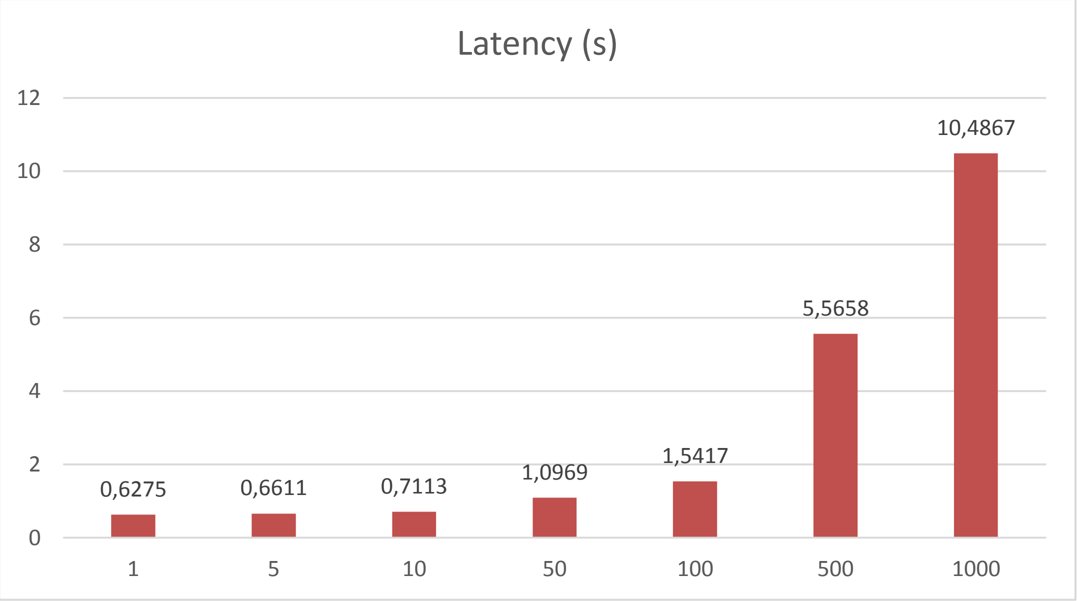

Figure 47 Tariff optimization algorithm latency

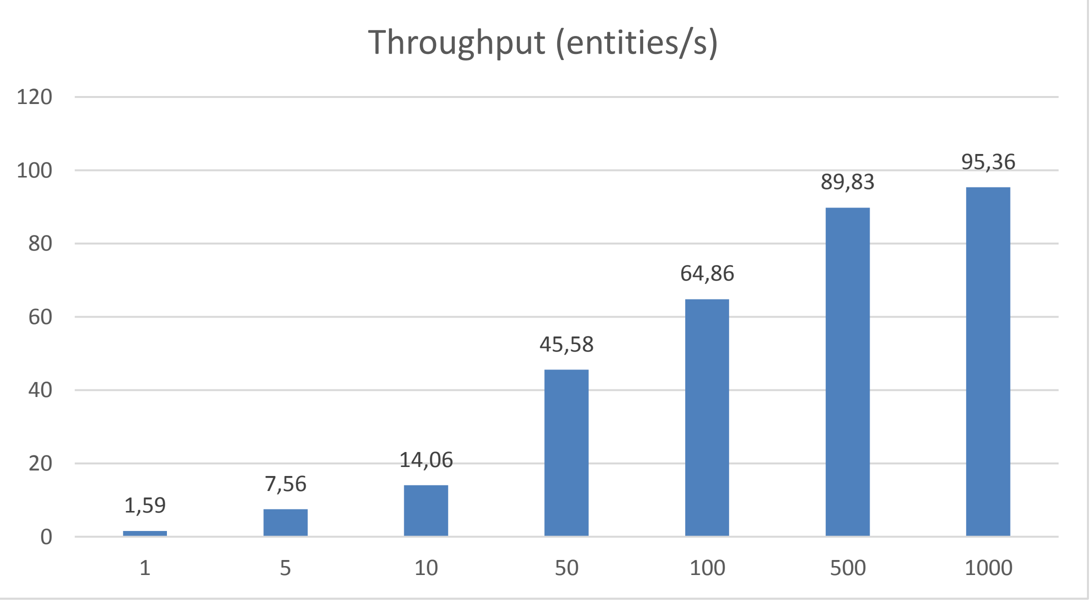

Figure 48 Tariff optimization algorithm throughput

Contrary to the previous cases, the increase in the number of entities does not bring an exponential rise of the latency, but quite the opposite: the bigger the amount of entities managed, the higher the throughput.

This evinces that the most costly part of the algorithm in terms of time is not related to the treatment of the measurements of each entity, but rather to the comparison to each possible tariff, which is performed with the aggregated values of the whole group.

3.4.4 Reliability

As we have seen over the course of the testing process, the BESOS DSSC relies strongly on good quality data coming from different external sources, mainly the different EMSs in the system via the OTESP. This approach could potentially expose the DSSC to diverse problems, from delays in communication to other kind of problems (e.g. exceptions, crashes) that could affect the normal functioning of the tool.

This problem was considered from the beginning of the development of the application, the intention being to uncouple as much as possible the tool from all those sources that escaped its scope. As a result, two decisions were taken: first, to separate the front-end of the application –the part the final user gets to see– from the back-end –that encompasses the communication with the aforementioned external sources–; second, to set up a local repository as an intermediate, controlled barrier that both isolated the external sources from the front-end application, and improved the user experience in terms of calculation and response times.

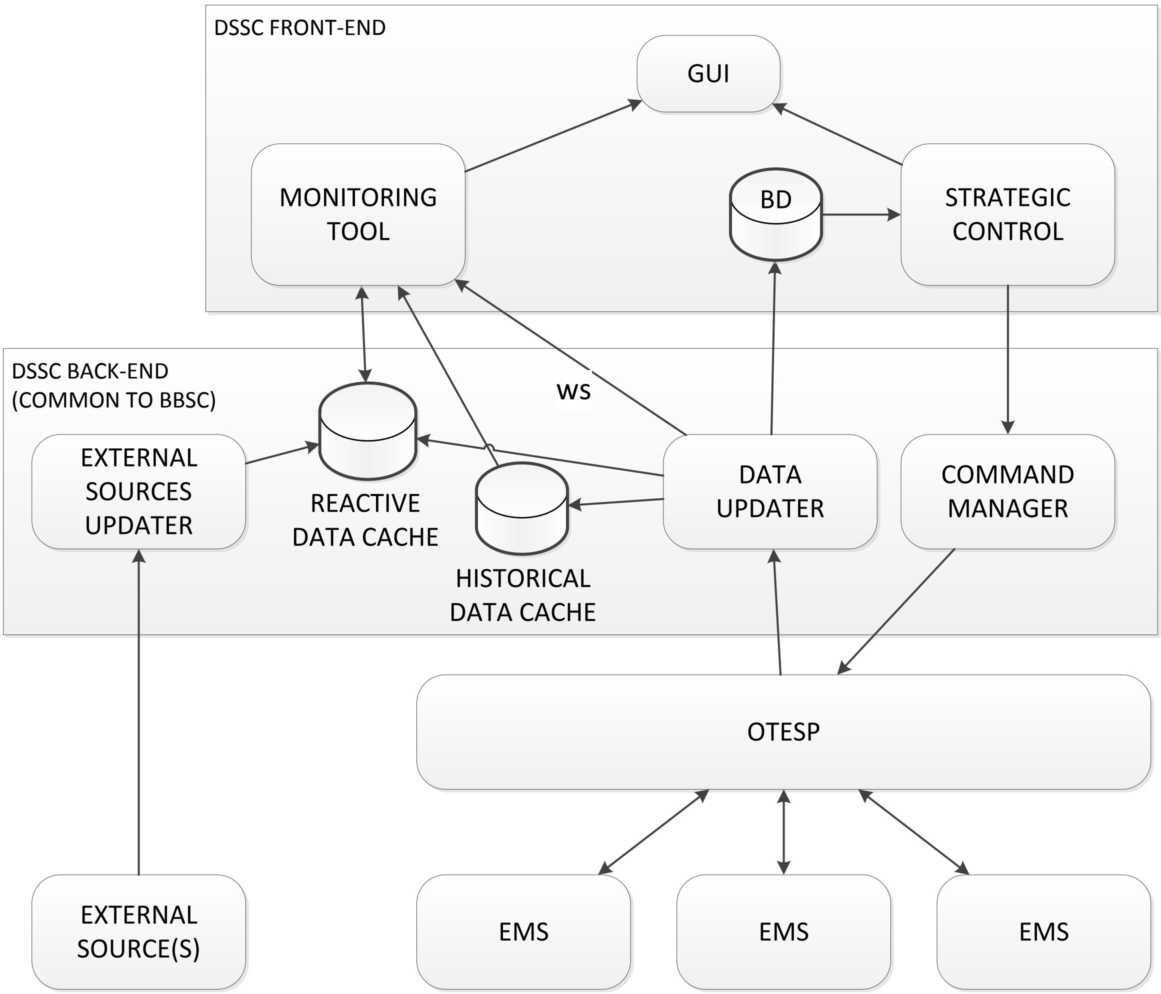

Figure 49 DSSC Architecture

This solution has been tested and adjusted during both periods of trials as reported on D5.1.1 and D5.1.2, and proved to be a successful way of preserving the reliability of the application.

However, this approach also resulted in additional efforts to maintain the stored data up to date. Due to the different nature of the EMS GWs, at early stages some of them underwent a series of adjustments –data correction, inclusion of offline historical data, etc.– that were not in place in the first time. Had the DSSC directly queried the EMSs via OTESP, any updates would have been reflected in late queries, but as the data was stored in the local cache, these changes were skipped by the processes that periodically ask for new data. The updates on old data eventually had to be gathered by manually triggering the specific recollection services.

3.4.5 Interoperability and Ease on deployment

The development of BESOS DSSC is following the same principles considered for the development of BESOS BBSC. Therefore, the good development practices are also considered for DSS application:

- An abstract software layer, separate from the rest of DSSC application, provides integration with OTEPS platform (via WSDL/REST API). This layer can be easily removed and replaced by any other software component required for integration with 3rd party platform. The DSS functionality is independent from the services required for interfacing with external platforms.
- IEC CIM data model is the basis for the development of BESOS DSSC. In that way, we ensure the easy transferability of our application in other demonstration sites, as IEC CIM is a widely adopted standard for smart energy management applications. Especially for the case of DSSC, we have adopted IEC CIM classes for control as the role of DSS is to trigger control commands in energy management systems in a standardized way.
- Finally, BESOS DSSC is a web application, adopting a responsive web design (RWD) to provide an optimal viewing and interaction experience—easy reading and navigation with a minimum of resizing, panning, and scrolling—across a wide range of devices (from desktop computer monitors to mobile phones).

Following the technical evaluation of BESOS business applications for main business stakeholders, we proceed with the evaluation of the mobile application for citizens involved in BESOS project.

3.5 Mobile App Assessment Analysis

The goal of this section is to examine the technical assessment of the mobile application for the citizens. It is evaluated both the mobile application (front end) and the backend engine to provide the supported functionalities.

3.5.1 Component testing process and indicators

The mobile application was developed in order to create public awareness campaigns to inform citizens on the usage of energy to support public services. The mobile application generally targets the entire community, but the specific objective to modify the behaviour of end-users is focused on the students of the school involved in the trials.

