Title:	Document Version:
D7.2 BESOS Evaluation and Assessment	1.0

Project Number:	Project Acronym:	Project Title:
FP7-SMARTCITIES-2013	BESOS	Building Energy Decision Support for Smart cities

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

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

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

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Abstract:

This document provides BESOS project Evaluation Analysis. This version focus on the impact assessment analysis of the project along with the evaluation of user experience as considered through the demonstration period of BESOS project.

Keywords:

BESOS Evaluation framework, Evaluation criteria, Performance Indicators, User Experience Evaluation

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Executive Summary

Since BESOS is a demonstration project, the rigorous measurement and evaluation of the energy and emissions savings achieved by the technologies developed in the project will be crucial to maximize their impact and wide scale market adoption.

This deliverable presents the report on the evaluation of pilot results and user experience for BESOS Project. The overall evaluation of the BESOS framework was performed based on the results obtained during the realisation of pilot use cases according to the pilot evaluation framework and business scenarios which were defined in deliverable D7.1.

Initially, the improvements brought by components of the BESOS framework are evaluated in terms of implementation, measurable results (based on actual pilot data) and progress beyond the state-of-the-art. An overview of the results from the evaluation of BESOS framework (based on data obtained during pilot realisation) is presented concerning the compliance against defined project objectives as well as the results from the defined evaluation tests per evaluation scenario.

Towards the actual involvement of BESOS stakeholders in the evaluation process, various dedicated pilot and end-user preparation activities were also performed, so that users' feedback would be on time, reliable and easy to analyse. In particular, among others specific workshops were organised in order to reach stakeholders, present BESOS project achievements and results, and gather feedback both through open discussions and delivered questionnaires. User Experience evaluation was conducted at the end of the pilot realisation phase for all types of end users (i.e. Citizens, Facility Managers & ESCOs, and Public Authorities) based on the corresponding evaluation framework.

To this end, the project has developed a specific evaluation methodology based on recognized best practices and standards. The different evaluation activities are further combined with key criteria and indicators associated with the context of operations to define the holistic evaluation process. All these aspects have been clearly defined at the evaluation plan in order to provide a concrete framework for BESOS platform evaluation.

1 Introduction

1.1 Purpose and Scope of the Document

This document reports the evaluation of BESOS project, considering user experience evaluation (ESCOs, Facility Managers and DSOs), evaluation of improvements brought by individual components of BESOS with regards to energy savings and energy efficiency and overall improvements offered by the BESOS platform as a Service at the examined business cases.

Qualitative and quantitative analysis is performed, in order to extract useful results about the performance of the system, not only on efficiency but also on reliability, robustness, cost-effectiveness and user acceptance. Along with questionnaires prepared as part of the evaluation plan, data collected during pilots' demonstration allow for a direct comparison between end users requirements and project R&D results. The evaluation analysis is performed following the definition of a baseline scenario and by using statistical methods and tools to provide a credible, clear picture on user acceptance, efficiency and reliability. Therefore, the role of this document is twofold:

- To provide the impact assessment analysis of BESOS components as part of BESOS platform
- To proceed with user acceptance analysis, considering direct feedback from the stakeholders that tested the different BESOS applications during the evaluation period.

The evaluation process will also include the technical and business evaluation of the project results in terms of cost-benefit and cost-effectiveness, within the framework of the business models defined at the initial stage. The technical dissemination and business evaluation, though part of the overall BESOS evaluation framework, is reported in D7.3 "Technical Dissemination and Exploitation".

1.2 Relation to other Deliverables

The evaluation and assessment of BESOS platform, following the initial evaluation plan, is provided in alignment with business scenarios, use cases and performance indicators of the project towards the evaluation of the different Business Models examined in BESOS project. Thus, the evaluation process is tightly connected with the work of T1.2 "Use-Case Identification and Selection" and T1.3 "New business Models to affect BESOS Architecture: SLAs vs. KPIs" (Deliverables: D1.1 Requirements and Use Case Specification ([1]), D1.2 BESOS Business Models ([2]), D1.3 Key Performance Indicators ([3])). The different business cases, business models and KPIs will set the skeleton for the evaluation of BESOS platform.