The design of the application was based on the requirements collected. Its assortment was done in two distinct phases. In the first one, a set of high level requirements were aligned based on the beneficiaries' inputs, and were present in D1.1 deliverable. This definition was particularly useful to scope the application context, but did not carry the details needed to develop the mobile application. The second phase came up with the details. Therefore, the end users were called to detail their main needs leading to a complete definition of the application framework, being this work presented in D5.2 deliverable. A snapshot of the main functionalities offered by the mobile app is presented in the following figure:

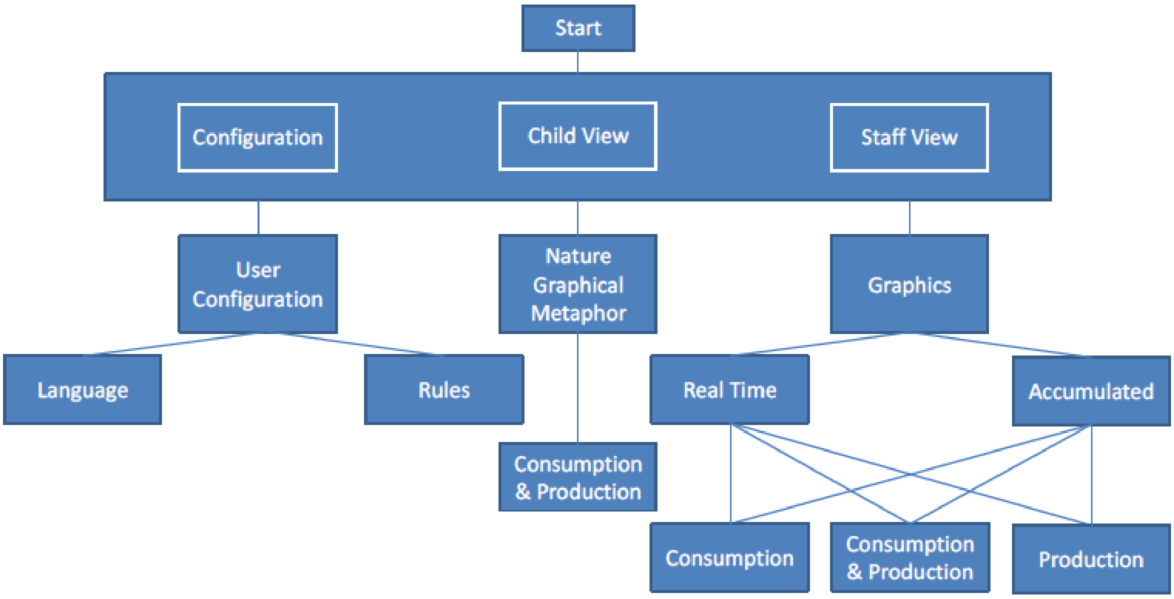

Figure 50 BESOS Mobile App functionalities

The full set of requirements are presented below, being the ones identified by the letters BMA the earlier project inputs and the ones starting by EU the end users requests. The row "Result" presents the success or failure of the requirement implementation and is used as a main indicative of the mobile application assessment.

ID:	BMA_001
Description:	The BMS will have the form of a web application adapted to mobile devices
Comment:	The application runs on both android-based mobile and tablet devices
Result:	**OK**

ID:	BMA_002
Description:	The BMS will allow EV users to introduce the details of the EV being plugged
Comment:	The application is focused on managing energy in public schools
Result:	**Not Applicable**

ID:	BMA_003
Description:	The charge of EV will not start until the mandatory data is entered in the BMS
Comment:	The application is focused on managing energy in public schools
Result:	**Not Applicable**

ID:	BMA_004
Description:	BMA must provide end user with information about the energy consumption of the installation
Comment:	The application allows to increase awareness of energy consumption by means of charts adapted to school staff and young students
Result:	**OK**

ID:	BMA_005
Description:	Data collection - residential level
Comment:	The application is focused on monitoring energy in public schools
Result:	**Not Applicable**

ID:	BMA_006
Description:	The mobile application has an integration with social networks
Comment:	The energy consumption and production information may be shared.
Result:	**OK**

ID:	BMA_007
Description:	Show the flow of energy to the educational communities
Comment:	The educational communities can access real time and accumulated consumption and production of energy
Result:	**OK**

ID:	BMA_008
Description:	Add a game/challenge component to the BMA
Comment:	The application allows setting specific energy parameters to motivate a sustainable usage of energy
Result:	**OK**

ID:	BMA_009
Description:	When available, user must have access to his energy consumption by device
Comment:	The application can be extended to enable the control of other devices
Result:	**OK**

ID:	BMA_010
Description:	When available, user must have access to his energy consumption by device type
Comment:	The application can be extended to enable the control of other device types
Result:	**OK**

ID:	BMA_011
Description:	User must have access to his energy consumption globally
Comment:	The application monitors the energy consumption globally in order to understand the user behaviour.
Result:	**OK**

ID:	BMA_012
Description:	When available, user must have access to his energy consumption cost by device
Comment:	The application supports the presentation of energy costs
Result:	**OK**

ID:	BMA_013
Description:	When available, user must have access to his energy consumption cost by device type
Comment:	The application can be extended to support other devices
Result:	**OK**

ID:	BMA_014
Description:	User must have access to his energy consumption cost globally
Comment:	The application provides the global costs of energy when the energy cost is available
Result:	**OK**

ID:	BMA_015
Description:	User must be able to subscribe to notifications about energy consumption exceed
Comment:	The application supports the configuration and notification of energy consumption limits
Result:	**OK**

ID:	BMA_016
Description:	User must be able to subscribe to notifications about energy consumption cost exceed
Comment:	The application supports the configuration and notification of energy costs consumption limits
Result:	**Not Applicable**

ID:	BMA_017
Description:	User must have access to energy consumption charts
Comment:	The application provides the energy consumption and production charts
Result:	**OK**

ID:	BMA_018
Description:	The BMA should support different languages
Comment:	The application supports both Portuguese and English languages
Result:	**OK**

ID:	EU_001
Description:	The application can be used by teachers and young students
Comment:	The application presents different looks according to the end users (school staff or children)
Result:	**OK**

ID:	EU_002
Description:	The application should present real time consumption of energy
Comment:	The application presents in graphical mode the real time consumption of energy
Result:	**OK**

ID:	EU _003
Description:	The application should present accumulated consumption of energy
Comment:	The application presents in graphical mode the accumulated consumption of energy
Result:	**OK**

ID:	EU_004
Description:	The application should present real time production of energy
Comment:	The application presents in graphical mode the real time production of energy
Result:	**OK**

ID:	EU_005
Description:	The application should present accumulated production of energy
Comment:	The application presents in graphical mode the accumulated production of energy
Result:	**OK**

ID:	EU_006
Description:	The application should present simultaneous view of real time consumption and production of energy
Comment:	The application presents in graphical mode the real time consumption and production of energy
Result:	**OK**

ID:	EU_007
Description:	The application should present simultaneous view of accumulated consumption and production of energy
Comment:	The application presents in graphical mode the accumulated consumption and production of energy
Result:	**OK**

ID:	EU_008
Description:	The application should allow the presentation of energy data using different time scales
Comment:	The application allows changing the time scale of the graphics for energy data
Result:	**OK**

ID:	EU_009
Description:	The application should provide a metaphoric view of energy data adapted to kids
Comment:	The application supports a fancy language adapted to young students
Result:	**OK**

ID:	EU_010
Description:	The application should allow the configuration of rules
Comment:	The application supports the configuration of different occurrences in order to motivate a sustainable usage of energy
Result:	**OK**

ID:	EU_011
Description:	The application should support the visualization of energy costs
Comment:	The application enables the visualization of energy costs associated with both real time and accumulated consumptions when the energy costs are provided
Result:	**OK**

It is clear that most of the initial requirements have been addressed, while the rest are not applicable considering the business view of the mobile application. In addition to the requirements analysis, the technical assessment is performed, focusing on the need for a responsible application that will further trigger the end users for an active participation. In addition, the reliability of the application is also tested.

About the responsiveness and the overall user experience of the application, the evaluation was performed as part of end users evaluation analysis in D7.2. The end users of the BMA App highlighted the simplicity and the friendliness of the application and they were impressed from the triggering messages and the information offered by the application.

Finally, testing the stability of the BMA framework, we can show high reliability levels. The back end of the BMA platform is deployed as a cloud application, with the sources required for the management of the (rather small number) of end users. On the other hand, the development as a native application of BESOS BMA App ensures high levels of reliability for the front end of the framework, as the development of the app was customized considering the specific requirements and specifications as defined in the project.

3.6 Forecasting Engine assessment analysis

We are considering BESOS Forecasting Engine as a main outcome of the project and thus a technical evaluation analysis is performed. We are following the same approach as with the rest of business applications, evaluating the scalability, reliability, latency and transferability of BESOS forecasting engine. BESOS Forecasting Engine is performing as a back end service, integrating with OTESP and further providing upon request/ periodically information associated with generation and consumption forecasting.

Scalability, reliability and transferability of BESOS forecasting engine

BESOS Forecasting Engine has been developed as a modular application, handling asset specific requests. Each active process of the software component is an independent process associated with a specific asset, ensuring that way the scalability and stability of the forecasting engine. In order to evaluate the scalability of the application in BESOS project, we first tested the functionality of the forecasting Engine at a specific generation/consumption asset, and then we easily adapt the service to fit to the full list of assets integrated in the project.

We have to point out that BESOS forecasting engine is deployed as a cloud service, with the allocated resources required per business application. This deployment approach ensures high reliability levels for the application. During project period, BESOS Forecasting Engine was always available, providing 100% forecasting data upon request.

The deployment of BESOS Forecasting Engine as a cloud application, further enables the easy transferability of this service to other case studies. A number of initial configuration parameters is required as a first step of the adaptation process. In the following table, we are presenting the configuration parameters required for Wind and PV generation assets adaptation.

Facility-ID	name/code of facility
Group-ID	Name of group which a) summarizes several single facilities for which power data is delivered separately for each facility or b) name of one big solar park consisting of several facilities, for which power data is delivered collectively
Latitude	in decimal degree
Longitude	in decimal degree
Azimuth	0=South, 180=North, +90=West, -90=East
Tilt	Tilt of mounting structure (e.g. 30 for 30°)
Country code	Country code
TimeZone	Time zone of the forecasts ("UTC" or "Europe/Berlin" e.g.)
Installed power	Peak power of the facility in KW
Date of operation	Date of operation for the existing installed power
Tracking	2=dual-axis-tracking, 1=single-axis-tracking, 0=fixed mounted
Meter location - ID	ID of meter location of measured energy
SLP/RLM	Standard load profile/registered load metering
EEG-ID	Feed-in ID of network operator
Direct marketing	Ratio of direct marketing (between 0-100%)
Own consumption	Ratio of own consumption (between 0-100%)
Voltage level	high-voltage=hv medium voltage=mv low voltage=lv

Table 4 Master Data for PV forecasting

Facility-ID	Name/code of facility
Group-ID	Name of group which a) summarizes several single facilities for which power data is delivered separately for each facility or b) name of one big wind park consisting of several facilities, for which powerdata is delivered collectively
Latitude	in decimal degree
Longitude	in decimal degree
Country code	Country code
TimeZone	Time zone of the forecasts ("UTC" or "Europe/Berlin" e.g.)
Installed power	The installed peak power of the facility in KW
Date of operation	Since when is the facility operating with its current capacity.
Hub height	Distance of rotor to the ground
Manufacturer	Manufacturer of wind turbine
Model name	type
Rotor diameter	in m

Meter location - ID	ID of meter location of measured energy
Number of turbines	Number of turbines
EEG-ID	Feed-in ID of network operator
Total height (m)	Total height of facility
Direct marketing	Ratio of direct marketing (between 0-100%)
Own consumption	Ratio of own consumption (between 0-100%)
Voltage level	high-voltage=hv medium voltage=mv low voltage=lv

Table 5 Master Data for wind forecasting

Facility-ID	name/code of facility
Group-ID	Name of group which a) summarizes several single facilities for which power data is delivered separately for each facility
Latitude	in decimal degree
Longitude	in decimal degree
City	The city
Street	The street
ZIP	The zip code
Country code	Country code
TimeZone	Time zone of the forecasts ("UTC" or "Europe/Berlin" e.g.)
Installed capacity (KW)	The installed capacity (KW)
Date of operation	Date of operation for the existing installed power
Meter location - ID	ID of meter location of measured energy
Voltage level	high-voltage=hv medium voltage=mv low voltage=lv

Table 6 Master Data for consumption forecasting

Then, and in order to retrieve real time and historical consumption/generation data from the assets, minor modifications are required for the development of the associated interfaces. This was a task performed in BESOS project where the interfaces with OTESP (in order to retrieve historical consumption and generation data) were adapted following BESOS common information model. This is a typical modification performed only at the interface layer of the application, without affecting the core of the Forecasting Engine and supporting that way the transferability of the service component.

Latency of BESOS forecasting engine

As the very last part of BESOS forecasting engine technical evaluation, we evaluate the latency of the application. We have to point out that the data required for the extraction of generation and consumption forecasts are not continuously retrieved from the assets, contrariwise these are retrieved only once and are further stored in the central data repository. In addition, we mention that the engine periodically updates forecasting data for the different assets, as an internal process of the mechanism. Considering the development of the application, a **low latency** is expected for the forecasting process.

Taking into account the demonstration of the engine in BESOS project, we evaluated 4 different scenarios:

- Scenario 1: Consumption forecasting (24 H) for a single asset
- Scenario 2: Generation forecasting (24 H) for a single asset
- Scenario 3: Consumption forecasting (24 H) for the full list of assets integrated
- Scenario 4: Generation forecasting (24 H) for the full list of assets integrated

The results from the evaluation process are presented:

Scenario ID	Latency (sec)
Scenario 1	0.586
Scenario 2	0.54
Scenario 3	6.23
Scenario 4	4.76

Table 7 BESOS forecasting engine latency

We have to point out that any latency associated with the number of assets has to do with network delays (request/response time) and not with any latency of the forecasting engine itself as we are handling the calculation through independent processes.

The technical evaluation was performed for the main components that consist of the BESOS platform, further enabling the technical evaluation of BESOS as a service. Special focus is delivered on the technical evaluation of OTESP module, as the core component of the system that enables the interconnection of EMSs with the business applications.

A main outcome of BESOS framework, highlighted also in this technical analysis, is the ability to easily transfer the platform in different case studies, focusing in the scalability and reliability parameters during the evaluation process. This is actually one of the main objectives of the project, to provide an end to end solution for smart cities, fully transferable in different pilot cases and further interoperable with existing assets and applications.

We have to further point out that one of the criteria for the evaluation of BESOS system is the affordability of each individual application. This is related with the work performed in the next section about the business evaluation of BESOS framework, complementing that way the holistic business and technical evaluation of BESOS platform.

4 Business Evaluation of BESOS Applications

Following the provision of BESOS technical evaluation in previous section, we proceed with the business evaluation of BESOS framework. The main objective of this section is to set a holistic model for the business evaluation of the different BESOS applications, either as single entities or under an integrated framework. The analysis is based on 1) cost estimations from the technical partners of the consortium (contributing on the development of the respective software components) and 2) the benefits as derived from impact assessment process and questionnaires analysis.

We have presented in Section 2 the different criteria that consist of the business evaluation framework, and therefore we proceed with the evaluation process in the following sections, starting from Cost Benefit Analysis.

4.1 Cost Benefit Analysis

The Cost Benefit Analysis is an analysis aiming to extract the costs and benefits that derive from a system for the different business stakeholders. This analysis aims to investigate if a system is viable in terms of qualitative / quantitative criteria. In this section, the Cost Benefit analysis is performed for each application of BESOS framework (Business Balance Scorecard for Municipalities, Decision Support System Tool for ESCOs, BESOS Forecasting Engine for Energy Managers) and for the BESOS application as a service. Therefore, two different view-points for Cost Benefit Analysis are defined.

The first view is the developer's perspective for the different applications, namely ETRA for BBSC and DSS, HYPERTECH for Visual Analytics tool, ENERCAST for BESOS Forecasting Engine. OTESP platform could be also considered as a potential exploitable outcome of BESOS project but as this solution is developed by UDE (university), there is no foreseen plan for market exploitation. The CBA analysis estimates the costs required to further commercialise each application and the foreseen benefits from their exploitation. A rough estimation is provided in this section, as the main objective of the project is to consider these applications as part of BESOS platform and not as standalone software components.

The second view of the analysis, which is the most relevant to BESOS evaluation, includes the CBA Analysis from the business stakeholders' point of view: ESCOs and Public Authorities. In this case, we evaluate the costs and benefits by considering the BESOS platform as the tool for assets management. Thus, we are examining "BESOS as a service' by integrating the different applications under a common BESOS framework.

In order to proceed with the business evaluation, the following indicators have already been identified:

- **Net Present Value (NPV):** This is defined as the sum of present values (PVs) of the individual cash flows of the same entity.
- **Internal Rate of Return (IRR):** The internal rate of return (IRR) or economic rate of return (ERR) is a rate of return used in capital budgeting to measure and compare the profitability of investments.
- **Pay Back Period:** This is considered the period of time required to recoup the funds expended in an investment, or to reach the break-even point.

The analysis starts with the cost benefit analysis for each specific exploitable asset of the platform.

4.1.1 Cost Benefit Analysis – Developers perspective

This analysis is performed taking into account the different applications of BESOS framework. There are four core components that may stand as commercially exploitable applications: BESOS Visual Analytics, BESOS BBSC & DSC tools and BESOS Forecasting Engine. For these applications, the responsible partners are performing a cost benefit analysis taking into account additional development costs required for commercialization and projected incomes from market exploitation.

BESOS Visual Analytics Exploitation Plan

A demonstration application, named as BESOS Visual Analytics tool, was developed during BESOS project. The main goal is to create a tool that allows users to explore data in different ways towards the extraction of useful patterns in the portfolio. The tool provides a good overview of EMS metrics, allows users/stakeholders to perform analytics, to navigate with interactive visualizations and extract details about portfolio performance. Therefore the role of the VA tool is to provide analytics over historical data and further visualize results through an appealing user interface. A detailed analysis of the BESOS Visual Analytics, highlighting the core system functionalities, is reported in D5.1.1 [7] & D5.1.2 [8].

The marketing plan is to offer the solution to SMEs, where there is no mandate or hard requirement for complex and costly BI tools. We have to point that during the development period, a modular approach was adopted and thus there is no requirement for high development costs for customization and maintenance of BESOS Visual Analytics application. The main assumptions considered for cost benefit analysis are presented in the following table:

Type of cost	Cost per Unit (€)
Software Update	-50,000.00 €
Marketing Expenses	10% of revenues
Payroll Expenses	15% of revenues
Maintenance and Upgrade	20% of revenues
Direct sales	1,350.00 €/ annual fee for average 10 users
Additional Services Revenues	10% of direct sales

Table 8 BESOS VA cost benefit analysis-Parameters

Where:

- **Software Update**: Costs for API development that will enable the easy deployment of the solution. BESOS VA stands on top of BESOS data management layer and provides the functional and presentation layer. Therefore, we are expecting minor modifications on the existing data management interfaces to support additional data management frameworks. In the apparent cost, we are considering also the cost for transforming BESOS solution to a commercial software product.
- **Software Modification:** Cost for deployment on existing infrastructures. This is a cost expected per client, towards the deployment of the solution in customer premises. More specifically this cost comes for interfacing BESOS VA solution to customer infrastructures, considering also deployment and testing costs. In this cost we have to add also payroll cost for supporting the development of these services/interfaces.
- **Marketing Expenses:** Cost for commercialization of BESOS VA solution. This is evaluated as a percentage from revenues, explicitly allocated for the marketing of business application.
- **License Cost:** The cost per license sold. An annual fee is examined as the most possible pricing model for Visual Analytics tool. The CBA analysis takes into account the estimation about the number of VA customers in order to further evaluate the profit coming from BESOS Visual Analytics commercialization. In addition, we have to consider additional revenues coming to the company by offering upgrading and testing services.

The following table summarizes the results of exploitation plan for BESOS VA:

Year	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Revenues						
Direct sales	0.00 €	20,250.00 €	25,312.50 €	30,375.00 €	35,437.00 €	40,500.00 €
Additional Services Revenues	0.00 €	2,025.00 €	2,531.25 €	3,037.50 €	3,543.70 €	4,050.00 €

Total Revenues	0.00 €	22,275.00 €	27,843.75 €	33,412.50 €	38,980.70 €	44,550.00 €
Expenses						
Software Update	40,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
Marketing Expenses	0.00 €	2,227.50 €	2,784.38 €	3,341.25 €	3,898.07 €	4,455.00 €
Payroll Expenses	0.00 €	3,341.25 €	4,176.56 €	5,011.88 €	5,847.11 €	6,682.50 €
Maintenance and Upgrade	0.00 €	4,455.00 €	5,568.75 €	6,682.50 €	7,796.14 €	8,910.00 €
Total Expenses	**40,000.00 €**	**10,023.75 €**	**12,529.69 €**	**15,035.63 €**	**17,541.32 €**	**20,047.50 €**
Profit						
Gross Profit	**-40,000.00 €**	**12,251.25 €**	**15,314.06 €**	**18,376.88 €**	**21,439.39 €**	**24,502.50 €**
Taxes	0.00 €	3,062.81 €	3,828.52 €	4,594.22 €	5,359.85 €	6,125.63 €
Net Profit	**-40,000.00 €**	**9,188.44 €**	**11,485.55 €**	**13,782.66 €**	**16,079.54 €**	**18,376.88 €**

Table 9 BESOS VA Business plan

By considering the annual cost & revenues from BESOS VA exploitation plan, we are calculating the different indicators associated with cost benefit analysis:

Visual Analytics Exploitation Plan			
	NPV	**IRR**	**Payback Period**
Year 1	($29,761.05)	18.7%	3.2 years
Year 2	($19,839.41)		
Year 3	($8,500.38)		
Year 4	$4,098.36		
Year 5	$17,811.46		

Table 10 BESOS Visual Analytics CBA Analysis

From the cost benefit analysis performed, we can easily define that BESOS VA is a promising application with high market potential. Data analytics is a trend in energy domain (considering the huge amounts of data from smart grids implementation) and there is a high demand for customized solutions, able to cover specific needs and requirements. BESOS Visual Analytics is a flexible solution which combines different algorithmic techniques and visualization models, providing that way an affordable solution for customized analytics to the Energy Stakeholders. It is of company's high interest to further extend the current version of BESOS VA and provide this application as a commercially available solution. A detailed analysis of HYPERTECH exploitation plan for Visual Analytics tool is reported in D8.2.

BESOS BBSC & DSC Tools or BESOS Cockpits

The BESOS Cockpits or BESOS tools were developed during BESOS project aiming at supporting strategical, managerial, operational and decision-making support processes; furthermore improving performance of a wide portfolio of entities and business sectors.

To cover all the aforementioned aspects and by addressing the targeted customers' requirements, two single cockpits or tools capable to be exploited either as a global solution or individually have been developed within the BESOS project. Respectively these tools are the Business Balance Scorecard (BBSC) and the Decision Support Cockpit (DSC). The BBSC targets decision-makers and provides a strategic performance management capability, which its goal is to assess if an entity, its components and its services reach the results specified in its strategic global plan. Furthermore it includes software engines that can measure the activities, processes and provided services of an entity in terms of its vision and strategy, and subsequently, performing ratings and assessments of the fulfilment of its commitments and obligations. The BBSC goes beyond the traditional financial and BI assessment tools by allowing to assess the business profitability also in terms of the performance of internal processes or SLAs fulfilment & compliance with its customers and providers, among others.