In addition, data collected during WP6 activities (BESOS demonstration framework) will set the input parameters for qualitative and quantitative analysis to be performed during the assessment of the project, in order to evaluate the performance of the system, not only on efficiency but also on reliability, robustness, cost-effectiveness and user acceptance. WP6 main objective is to validate and further demonstrate the different systems developed in previous WPs of BESOS and thus the system functionalities will be evaluated according to the data gathered by a prolong period of testing.

The evaluation framework, defined as an initial work (T7.1), set the objectives for the actual evaluation of BESOS platform, considering also user experience and evaluation of improvements brought by BESOS individual components. Furthermore, the evaluation analysis performed in BESOS is based on the ex-ante analysis delivered for the demonstration sites of Barcelona and Lisbon City. More specifically, the evaluation assessment approach is delivered in line with the **baseline evaluation** of pilot cases of BESOS project (T7.2 - Ex-ante analysis) to "screen the landscape" before the deployment of the actual pilot activities of the project and thus allowing for 1) the definition of a point of reference for the conduction of the project assessment and 2) the extraction of valuable contextual and business-oriented information to be used as input during the exploitation and business planning of BESOS. Therefore, **demonstration business cases** along with **simulation tests** are defined in D7.1 ([4]), setting the baseline for the real evaluation and validation of BESOS framework. On the other hand, and as the evaluation analysis will also define the exploitable assets of the project, this deliverable is tightly connected to D7.3 about the Technical Dissemination and Exploitation of BESOS main results ([5]). D7.2 and 7.3 are combined to set the evaluation analysis of BESOS platform.

1.3 BESOS Evaluation and Assessment - Document Structure

The BESOS Evaluation and Assessment document is organised in the following sections. This chapter introduces the main aspects and the structure of the document. Then, the structure of the document is:

- Chapter 2 provides the **outcomes** from pilot sites analysis and the definition of the time plan for evaluation process. We are highlighting the two rounds of trials considered for BESOS demonstration and evaluation. Therefore, this work is in line with the demonstration process performed in WP6.
- In Chapter 3 the **impact assessment analysis for the 1st evaluation period** is provided, taking into account input data, methodology and final impact. The analysis is in line with the evaluation plan as defined in Task 7.1.
- Following 1st evaluation period, in Chapter 4 we report the results from the **2nd evaluation period**, along with the comparative analysis among these two testing periods.
- Chapter 5 provides **end users evaluation of system applications.** The analysis is based on questionnaires review after pilot demonstration period. Different types of questionnaires have been conducted for the business stakeholders of BESOS project: Authorities, ESCOs/ Facility Managers and Citizens.
- Finally, Chapter 6 reports the conclusions of the evaluation assessment along with next steps needed for further exploitation of project outcomes.

We have to point out that the evaluation framework covers parts related to the technical evaluation of system components along with the definition of the business framework for BESOS platform. Though, we have decided to split the work about evaluation, reporting these parts of the work in Deliverable D7.3 “Technical Dissemination and Exploitation”.

2 Pilot Premises Demonstration Analysis

2.1 Introduction

The goal of this section is to summarize the results from demonstration of BESOS platform in pilot premises. Thus, this section is a summary of WP6 activities with special focus on the presentation of parameters, directly related to the evaluation process. Therefore the analysis is in line with the evaluation plan and the ex-ante review (BaU scenario). In addition, a review of BESOS installations in pilot premises is provided.

2.2 BESOS demonstration in Pilot Premises

The goal of this section is to summarize the demonstration scenarios at the pilot sites of BESOS project. The analysis is provided per pilot site, further presenting the scenarios tested during the 1st and 2nd iteration phase.

Lisbon City Demonstration

Different type of assets have been selected to set the pilot site of Lisbon city, addressing the goal of the project for integration of heterogeneous types of devices. The detailed analysis and integration methodology is presented in WP4, thus a summary is reported here towards the definition of evaluation framework. The next Table summarizes the list of assets from Lisbon site during 1st and 2nd iteration phase.