The Support and Decision tool (DSC), in turns, targets the technical operation business roles of a certain system and is a software component that provides fine-grained technical information as well as management capabilities when available. The tool, in summary, gathers and processes real-time data and generates valuable analytics from this information to affect the strategies that operate a system or a subset of services deployed; that is, the DSS tool supports to those targeted business roles in the operational and managerial tasks, so that this software component recommends strategies to users and provides actions to be applied within the system according to a certain situation and the business's vision & strategy to improve the system performance. With a wide number of interfaces, the solution is able not only to interact with whatever the subsystem or management platform for monitoring purposes, but also to send automated actuation commands to them, according to the strategy calculated. A common feature inherent of both the BESOS Cockpits is the standards-based interoperability by design with the most adopted international standards, not only with well-known industrial platforms, but also with other management platforms/frameworks in innovative business areas such as Smart City or Smart Grids, for example; the latter when user-oriented and customized instances of the BESOS tools in marketing phases.

Therefore the role of the BESOS cockpits described in previous paragraphs a detailed analysis of the BESOS Cockpits, highlighting respectively their core system functionalities is reported in D5.1.1 [ref] and D5.1.2 [ref] documents.

It is worthy to point out that more than a marketing plan has been defined derived from the assessment and analysis of potential market niches, market volume, customer segmentation and targeted customers. Main differences among marketing options rest on foundations such us: (i) lack off expertise and/or technical & operational human resources for facilities operation, (ii) benefits derived from the strategic management of the entire organization beyond the focus-centred financial business intelligence solutions, (iii) cloud-based solutions for improving integration, interoperability and migration capabilities, among others. So, different business models have been established.

According to that the table below shows the main scenarios:

Scenario	Products	Target Customers	Comments
1	BBSC and DSC	Smart Cities < 100.000 inhabitants with novel Smart City Strategy	For cross-border municipal services. Beyond the software tools, operation and maintenance services are provided. Cities outsource the services management
2	BBSC and DSC	Facility Managers: ports … RESCOOP Hotels Aggregators (*)	Strategical business managerial and operation improvement. Improvement of systems performance and customer-services delivery.
3	BBSC	Smart Cities < 100.000 inhabitants with Urban Platforms already deployed	Dashboard and business cockpit multi-site and multi-system beyond financial auditing and performance

Table 11 BESOS Cockpits Business Cases or Scenarios

(*) Innovative business model. Not evaluated. In a medium-term future according to the development of the legal framework in the energy market.

The main assumptions considered for cost benefit analysis are:

- Due to the modular approach and foundations on open and standards-based software design during the development period, there is no requirement for high development costs for customization and maintenance of BESOS Cockpits solutions.

- The targeted customers and the associated market share is derived from the analysis carried out by ETRA based on the accumulative experience in commercialising and selling products in the ICT, facility management or public services arenas.

- Calculations of the expected market volume have been made taking into account geographical areas and business sectors on where the company does already business

- It has been identified different market niches and target customers as stated in the previous table showing the BESOS Cockpits scenarios. According to what exposed:

    - In the third scenario, cities which have some characteristic of smart city with already existing smart services and a "core brain" of city-wide management and governance are targeted. The market niche is cities with < 100.000 inhabitants. As expected market volume is envisage a share of 10%.

    - First and second scenarios focus on facility management services. Due to the great flexibility provided by the combination of the outcomes from the two software tools BSSC and DSC, the BESOS Cockpit, a wide ecosystem of different customers should be addressable. As their nature, one can speak about cities or municipalities and private companies from different economic activity sectors characterized by multi-site locations and a wide number of processes, facilities and energy consuming systems/subsystems. That is, business and entities which their role is close and similarly to the facility managers in their own organizations. So that, main assumptions with this respect are: cities with population minor than 100.000 inhabitants, sea-port authorities, 3* hotels, and renewable energy cooperatives. In numbers:
        - 5% of the market share of the identified key ports in EU for the development of a trans-European transport network
        - 3% of municipalities (<100.000 inhabitants) in Spain
        - 5% of 3* hotels in Spain
        - 1% of RESCOOPs in EU

Regards cost and revenues main assumptions are:

COST	Cost per Unit (€)
Marketing Expenses	Amortization (year-1)
Customization of user's requirements	80€/hour per sales unit for average 20 hours
General expenses	8%
Other Expenses	2% total costs

REVENUES	Cost per Unit (€)
FM Cockpit & DSS	30,00 €/ annual fee per control event/signal. Minimum pack 100 signals
FM "Premium" Quote. Multi-site and multi-facilities	Premium Users. Unlimited facilities, processes and EMSs to manage. Self-management or to third-parties
Operation Service	Outsourcing service. Portfolio operation and management
BBSC City Dashboard	50,00 €/ annual fee per control event/signal. Minimum pack 24 signals
Standard-based connector to Urban Smart City Platforms	15.000/ sales unit

Table 12 BESOS Cockpits cost benefit analysis-Parameters

The following table summarizes the results of exploitation plan for BESOS Cockpits:

	0	1	2	3	4	5
INCOMES	-	85.986	554.773	1.023.366	1.674.122	2.453.758
FM Cockpit & DSS		12.870,00	85.800,00	171.600,00	287.430,00	429.000,00
FM "Premium" Quote. Multi-site and multi-facilities		51.480,00	343.200,00	686.400,00	1.149.720,00	1.716.000,00
Operation Service		3.168,00	21.120,00	42.240,00	70.752,00	105.600,00
BBSC City Dashboard		1.368,00	7.753,14	9.126,46	12.319,60	15.058,26
Standard-based connector to Urban Smart City Platforms		17.100,00	96.900,00	114.000,00	153.900,00	188.100,00
	0					
COSTS	-	636.074	794.367	851.499	932.725	1.022.203
(gross margin)		-640%	-43%	17%	44%	58%
Direct Personal Cost		564.876	576.174	587.697	599.451	611.440
Marketing and commercial activity		0	75.910	75.910	75.910	75.910
Customization of user's requirements		6.950	39.386	46.336	62.554	76.454
SW Licenses and related costs		36.528	37.259	38.004	38.764	39.539
Other costs		8.640	8.813	8.989	9.169	9.352
Other expenses (indirectos)		12.201	12.445	12.694	12.948	13.207
GENERAL EXPENSES	8%	6.879	44.382	81.869	133.930	196.301
Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA)	-	- 550.088	- 239.594	171.868	741.397	1.431.555
Amortization		75.910	75.910	75.910	75.910	75.910
Earnings Before Interest and Taxes (EBIT)		- 625.998	- 315.504	95.958	665.487	1.355.645
Corporate Tax (25%)		- 156.500	- 78.876	23.989	166.372	338.911
NOPAT. Net operating Profit After Tax (without f. cost)		**- 469.499**	**- 236.628**	**71.968**	**499.115**	**1.016.734**
(NOPAT project %)		-546,02%	-42,65%	7,03%	29,81%	41,44%
INVESTMENTS	-	379.550	-	-	-	-
Subcontracting	0	-				
Control and telecontrol central	0	-				
CAPEX	379.550	379.550				
Rest of materials	0	-				
TOTAL Investments	379.550					-
NET CASH FLOW	-	- 614.677	- 411.544	25.386	697.313	1.083.280
Project Cash flow (incomes minus costs)		- 550.088	- 239.594	171.868	741.397	1.137.658
Working capital		- 314.962	- 143.012	3.470	47.554	101.932
Working capital variation		- 314.962	171.950	146.482	44.084	54.378
IRR (Internal Rate of Return)	19,44%			**Discount Tax**	6,3%	
VNA (5 years)	43.389					

PROFITABILTIY AND FINANCIAL COSTS CONSIDERING FINANCIAL EXPENSES						
Main financing cost		-	-	-	-	-
Financing cost. Financing capital (Financiación Circulante?)		12.473	21.019	20.824	6.982	-
Tax deduction (finance costs)		- 3.492	- 5.255	- 5.206	- 1.746	-
Net operating Profit After Tax (real NOPAT with FC)		**-478.479,44**	**-252.392,55**	**56.350,21**	**493.878,45**	**1.016.734,00**
Grant	0,00	0	0	0	0	0
REAL CASH FLOW (after debt service)	**0,00**	**-623.657,33**	**-427.308,41**	**9.767,97**	**692.076,26**	**1.083.280,19**
Treasury position (After debt payment)	0,00	-623.657	-1.050.966	-1.041.198	-349.122	734.159
Real margin with financial costs		-556,46%	-45,49%	5,51%	29,50%	41,44%
Cash Flow	- 379.550	- 623.657	- 427.308	9.768	692.076	1.083.280
IRR(economical-financial)	**6,39%**					
VNA	**17.672**					

Table 13 BESOS Cockpits cost benefit analysis

The results extracted from the tables show both business and financial viability with a yearly turnover of 2,45 M€ in year 5, an accumulated turnover of 5,79 M€ and a business IRR out of 19,44%. In other vein, the financial result when the business is supported by own funds, financing costs are included, etc. is an IRR worth 6,39% and a financial value of Return on Sales out of 14,44%, so in terms of the economic situation today, this is an interesting business to invest in. The Net Present Value is represented by means the VNA parameter and is positive, in both business and financial results, with as a maximum discount rate 6,3%. And ROI is 3 years.

From the cost benefit analysis performed, we can easily define that BESOS Cockpits are a promising solutions with high market potential. Trends in recent years show that the compelling reasons for organizations and entities when investing in energy efficiency are, beyond saving on costs, implementing measures for greater operational efficiency in business as achieving corporate environmental goals while progress towards the goals of reducing energy consumption are tracked. All this combined with the basic need to measure the profitability of the business makes BESOS Cockpits are attractive for numerous sectors. Both for an intelligent city defined today as a system of systems and for an organization of any kind. It is company's interest to extend the features of the BESOS Cockpits and provide these solutions as a commercially available solution. A detailed analysis of ETRA exploitation plan is reported in D8.2.

Forecasting Engine

The BESOS Forecasting Engine has been developed by Enercast, as an adaptation of the tools offered by the company. Enercast GmbH is a Kassel-based forecasting specialist for renewable energies. Since 2011, the company has been developing applications for the energy sector, mainly focusing on generation forecasting. Customers of Enercast are the TSOs from Germany and the Austria, DSOs, utilities, energy traders, energy producers, etc. providing forecasting data about renewable power plants in more than 15 countries worldwide. As the generation Forecasting Engine is a mature product for the company, the goal of the following business plan is on the commercialization of the demand site forecast algorithm, initially developed and tested in BESOS project. While the estimated licence cost is the one considered also for generation forecasting services, a rather pessimistic approach is considered for the number of customers for the demand site forecast engine (total number of 90 customers by the end of the 5-year period.). Considering further investment costs for the deployment of demand site forecast engine as a standalone solution, the detailed evaluation plan is presented in the following table:

Year	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Revenues						
Direct sales	0.00 €	11,000.00 €	22,000.00 €	44,000.00 €	66,000.00 €	99,000.00 €
Additional Services Revenues	0.00 €	1,100.00 €	2,200.00 €	4,400.00 €	6,600.00 €	9,900.00 €
Total Revenues	**0.00 €**	**12,100.00 €**	**24,200.00 €**	**48,400.00 €**	**72,600.00 €**	**108,900.00 €**
Expenses						
Software Upgrade	40,000.00 €	25,000.00 €	10,000.00 €	7,500.00 €	7,500.00 €	7,500.00 €
Marketing Expenses	0.00 €	1,210.00 €	2,420.00 €	4,840.00 €	7,260.00 €	10,890.00 €
Payroll Expenses	0.00 €	1,815.00 €	3,630.00 €	7,260.00 €	10,890.00 €	16,335.00 €
Maintenance and Upgrade	0.00 €	2,420.00 €	4,840.00 €	9,680.00 €	14,520.00 €	21,780.00 €
Total Expenses	**40,000.00 €**	**30,445.00 €**	**20,890.00 €**	**29,280.00 €**	**40,170.00 €**	**56,505.00 €**
Profit						
Gross Profit	**-40,000.00 €**	**-18,345.00 €**	**3,310.00 €**	**19,120.00 €**	**32,430.00 €**	**52,395.00 €**
Corporate Taxes	0.00 €	0.00 €	827.50 €	4,780.00 €	8,107.50 €	13,098.75 €
Net Profit	**-40,000.00 €**	**-18,345.00 €**	**2,482.50 €**	**14,340.00 €**	**24,322.50 €**	**39,296.25 €**

Table 14 BESOS Forecasting Engine cost benefit analysis

At the end of the 5-year period, the NPV value is €7,588.12, with an IRR of 8.6% and payback period of 4.2 years. This is a viable investment for ENERCAST considering that this is not the major activity of the company (the company provides generation forecasting services as the main business), while the capital money required for the investment can be easily raised by the investors of the company.

OTESP Platform

The OTESP has been developed by the University of Duisburg-Essen. As a university, the UDE does not pursue any commercial interests for exploitation. The primary exploitation and dissemination interests are to improve upon the state of the art in Pervasive Computing, Embedded Systems and Machine-to-Machine communication using the knowledge and expertise gained during the development of the Open Trustworthy Energy Services Platform. Aside from references in publications and university courses as well as further advancements in functionality, it is considered to release the code as open-source as a final step, allowing for further development and extension by everyone interested in this project. Therefore a cost benefit analysis is not expedient and essential in the context of UDE's exploitation plans.

Following the presentation of the individual exploitation plans conducted by the technical partners (with commercialization interest) of the consortium for the different business applications, we proceed with the cost benefit analysis of BESOS platform.

4.1.2 Cost Benefit Analysis – Business Stakeholders' perspective

The goal of the section is to provide the Cost Benefit analysis for BESOS as a Service. Therefore, feedback from the main business system stakeholders (mainly ESCOs) was taken in consideration for the concrete evaluation of the holistic framework. As the main market objective of the platform is on the adaptation of existing EMS solutions, the hardware costs are limited and thus the potential for market penetration of BESOs solution is high, taking also into account the market trend for ICT solutions and new business models in modern cities (moving to smart cities era). In the specific case of BESOS, investment in technology is applied to achieve energy efficiency in buildings, by the following parameters to constitute the potential revenue streams:

- **Energy saving from energy curtailment:** demand reduction in the installation when compared to a baseline load that corresponds to the energy demand of the building before the installation of the energy management system. This is calculated as the product of the energy not consumed with the tariff that corresponds to the hours during which the curtailment takes place.
- **Cost saving from load shifting:** load shifting from hours with high prices to hours with low prices results in a reduction of the total cost of the energy supply. This is calculated as the product of the energy shifted between the high and the low energy prices. This is the case of EVs as examined in the project. In addition, the evaluation of alternative tariff policies may also lead to cost reduction for the consumers, increasing that way the potential revenues for ESCOs.
- **Reduction of CO2 emissions:** This is a critical parameter for large cities as there is a mandate to support CO2 emissions reduction planning. Towards this direction, and in order to examine the impact of the proposed framework, we are quantifying the profit from CO2 emissions reduction, achieved by the deployment of BESOS platform.

Apart from revenues, the costs for integrating BESOS platform as part of the existing energy management framework in demonstration sites are considered

- **Initial investment expenditure:** this corresponds to the equity capital that is invested. Investment cost includes all the necessary expenses made at the beginning of the implementation of the investment, i.e. the cost for the hardware and software used. The total cost is closely related to the number of assets integrated and thus the analysis is delivered for similar to BESOS case studies.
- **Operation & maintenance cost (OMC):** this includes the expenses for maintenance of the hardware and software.

The data needed for CBA are retrieved from impact assessment analysis and more specifically from the integrated scenario, named as **Smart city Energy demand curve optimization** scenario. In this scenario, a holistic optimization framework is performed, and thus the total energy savings (energy curtailment and load shifting) are considered. We have to point out that revenues from RES penetration (as energy source) are not examined in the analysis, as we don't explicitly allocate investment costs for this type of technology. The focus of the analysis is on BESOS platform itself, as a platform for the management and coordination of the **existing assets.**

The following table summarizes the input parameters for cost benefit analysis while a more detailed analysis for the extraction of these values is provided in Annex I.

Investment Costs		
Category	**Lisbon**	**Barcelona**
Investment cost (IC)	**12.640 €**	**22.350 €**
Inflation rate (IR)	**10%**	**10%**
Operation & maintenance cost	**1.264 €**	**2.235 €**
Investment Revenues		
Category	**Lisbon**	**Barcelona**
Energy Curtailment & Load Shifting Savings	**-23.91%**	**- 22.5%**
CO2 emissions Savings	**-23.99%**	**-20.65 %**

Table 15 CBA Analysis Parameters

The size of pilot for CBA analysis is the same as the demonstration scenario in order to establish a viable case for the cost evaluation of the platform. Actually, this is one of the main objectives of the project, to provide a platform that enables the management of multiple assets in smart cities.

For **investment costs** we are considering the costs of licensing BESOS platform (software licences and cloud hosting for BESOS platform, hardware costs required for physical adaptation of assets, software licenses for cloud adaptation of commercial EMS assets). The detailed estimation of investment costs is provided in the Annex.

For **O&M costs**, we consider a 10% of total annual revenues, for further development and configuration of BESOS platform. This cost is further extrapolated to the configuration of the different modular components that consist of the BESOS platform.

For **inflation rate**, this is the discount rate for Net Present Value calculation. For BESOS platform CBA analysis a 10% inflation rate is considered, following the approach adopted during standalone applications evaluation.

On the other hand, we are considering the revenue streams from the different pilot sites of the project. The results are taken from D7.2 “Evaluation and Assessment” and the impact assessment analysis performed.

For **energy curtailment savings** we are considering energy and subsequently costs savings through the management of sheddable loads (traffic and public lighting assets)

For **load shifting savings** we are considering the cost savings from optimal management of EV fleet along with the ToU optimization scenarios in public buildings.

For **CO2 emissions savings** we are considering the impact on final CO2 emissions and the associated cost savings due to CO2 emissions reduction. A carbon tax is a price-based policy since the regulator sets the price directly. For the case study examined we are considering the total cost of $15 euro/ton.

Finally, we are defining two different business scenarios for CBA evaluation:

- Static analysis. In this case scenario the assets are integrated in the platform from Day 0 and thus we have a static analysis of the portfolio.
- Dynamic portfolio. In this case scenario, which is closer to real life demonstration, we have a continuous adaptation and integration of new assets through the 5-year evaluation period. A limited number of assets is initially integrated and then we have an increasing number of assets that consist of the portfolio of the ESCO manager.

Following the definition of parameters, the cost benefit analysis is performed addressing the business indicators defined above.

4.1.3 Net Present Value

Assuming a discount rate of 10% for the projects, the Net Present Value is calculated. The results are presented in the following Table:

Pilot Site	NPV- Case 1	NPV- Case 2
Lisbon	€ 2,444.18	€ 1,534.88
Barcelona	€ 3,819.47	€ 1,816.00

Table 16 BESOS NPV Analysis

For the pilot project in Portugal, where a limited number of assets is integrated in BESOS, the NPV in the simplest case is € 2,444.18. This is the case where the assets are integrated in the platform from Year 0. Towards a sensitive analysis of BESOS platform, we are considering the dynamic integration of assets and further NPV calculation for a 5-year period. For this Case 2 scenario the NPV value is: € 1,534.88.

As expected, for the pilot site in Spain, the NPV is positive for the case scenarios examined with NPV values € 3,819.47 and € 1,816.00 respectively.

The results are presented for both pilot sites. We first present the results for Lisbon Pilot Site. The results from business scenario 1 are presented in the following table.

Year	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Revenues						
Energy Curtailment Savings	0.00 €	17,674.53 €	17,674.53 €	17,674.53 €	17,674.53 €	17,674.53 €
CO2 emissions Savings	0.00 €	277.60 €	277.60 €	277.60 €	277.60 €	277.60 €
Total Revenues	**0.00 €**	**17,952.13 €**	**17,952.13 €**	**17,952.13 €**	**17,952.13 €**	**17,952.13 €**
Expenses						
Investment cost	7,340.00 €	14,240.00 €	14,240.00 €	14,240.00 €	14,240.00 €	14,240.00 €
Maintenance and Upgrade	0.00 €	1,424.00 €	1,424.00 €	1,424.00 €	1,424.00 €	1,424.00 €
Total Expenses	**7,340.00 €**	**15,664.00 €**	**15,664.00 €**	**15,664.00 €**	**15,664.00 €**	**15,664.00 €**
Profit						
Profit	**-7,340.00 €**	**2,288.13 €**	**2,288.13 €**	**2,288.13 €**	**2,288.13 €**	**2,288.13 €**

Table 17 BESOS CBA Analysis (Case 1) - Lisbon Site

Furthermore, the results from the 2nd business scenario (and the dynamic adaptation of assets as part of ESCO portfolio) are presented in the following table.

Year	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Revenues						
Energy Curtailment Savings	0.00 €	12,480.00 €	14,235.00 €	15,856.00 €	16,848.00 €	17,674.53 €
CO2 emissions Savings	0.00 €	187.20 €	213.53 €	237.84 €	252.72 €	277.60 €
Total Revenues	**0.00 €**	**12,667.20 €**	**14,448.53 €**	**16,093.84 €**	**17,100.72 €**	**17,952.13 €**
Expenses						
Investment cost	6,340.00 €	11,040.00 €	11,540.00 €	12,640.00 €	13,140.00 €	14,240.00 €

Maintenance and Upgrade	0.00 €	1,104.00 €	1,154.00 €	1,264.00 €	1,314.00 €	1,424.00 €
Total Expenses	**6,340.00 €**	**12,144.00 €**	**12,694.00 €**	**13,904.00 €**	**14,454.00 €**	**15,664.00 €**
Profit						
Gross Profit	**-6,340.00 €**	**523.20 €**	**1,754.53 €**	**2,189.84 €**	**2,646.72 €**	**2,288.13 €**

Table 18 BESOS CBA Analysis (Case 2) - Lisbon Site

As there is a fixed cost per licence for the business applications developed in the project (Annex I), it is beneficial for the ESCO manager to get the portfolio assets integrated from the beginning of the management period, to further exploit the maximum from each asset of the portfolio.

The same evaluation analysis is performed for Barcelona pilot testbed. The results from business scenario 1 are presented in .

Year	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Revenues						
Energy Curtailment Savings	0.00 €	27,456.24 €	27,456.24 €	27,456.24 €	27,456.24 €	27,456.24 €
CO2 emissions Savings	0.00 €	549.60 €	549.60 €	549.60 €	549.60 €	549.60 €
Total Revenues	**0.00 €**	**28,005.84 €**	**28,005.84 €**	**28,005.84 €**	**28,005.84 €**	**28,005.84 €**
Expenses						
Investment cost	10,800.00 €	22,350.00 €	22,350.00 €	22,350.00 €	22,350.00 €	22,350.00 €
Maintenance and Upgrade	0.00 €	2,235.00 €	2,235.00 €	2,235.00 €	2,235.00 €	2,235.00 €
Total Expenses	**10,800.00 €**	**24,585.00 €**	**24,585.00 €**	**24,585.00 €**	**24,585.00 €**	**24,585.00 €**
Profit						
Gross Profit	**-10,800.00 €**	**3,420.84 €**	**3,420.84 €**	**3,420.84 €**	**3,420.84 €**	**3,420.84 €**

Table 19 BESOS CBA Analysis (Case 1) - Barcelona Site

Furthermore, the results from the 2^{nd} business scenario (and the dynamic adaptation of assets as part of ESCO portfolio) are presented in the following table.