City	Partner	EMS Type	Source
1st adaptation period			
Lisbon	LISBOA E-Nova	Public building system	Campo Grande Municipal building data consumption
Lisbon	LISBOA E-Nova	Public building system	DIEM/DRMM Municipal Building
Lisbon	LISBOA E-Nova	Public building system	Olivais school consumption
Lisbon	LISBOA E-Nova	Energy generation system	Olivais school PV production
Lisbon	LISBOA E-Nova	Energy generation system	University Lisbon PV park
Lisbon	COBRA	Energy generation system	WF Montegordo
2nd adaptation period			
Lisbon	LISBOA E-Nova	Public building system	Municipality Social Services' Building
Lisbon	LISBOA E-Nova	Electric Vehicles	15 charging points
Lisbon	LISBOA E-Nova	Public Lighting	Light flux control and monitoring
Lisbon	LISBOA E-Nova	Traffic Lighting	Light flux energy consumption monitoring

Table 1 Lisbon city EMS adaptation

Barcelona City Demonstration

The same analysis is provided for Barcelona pilot site in the following Table.

City	Partner	EMS Type	Source
1st adaptation period			
Barcelona	ETRA	Energy generation system	Ficosa Renewables Plants site
Barcelona	ETRA/COBRA	Energy generation system	Cobra CECOVI Centre
Barcelona	ETRA/BCN	Public building system	Public buildings in Barcelona (8 building blocks)
Barcelona	ETRA/SODEXO	Public building system	Public buildings in Barcelona (8 building blocks)
Barcelona	ETRA/BCN	Public lighting system	Number of segment controllers (#4)
Barcelona	ETRA	Electric Vehicles	150 Charging points in Barcelona
2nd adaptation period			
Barcelona	ETRA/BCN	Traffic lighting system	491 Traffic Lighting Points
Barcelona	ETRA/SODEXO	Energy generation system	Energy generation system at Public buildings in Barcelona
Barcelona	ETRA/SODEXO	Public building system	Public buildings in Barcelona (updates on buildings integrated)
Barcelona	ETRA/BCN	Public lighting system	Number of segment controllers (#15)

Table 2 Barcelona city EMS adaptation

In order to proceed with the evaluation of BESOS platform in pilot sites, we need to define the Baseline (BaU) for further comparing the impact of BESOS platform. The baseline definition has been defined during the ex-ante evaluation and the same approach is considered also for the actual evaluation of BESOS tools. More specifically, we have defined two intertwined evaluation periods, based on demonstration of BESOS platform in pilot cities. The results from this analysis are summarized in the following sections.

2.3 1st Demonstration Period - Data Summary

The 1st demonstration period (June 2015 - January 2016) is focusing mainly on integration of EMS systems in BESOS platform, and a limited number of BESOS use cases was evaluated during this period. The evaluation phase started in October 2015 with a limited number of assets integrated in the platform, reliably reporting energy and contextual data.

The goal of this section is to provide a review of the data collected during 1st demonstration period. Again, the analysis is performed per pilot site, focusing on scenarios tested during the 1st evaluation period.

Lisbon City - Data Summary

The next figure presents the detailed evaluation plan for the 1st evaluation period of the project, specifying the EMSs and use cases evaluated. The evaluation plan is in line with the demonstration activities during the 1st reporting period as presented also in D6.1.

Use Case	Pilot	05-Oct	12-Oct	19-Oct	26-Oct	02-Nov	09-Nov	16-Nov	23-Nov	30-Nov	07-Dec	14-Dec	21-Dec	28-Dec	04-Jan	11-Jan	18-Jan	25-Jan
UC1 - Visualization and Monitoring of energy data	**Pilot**																	
Public building system	Campo Grande Building																	
Public building system	DRMM Building																	
Energy generation system	University PV Park																	
Energy generation system	W.F. Montegordo																	
Public building system & Energy generation system	Olivais school																	
UC2 - Data analytics on historical information of Prosumer Flexibility	**Pilot**																	
Public building system	Campo Grande Building																	
Public building system	DRMM Building																	
Energy generation system	University PV Park																	
Energy generation system	W.F. Montegordo																	
Public building system & Energy generation system	Olivais School																	
UC7 - Energy demand monitoring and optimization in public buildings	**Pilot**																	