Year	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Revenues						
Energy Curtailment Savings	0.00 €	10,982.50 €	16,473.74 €	21,964.99 €	24,710.62 €	27,456.24 €
CO2 emissions Savings	0.00 €	329.76 €	329.76 €	439.68 €	494.64 €	549.60 €
Total Revenues	**0.00 €**	**11,312.26 €**	**16,803.50 €**	**22,404.67 €**	**25,205.26 €**	**28,005.84 €**
Expenses						
Investment cost	8,940.00 €	8,940.00 €	13,410.00 €	17,880.00 €	20,115.00 €	22,350.00 €
Maintenance and Upgrade	0.00 €	894.00 €	1,341.00 €	1,788.00 €	2,011.50 €	2,235.00 €
Total Expenses	**8,940.00 €**	**9,834.00 €**	**14,751.00 €**	**19,668.00 €**	**22,126.50 €**	**24,585.00 €**
Profit						
Gross Profit	**-8,940.00 €**	**1,478.26 €**	**2,052.50 €**	**2,736.67 €**	**3,078.76 €**	**3,420.84 €**

Table 20 BESOS CBA Analysis (Case 2) - Barcelona Site

In this case scenario, we are reporting an increase on investment costs (increased number of assets integrated) which leads to a higher energy costs reduction, supporting that way the viability of BESOS platform as an integrated solution.

From the aforementioned analysis is it is clear that the monetary benefits for BESOS platform are expected to be even higher, considering the potential of integrating additional assets. This is actually the goal of BESOS platform, to stand as the central platform where multiple types of assets are integrated under a unified management framework.

4.1.4 Internal Rate of Return

By applying the input data of Table 15, the IRR of BESOS platform is calculated. For the pilot sites, different business cases are examined; we have selected for our analysis the scenario where the demonstration assets are integrated in the platform on and the results are presented in the following Table:

Pilot Site	IRR Case-1	IRR Case-2
Lisbon	16.9%	12.3%
Barcelona	17.6%	11.5%

Table 21 BESOS CBA Analysis – IRR calculation

By simulating the demonstration scenarios in order to show the impact of BESOS platform to business stakeholders, the resulting IRR is **14.5%** as an average for both pilot sites

4.1.5 Payback Period

This is a simple calculation process in order to quickly estimate the feasibility of BESOS framework. Payback period intuitively measures how long an investment takes to "pay for itself." For the case scenarios examined in the project, the results from the analysis are provided in the next Table where we are presenting for both pilot sites the payback period value:

Pilot Site	Payback Period- 1	Payback Period- 2
Lisbon	3.4 years	4.1 years
Barcelona	3.1 years	4.4 years

Table 22 BESOS CBA Analysis – Payback Period calculation

The Cost Benefit Analysis is deemed necessary, as indicated by the previously presented results, with both IRR and NPV to be presented as the indicators about the evaluation of investment viability. In any case, the focus is on BESOS platform to perform in large scale applications (city level), and thus the interest is not only on monetary terms but a wider and multi- parametric analysis should be performed to get a clearer view of the impact of BESOS platform. Towards this direction, the cost effectiveness analysis of BESOS platform is provided in the next section.

4.1.6 CBA Analysis Summary

The role of cost benefit analysis as delivered in this document is twofold. First we evaluated the affordability of each application as a standalone solution. Then, we evaluated the overall platform as a service, focusing on the impact that BESOS platform can bring to the business stakeholders of the project (mainly ESCOs and Asset managers).

The benefits for the end users of the platform are proved through simulations and show that there are remarkable economic benefits under specific circumstances. In addition, qualitative benefits are also foreseen for the business stakeholders, but also further economic benefits that could not be estimated in the context of BESOS as they are long term. Therefore, a more detailed analysis is mandatory before any physical deployment of the proposed framework, considering the specific barriers and boundaries that may affect the demonstration of BESOS framework.

4.2 Cost Effectiveness Analysis

In previous section, we focus on the economic evaluation of BESOS platform. Though, qualitative benefits are also foreseen for the business stakeholders and thus should proceed with a more generic evaluation of BESOS platform. The goal of the cost effectiveness analysis is to provide a **qualitative methodology** that evaluates costs and outcomes (effects) without addressing only monetary indicators. The methodology of BESOS Cost Effectiveness Analysis has already been described in the evaluation plan in T7.1 [9]. The analysis is based on the role of business stakeholders and the impact of BESOS system to the following factors:

- Reduction of Energy Consumption
- Reduction of Energy Cost
- Reduction of CO2 emissions
- Quality of energy
- RES penetration
- Installation Costs
- OEM Costs

The goal of CEA analysis is to combine these KPIs under a multi parametric framework and further evaluate the impact on the different business scenarios examined in the project. The high level deployment scenarios, which serve as the “alternative objectives” for the evaluation analysis, are the following:

- Deployment Scenario 1: “Energy efficient operation” where the main objective is the reduction of energy consumption
- Deployment Scenario 2: “Cost efficient operation” where the main objective is the reduction of energy costs
- Deployment Scenario 3: “CO2 emissions reduction operation” where the main object is the reduction of CO2 emissions.

In order to proceed with the CEA analysis, we need to define the weights for each indicator. As BESOS platform is a platform for end users, the significance of each indicator is defined by them, through questionnaires analysis.

The pairwise comparisons were performed by 2 clusters of stakeholders, namely facility owners (3 experts) and ESCOs (3 experts) which were directly involved in this process (contribution for cost effectiveness analysis). Based on their feedback about the criticality of each indicator, the corresponding values were averaged, leading to a single template at the end, which was normalised, to the final ranking of the evaluation criteria. The next two figures depict the ranking or, in other terms, the importance of each parameter in contrary to any other, as defined by Building Owners and ESCOs/FMs respectively.

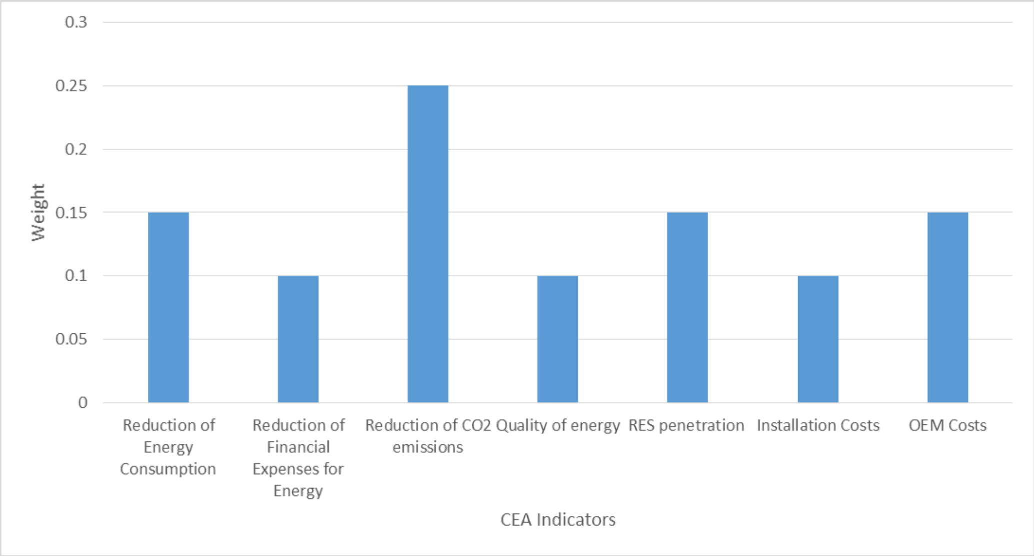

Figure 51 CEA Weights for Building Owners

As presented in the above schema, the most important factor for the municipalities/building owners is the establishment of an energy efficient environment, setting also a mandate for CO2 emissions reduction. In addition, OEM cost is a critical parameter for the municipalities as the cost of implementing further energy management programmes should be ensured in an affordable way.

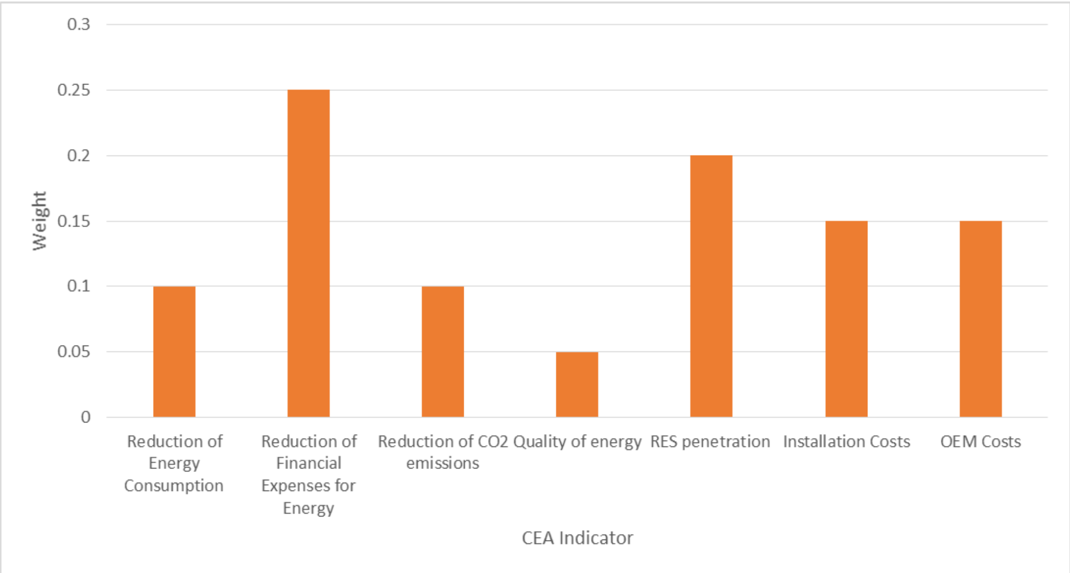

Figure 52 CEA Weights for ESCOs

On the other hand, ESCOs consider the financial parameters as the most critical, mainly due to their commercial role as energy serving companies. In addition, it seems that RES penetration is also a main factor, as they are also involved in this business (ESCOs are companies directly involved in RES installation projects).

By quantifying the importance of each CEA indicator, and in order to holistically examine the impact of BESOS platform for end users, we need to cross correlate the results from impact assessment analysis with the priority criteria as defined by the system stakeholders.

The analysis demonstrates the level up to which, each of the **demonstration scenarios** is expected to influence one of the indicators, taking into account CEA survey participants feedback. The focus of each demonstration scenario is on a specific indicator, Energy efficient scenario is focusing on reduction of energy consumption, Cost efficient scenario is about reduction of financial expenses for energy while CO2 emissions reduction is about the reduction of CO2 emissions values.

Therefore, the CEA survey participants were informed about the demonstration of the different business scenarios and the impact on evaluation results, providing their positive/negative view about each process.