Use Case	Pilot	05-Oct	12-Oct	19-Oct	26-Oct	02-Nov	09-Nov	16-Nov	23-Nov	30-Nov	07-Dec	14-Dec	21-Dec	28-Dec	04-Jan	11-Jan	18-Jan	25-Jan
Public building system	Campo Grande Building																	
Public building system	DRMM Building																	
Public building system & Energy generation system	Olivais school																	
UC8 - Smart city Energy demand curve optimization	**Pilot**																	
Public building system	Campo Grande Building																	
Public building system	DRMM Building																	
Energy generation system	W.F. Montegordo																	
Energy generation system	University PV Park																	
Public building system & Energy generation system	Olivais school																	
UC12 - Measurement of the renewable energy produced and predicted in the distribution network	**Pilot**																	
Energy generation system	University PV Park																	
Energy generation system	W.F. Montegordo																	

Use Case	Pilot	05-Oct	12-Oct	19-Oct	26-Oct	02-Nov	09-Nov	16-Nov	23-Nov	30-Nov	07-Dec	14-Dec	21-Dec	28-Dec	04-Jan	11-Jan	18-Jan	25-Jan
Energy generation system	Olivais School																	
UC13 - Predict the energy consumption on weather data	**Pilot**																	
Public building system	Campo Grande Building																	
Public building system	DRMM Building																	
Public building system	Olivais School																	
UC14 - Measurement / control of the electric energy quality	**Pilot**																	
Public building system	Campo Grande Building																	
Public building system	DRMM Building																	
Public building system & Energy generation system	Olivais school																	

Table 3 Lisbon City Evaluation Time plan- 1st phase

As mentioned above, the focus of the 1st evaluation period is on testing and evaluating scenarios related to **monitoring capabilities** of integrated assets. The control functionality, which is one of the main objectives of BESOS project, will be evaluated during the 2nd evaluation period along with the integration of the full list of assets. The following metrics are retrieved from Lisbon City assets to support the evaluation process for the reporting period.

ID	Metrics	System Component				
		EV	RES	PLS	Buildings	Forecast
1	Public/ Facility Consumption				x	
2	RES Energy Production		x			
3	Active Power {Max-Min} setting the potential generation limits of the Asset		x			
4	Electricity Prices & Cost of Energy				x	
5	CO2 emissions				x	
6	Weather Conditions (Temperature)		x		x	
7	Forecast for energy to be produced					x
8	Usage of each entity		x		x	
9	Power Factor				x	

Table 4 Lisbon city Evaluation metrics - 1st phase

This is the list of metrics required in order to perform the evaluation during the 1st reporting period. These metrics are further associated to the evaluation criteria and evaluation indicators that consist of the BESOS evaluation framework.

Barcelona City Demonstration - Data Summary

The same analysis is followed for Barcelona Pilot Site. The detailed evaluation timeplan for 1st iteration period is presented, along with the detailed report for the metrics captured during the evaluation period. By extending the list of assets integrated in Lisbon pilot site, we are considering also public lighting assets in Barcelona testbed. We have to point out that Electric Vehicles are also integrated at the 1st reporting period, though the evaluation of this asset type will be performed during the 2nd iteration period (to address also control functionalities). The next table presents the 1st evaluation period time plan for Barcelona test site.