Once again, the pairwise comparisons by the participants were averaged leading to the following diagrams for the respective business scenarios:

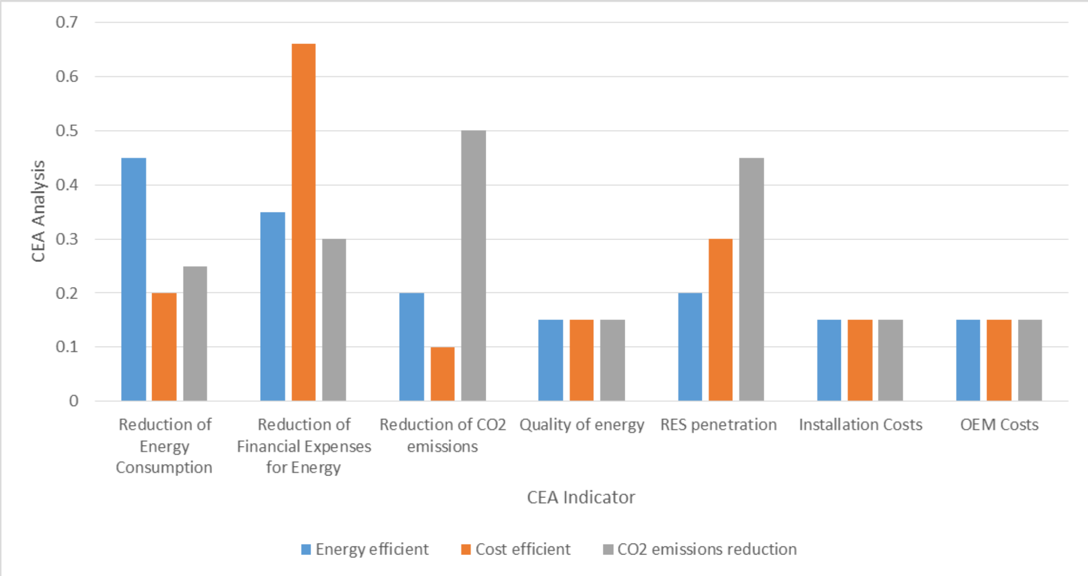

Figure 53 CEA Analysis on business Scenarios

From this figure, we can extract that **business model 1** is not that efficient to the eyes of CEA stakeholders, compared to the rest of business scenarios. The reason for this is the fact that the demonstration and evaluation process is mainly focusing on the **business perspective of BESOS platform** and how to evaluate the financial impact without focusing at total energy consumption. In addition, the impact on energy consumption is underestimated, due to limited controllability available at smart city assets. On the other hand, the mass penetration of RES, along with the integration of forecasting engine, ensures the high interest for **CO2 emissions** reduction, rewarded by the reviewers/stakeholders at business model 3. Overall, the process reveals the main points of interest for BESOS platform:

- Focus on business management of assets, providing that way a framework for energy service companies to provide their services
- Focus on RES penetration in smart city level business models, ensuring that way a high level of flexibility about the available energy services.

Finally, to point out that as a specific objective is allocated at each demonstration scenario, the reviewers have misjudged the impact of BESOS project to other factors, e.g. quality of energy or OEM costs where a neutral approach was observed during the evaluation process.

We have to point out that CEA analysis goes beyond the typical CBA analysis, trying to gather the view of business stakeholders for the different business models examined in the project. The different business stakeholders vote for the importance of each indicator of CEA analysis, and then they express their personal feeling about the specific demonstration models evaluated in the project. To this end, this analysis provides the qualitative evaluation of the specific business scenarios examined, focusing on the specific criteria of interest for business stakeholders.

4.3 SWOT Analysis

The main scope of SWOT analysis, is to provide a holistic evaluation of BESOS platform, considering feedback from the different business stakeholders. Towards this direction, the business stakeholders of the project were expressed their personal feelings about the benefits/drawbacks from BESOS application. The main factors of SWOT analysis are:

- Strengths: characteristics of the business or project that give it an advantage over others
- Weaknesses: are characteristics that place the team at a disadvantage relative to others
- Opportunities: elements that the project could exploit to its advantage
- Threats: elements in the environment that could cause trouble for the business or project

The detailed BESOS evaluation analysis for the different parameters defined by SWOT methodology follows:

4.3.1 Strengths

The main advantages of BESOS platform are reported:

- ***Real time monitoring** of multiple asset types*

The scope of the project is to provide real time information from the types of assets examined in the project. A direct monitoring and control functionality is provided to ensure the establishment of a management framework

- *Management of **different asset types***

For realizing the vision of an integrated city, several components are needed, and have been already investigated for the context of energy services. An open energy management service platform must cope with the fact that a large number of units are operated by independent customers with various EMS. The scope of BESOS platform is to integrate different asset types at a city level. Thus, different EMS systems are examined as part of the integrated framework:

1. Public Building EMS
2. Public Lighting
3. Traffic Lighting
4. Electric Vehicles
5. Local RES Generation

The integration of heterogeneous assets under a common framework is one of the main objectives of the project towards the evaluation of different business scenarios.

- *Benefits for **different business stakeholders***

The main scope of the project is to provide services to the different stakeholders in city level. Municipalities, Facility owners, ESCOs & Facility Managers are addressed as the business stakeholder of the system. Thus, BESOS application is examined for the high impact to the different end stakeholders with heterogeneous interests on the issues addressed by the project.

- *Benefits through **different business services***

As a bunch of stakeholders have been addressed by the project, different kinds of services are also available (balance scorecard, data analytics, decision support system, forecasting engine etc.…). Taking into account the different roles, customized services are defined for the optimal management of the associated assets.

- *Evaluation of new **business models/scenarios***

This is an impact from the integration of heterogeneous assets types as this approach enables for the definition of new business models for the different stakeholders: e.g. public lighting ESCO, traffic lighting manager etc.… In addition, the platform is customized to the new business roles introduced in the project, and further enables the definition of SLAs through specific KPIs and further the dynamic renegotiation of SLAs taking into account operational conditions.

- *User Driven knowledge based **control framework***

The main scope of the project is to provide a DSS tool for asset managers in order to perform optimal strategies for their portfolio. The Decision Support System not only provides access to the monitoring & control interfaces of the EMS involved, but also provides a decision support tool to help ESCOs operating several EMSs in smart city and analyse the impact of new energy positive elements in its districts – heating distribution and RES. The objective is to have a coordinated control of public entities that are of the responsibility of an ESCO, but also to support the operator on the decision process. In this way, once a lack of efficiency is detected the Decision System will count with a Knowledge Basis to provide corrective actions. Taking into account the role of the stakeholder, a decisions process is provided by the system through an automated way.

- *Added value through **visual analytics***

The project investigates the use of an innovative visual analytics framework, a novel research field that aims to provide visualization based methods for human supported analysis of large, complex datasets. Visual analytics differs to classic information visualization in that it attempts to take into account properties of human cognition, perception and sense making. Essentially, visual analytics aims to develop appropriate visualization and interaction mechanisms that match the mental processes of humans.
The visual analytics are expected to occur mostly on the business side in order to provide added value information for the optimal management of city assets. The extraction and combination of different KPIs under a common application framework provides a thorough view on different aspects addressed by the platform.

- *Open framework for **assets integration***

In order to aggregate the various EMS provided into an open service platform connected to an energy supplier and the distribution system operator not only interfaces have to be implemented, but also local visualization and safety requirements have to be implemented by appropriate algorithms. This requires a runtime environment providing a common programming environment as well as common data models for accessing the different environments of the EMS solutions. To this end, BESOS platform has adopted a modular approach to further support the easy integration of additional assets. In addition, and by the adoption of IEC CIM, a commonly accepted semantic model supports the integration of assets from different vendors.

- *Establishment of a **behavioural triggering framework***

Along with the services for the main energy business stakeholders, BESOS provides a customized mobile application to the citizens in order to inform about the status of their buildings and further engage them towards more energy efficient process through a behavioural triggering framework. The main advantage of BESOS platform is that this framework is examined as part of the overall management framework, offering that way an environment that citizens are actively participated in the coordinated management framework.

- *Added value through **the integration of a forecasting engine***

The project further incorporated an innovative forecasting engine, addressing both energy consumption and generation forecasting. To this end, accurate information about short term operation of the different assets is further incorporated in the DSS system for further exploitation. Therefore, the holistic DSS framework is expanded to address the temporal character of the different assets types, providing that way a more sophisticated management framework.

We proceed with the strengths analysis of BESOS platform, highlighting the different (& innovative) business applications developed in the project. BESOS tool is a multifunctional platform offering different business services to several business stakeholders by integrating multiple asset types.

4.3.2 Weaknesses

There are limited weaknesses to point out related to the operational environment of BESOS platform. We are highlighting:

- *Lack of **EMS hardware deployment***

The scope of the BESOS system is to examine the integration of different assets under a common framework. Thus, and as a main prerequisite for the implementation of BESOS framework, the actual installation of EMS is required offering also an open API for the adaptation. The current deployment of EMS is limited and thus we are addressing a limited number of proprietary EMSs. This is a main drawback not only for BESOS but for any other integration platform, due to the existing hardware installations which do not support the openness of the solutions.

- *Need for **large scale deployment***

One of the main objectives of the BESOS is to provide a platform for the management of assets in a city level scale. Two demonstration cities are addressed in the project (Barcelona City and Lisbon City) but a limited number of assets per each pilot set the testbed of the system. Thus, a large scale deployment is needed in order to evaluate the impact of BESOS system in an extended operational environment.

- ***Behavioural analysis** of citizens has **ambiguous results***

As an example of the openness of the approach at BESOS, a mobile application has been developed to present information directly to citizens. The objective is to use the data captured for management purposes, in order to create public awareness campaigns to inform the citizens about the costs and the use of energy to support public services, etc...

The task is generally targeting the entire community, as the application will be available for citizens, but the specifics objectives to modify the behaviour of end-users focus during demonstration period at students of the schools involved in the trials. Therefore, we have no representative group of people to actually evaluate the impact of the mobile application in real time conditions.

- ***Uncertainty** about expected **energy savings***

As the analysis is delivered on a limited number of assets it is not easy to accurately estimate the actual amount of energy savings. To highlight also the limited controllability at pilot assets and thus the overall evaluation was performed mainly in a simulated environment rather on the actual pilot conditions.

4.3.3 Opportunities

Following the analysis of BESOS platform itself, we are moving to the placement of BESOS in the market environment. The main opportunities for BESOS platform are:

- ***EU legislation** promoting energy efficiency*

The framework presented agreed on 23 October 2014 continued progress towards a low-carbon economy. It aims to build a competitive and secure energy system that ensures affordable energy for all consumers, increases the security of the EU's energy supplies, reduces our dependence on energy imports and creates new opportunities for growth and jobs.

1. Reducing greenhouse gas emissions by at least 40% A center piece of the framework is the binding target to reduce EU domestic greenhouse gas emissions by at least 40% below the 1990 level by 2030.
2. Increasing the share of renewable energy to at least 27%. Renewable energy will play a key role in the transition towards a competitive, secure and sustainable energy system. The Commission proposed an objective of increasing the share of renewable energy to at least 27% of the EU's energy consumption by 2030. The European Council endorsed this target which is binding at EU level.
3. Increasing energy efficiency by at least 27%. The European Commission proposed a 30% energy savings target for 2030, following a review of the Energy Efficiency Directive. The proposed target builds on the achievements already reached: new buildings use half the energy they did in the 1980s and industry is about 19% less energy intensive than in 2001. The European Council, however, endorsed an indicative target of 27% to be reviewed in 2020 having in mind a 30% target.

- ***Deregulation of energy market*** *and new business roles*

As there is a trend on the deregulation of energy market, new business models are defined (ESCOs and Aggregators). To this end, BESOS platform may be considered as the dynamic tool to support the new business stakeholders to actively participate in the new energy markets defined.

- ***Investment*** *on* ***clean energy*** *solution*

Towards the rapid establishment of smart grids concepts in European Grids, national and international funds massively invest on clean energy solutions. Therefore, there is a high opportunity for solutions like BESOS to get private and public investments to further support and extend their solutions. Especially for smart cities applications, more and more large E.U. cities are promoting the integration of the different types of cities entities and further the provision of services to citizens.

- ***Increased cost of energy***

Now the cost of energy is relatively low, but it is expected a rapid increase of the total cost in the near future. Towards this direction, there is an opportunity on the installation of EMS solutions that will further enable on the establishment of an energy efficient operation in tertiary buildings.

- ***EMS adaptation plan and IoT concept promotion***

As mentioned above, the current status on penetration of EMS systems in public buildings is low. Though, and following the energy efficiency directives along with the high investment on energy management services, there is a high trend on mass penetration of EMS systems in the near future. Towards this direction, there is a high opportunity for platform like BESOs to set the market for the integration of additional EMS systems.

4.3.4 Threats

The main threats from the external environment are reported:

- ***Lack*** *of* ***user acceptance***

As in most innovative technologies users are not always willing to adopt services that would change their daily routine and thinking. In addition and as the cost of energy remains low, there is no need for solution that could establish an energy efficient environment.

- *High* ***competition at ICT services***

As there is a high trend on the adoption of EMS solutions, different energy management platforms (either funded by EU or by private companies) have been developed the very recent years. Towards this direction, there is a high competition on the market, to further prevent the penetration of BESOS solution.

- ***Absence of national bodies/institutions*** *promoting BESOS like solutions*

Though EU supports the integration of EMS solutions, towards the establishment of an energy efficient environment, there is a lack of interest from national bodies/institutions to translate the national targets to specific, tangible measures

- ***Not clear role*** *and* ***responsibilities*** *of energy stakeholders*

Overlapping responsibilities between different entities, such as DSOs, ESCOs and Aggregators, combined with the lack of coordination from regulatory authorities creates a blurred market on the adaptation of EMSs. Thus, this is a main barrier on the penetration of EMSs solutions that would further enable the implementation of BESOS framework.

As there are a lot of barriers towards the exploitation of BESOS platform, the most critical are related to the lack of existing infrastructures in public assets. However, the E.U. supports the penetration of EMS systems in public assets and further integration of them in a common management framework, enabling that way the viability of BESOS as a platform for management of heterogeneous asset types at city level.

In this section, we are providing the business evaluation of BESOS platform. We started the analysis with Cost Benefit Evaluation of standalone applications and BESOS as a service and then we proceed with Cost Effectiveness Evaluation and SWOT analysis. This multi parametric evaluation provides a holistic business evaluation, by incorporating both monetary/financial parameters and business stakeholders' direct feedback. BESOS business evaluation complements the technical evaluation of BESOS platform performed in previous section towards the holistic "technical dissemination and exploitation" of BESOS outcomes.

5 Conclusions

The results of BESOS evaluation process show that the proposed platform can reach the goals set by the project. Following the impact assessment analysis and the user experience evaluation in D7.2, we focus on the technical and business evaluation of BESOS individual components and BESOS integrated framework towards the further technical dissemination and exploitation of project outcomes.

The 1st part of the deliverable is focusing on the technical evaluation of the system components that consist of the overall framework. Different performance tests were performed to evaluate the business applications and EMSs gateway, with the main focus to be delivered on the evaluation of OTESP platform. OTESP stands as the heart of platform and thus multiple tests were performed in order to evaluate the scalability and reliability of the core platform that enables interaction of business stakeholders with different asset types.

Following the technical evaluation of the platform, we report the socioeconomic analysis of BESOS platform, considering CBA and CEA methodologies during the evaluation process. Potential costs and benefits were analysed for all actors and specific economic indicators were calculated when possible. More specifically, individual CBA plans were provided for the different system components, though the focus is on the evaluation of “BESOS as a service”, as the main objective of the consortium is to provide an end to end solution, applicable at different case scenarios. The socioeconomic analysis includes also the CEA, as a standardized qualitative methodology to investigate socioeconomic impacts. The CEA is performed by getting the feedback from the 2 main categories of stakeholders (energy stakeholders and public authorities) and handles the evaluation of BESOS framework considering different socioeconomic criteria for the business models addressed by the evaluation process. Following the CEA analysis, a complementary SWOT analysis is also provided as part of the business evaluation of BESOS, defining the strengths and weaknesses of the proposed framework.

This document complements the evaluation process of BESOS platform as initiated in D7.2. The focus of this document is on technical and business evaluation of the constituent components that consist of BESOS platform towards the technical dissemination and exploitation of project outcomes. To point out that this document will further support the updated version of BESOS exploitation plan delivered in WP8.

ANNEX A: References and Acronyms

5.1 References

[1] BESOS DoW, BESOS Project

[2] BESOS Consortium, D7.1 “Ex-Ante Analysis and Baseline Definition”

[3] BESOS Consortium, D7.2 “Evaluation and Assessment”

[4] BESOS Consortium, D8.2.2 “Exploitation Plan v2.0”

[5] BESOS Consortium, D1.1 “Requirements and Use Case Specification”

[6] BESOS Consortium, D1.2 “BESOS Business Models”

[7] BESOS Consortium, D5.1.1 “DSS cockpit and Business Balanced Score Card v1”

[8] BESOS Consortium, D5.1.2 “DSS cockpit and Business Balanced Score Card v2”

[9] BESOS Consortium, T7.1 “Evaluation Framework” Internal Report

5.2 Acronyms

Acronyms List	
EMS	Energy Management System
OTESP	Open Trustworthy Energy Service Platform
SWOT	Strengths, Weaknesses, Opportunities, Threats
DSS	Decision Support System
BBSC	Business Balanced Scorecard
NPV	Net Present Value
CBA	Cost-Benefit Analysis
IRR	Internal Rate of Return
PBP	Pay Back Period
CEA	Cost-Effectiveness Analysis
ToU	Time of Use
QALY	Quality-Adjusted Life Years
BMA	Behavioral Mobile App
CIM	Common Information Model
BCN	Barcelona
KPI	Key Performance Indicator
VA	Visual Analytics
CEP	Complex Event Processing
OMC	Operation & maintenance cost
FM	Facility Manager
ESCO	Energy Service Company
IoT	Internet of Things
ICT	Information and Communications Technology
UCD	User Centric Design
RWD	Responsive Web Design
RES	Renewable Energy Sources

6 ANNEX B: BESOS License Cost

The goal of this section is to provide an abstract estimation of BESOS license cost, taking into account the perspective from the different end users of the system. The analysis is performed for both pilot sites examined in the project considering:

- A license for an ESCO company, responsible for the management of the different asset types. Therefore the simplest case is considered for exploiting the business applications developed in the project, namely BESOS VA, BESOS Cockpits and the forecasting engine.
- A low cost cloud hosting infrastructure for the deployment of BESOS application. The hardware capabilities of the cloud engine are calculated taking into account the technical evaluation of OTESP platform in previous section.
- The cost of adaptation of 3rd party EMSs in BESOS platform. This analysis is performed per pilot site, directly affecting the investment costs for the deployment of BESOS framework.
- As an initial cost, we are considering the cost for deployment of OTESP platform and part of the cost for adaptation of 3rd party software components.

A detailed cost analysis for EMSs adaptation is provided per pilot site:

- For Lisbon Pilot Site, the testbed for evaluation includes:
    - Public Buildings: Olivais & DRFM & LMIT buildings taking into account data about maximum power consumption *(two 3rd party services for software adaptation)*
    - EV fleet: A total number of 25 EVs is selected for simulation, by extrapolating the data from available EVs *(1 service)*
    - PLS portfolio, considering simulated data as coming from BCN municipality pilot site (as we are not retrieving energy data from Lisbon PLS pilot site) *(1 service)*
    - TLS assets: considering energy consumption and traffic density simulation data from PT traffic lighting system (a total number of 5 traffic lighting points is considered for the evaluation process) *(1 service)*
    - RES integration, considering integration of Olivais PV (3 x) and Montegordo (0.1 x) wind park in order to examine an integrated case scenario. *(2 service)*

  While there is no need for hardware adaptation, we are considering only costs for 3rd party software adaptation.

License Category	Units	Cost/Unit/year	Cost
BESOS VA	**1**	1250	1250
BESOS BSC	**1**	2500	2000
BESOS DSSC	**1**	3000	2500
Forecasting Engine	**1**	1150	1150
Cloud Hosting Infrastructure	**12**	320	3840
Software EMS Adaptation (3rd party licensing)	**7 different asset types**	500	3500

The costs allocated are annual costs for services offered by the technical partners of the consortium taking into account the individual exploitation plans reported in this document. As mentioned above, we are allocating as initial investment costs, the cost of Cloud Hosting Infrastructure and the cost for Software EMS Adaptation for the 1st annual period.

The same analysis is performed for BCN pilot site

- We are examining two types of assets integration in the project:

- Hardware EMS adaptation (SODEXO buildings and Ficosa wind & PV integration) where a mini PC is installed in premises with the associated software to interface the BMS systems available in premises
- Software EMS Adaptation for the rest of assets integrated. In this case scenario, an EMS is already installed providing data to a web application, and thus we are considering the license cost for interfacing and gathering these data. More than 150 assets are integrated in BCN pilot site though we proceed with an average cost estimation per cloud vendor
  - Public Buildings Adaptation (8 buildings integrated)
  - Electric Vehicles Management Centre
  - Public Lighting Management Centre
  - Traffic Lighting Management Centre considering also data coming from the traffic sensors installed
  - RES Generation Management Centre (1 COBRA wind park and multiple roof PVs)

Therefore, the total annual cost for BESOS platform operation is calculated:

License Category	Units	Cost/Unit/year	Cost
BESOS VA	**1**	1250	1250
BESOS BSC	**1**	3750	3750
BESOS DSSC	**1**	4500	4500
Forecasting Engine	**1**	1550	1050
Cloud Hosting Infrastructure	**12**	400	4800
Hardware EMS Adaptation	**10**	350	3500
Software EMS Adaptation (3rd party licensing)	**7**	500	3500

The initial costs, for the 1st year of evaluation are the costs for Cloud Hosting Infrastructure & Hardware EMS Adaptation & Software EMS Adaptation

It is clear that the viability of BESOS platform is dependent on the types of hardware/software adaptations. The cost of hardware adaptation is higher and thus considered as the main boundary for mass deployment of BESOS solution.

Along with the detailed analysis of the investment costs for BESOS platform deployment, we are reporting here the benefits from BESOS platform deployment in both pilot sites. Therefore, we are considering the results of impact assessment analysis performed in D7.2.

Lisbon Pilot Site

Following average week calculation and further extrapolation in an annual period.

	Week 1	Week 2	Week 3	Week 4	Week 5	Average	Average Annual
Total Load							
Consumption (KWh)	6029.227	4978.774	5304.404	5396.166	4993.468	5340.407585	277701.1944
Cost (euro)	1032.807	852.8639	908.6444	924.3632	855.381	914.8118193	**47570.2146**
CO2 Emissions(gr)	1688.755	1391.802	1481.612	1509.632	1395.475	1493.455117	77659.6661
Holistic Management Scenario							
Consumption (KWh)	4798.882	3554.418	4082.79	4110.477	3811.763	4071.665975	211726.6307
Cost (euro)	709.2684	493.238	562.9605	584.2535	524.865	574.917082	**29895.68827**
CO2 Emissions (gr)	1344.111	991.7359	1139.92	1148.217	1063.657	1137.528141	59151.46333

Cost Reduction	**17674.53**

Barcelona Pilot Site

The same analysis is performed for BCN smart city scenario, through average week energy cost reduction calculation and further extrapolation in an annual period.

	Week 1	Week 2	Week 3	Week 4	Week 5	Average	Average Annual
Total Load							
Consumption (KWh)	16169	18763	16545	18383	20781	18128.2	942666.4
Cost (euro)	1778.567	2063.907	1819.966	2022.131	2285.922	1994.0986	103693.1272
CO2 Emissions(gr)	3066.305	3580.039	3124.869	3512.589	3967.837	3450.3278	179417.0456
Holistic Management Scenario							
Consumption (KWh)	10652	15341	13257	15025.3	16204.4	14095.94	732988.88
Cost (euro)	1047.131	1610.287	1349.404	1616.414	1707.234	1466.094	76236.888
CO2 Emissions (gr)	2099.455	3003.211	2576.574	2906.152	3143.024	2745.6832	142775.5264

Cost Reduction	**27456.24**