Use Case	Pilot	05-Oct	12-Oct	19-Oct	26-Oct	02-Nov	09-Nov	16-Nov	23-Nov	30-Nov	07-Dec	14-Dec	21-Dec	28-Dec	04-Jan	11-Jan	18-Jan	25-Jan
UC1 - Visualization and Monitoring of energy data	**Pilot**																	
Public building system	BCN																	
Public building system	SDX																	
Energy generation system	W.F. VIUDO																	
Energy generation system	Sant Guim																	
Electric Vehicles	BCN																	
Public lighting system	BCN																	
UC2 - Data analytics on historical information of Prosumer Flexibility	**Pilot**																	
Public building system	BCN																	
Public building system	SDX																	
Energy generation system	W.F. VIUDO																	
Energy generation system	Sant Guim																	
Electric Vehicles	BCN																	
Public lighting system	BCN																	
UC3 - Energy demand optimization of the public lighting based on light environment	**Pilot**																	
Public lighting system	BCN																	
UC7 - Energy demand monitoring and optimization in public buildings	**Pilot**																	
Public building system	BCN																	
Public building system	SDX																	
UC8 - Smart city Energy demand curve optimization																		

Use Case	Pilot	05-Oct	12-Oct	19-Oct	26-Oct	02-Nov	09-Nov	16-Nov	23-Nov	30-Nov	07-Dec	14-Dec	21-Dec	28-Dec	04-Jan	11-Jan	18-Jan	25-Jan
Public building system	BCN																	
Public building system	SDX																	
Electric Vehicles	BCN																	
Public lighting system	BCN																	
UC12 - Measurement of the renewable energy produced and predicted in the distribution network	Pilot																	
Energy generation system	W.F. VIUDO																	
Energy generation system	Sant Guim																	
UC13 - Predict the energy consumption on weather data	Pilot																	
Public building system	BCN																	
Public building system	SDX																	
UC14 - Measurement / control of the electric energy quality (in the distribution network)	Pilot																	
Public building system	BCN																	

Table 5 Barcelona city Evaluation Time plan- 1st phase

The data captured during demonstration period and considered for the evaluation processes are further presented. The main differentiation from Lisbon Pilot site is the integration of PLS and EV assets at the reporting period, enabling the evaluation of the associated use cases and business models.

ID	Metrics	System Component				
		EV	RES	PLS	Buildings	Forecast
1	Public/ Facility Consumption				x	
2	RES Energy Production		x			
3	Active Power {Max-Min} setting the potential generation limits of the Asset		x			
4	EVs Energy consumption	x				
5	PLS Energy consumption			x		
6	Electricity Prices/ Cost of Energy	x	x	x	x	
7	CO2 emissions	x	x	x	x	
8	Weather Conditions (Temperature)	x	x	x	x	x
9	Forecast for energy to be produced					x
10	Usage of each entity	x	x	x	x	
11	Power Factor				x	
12	Control Commands to PLS			x		
13	Control Commands to Facility Premises				x	

Table 6 Barcelona city Evaluation metrics - 1st phase

The same analysis is performed for the 2nd evaluation period of the project, to ensure that all metrics needed for the evaluation process are captured from the different EMS integrated.

2.4 2nd Demonstration Period- Data Summary

The goal of this section is to provide an update on data types collected during 2nd demonstration period of BESOS. The focus is on the presentation of metrics directly related to the evaluation process. Once again, the analysis is provided per pilot site, focusing on the scenarios tested during the 2nd evaluation period.

Lisbon City - Data Summary

The detailed time plan for the evaluation activities during the 2nd reporting period is presented:

		06-Jun	13-Jun	20-Jun	27-Jun	04-Jul	11-Jul	18-Jul	25-Jul	01-Aug	08-Aug	15-Aug	22-Aug	29-Aug	05-Sep	12-Sep	19-Sep	26-Sep
UC1 - Visualization and Monitoring of energy data	**Pilot**																	
Public building system	Societal Building																	
Public building system	ISA																	
Energy generation system	University PV Park																	
Energy generation system	W.F. Montegordo																	
Electric Vehicles	Lisbon																	
Public lighting system	Lisbon																	
UC2 - Data analytics on historical information of Prosumer Flexibility	**Pilot**																	
Public building system	Societal Building																	
Public building system	ISA																	
Energy generation system	University PV Park																	
Energy generation system	W.F. Montegordo																	
Electric Vehicles	Lisbon																	
Public lighting system	Lisbon																	
UC3 - Energy demand optimization of the public lighting based on light environment	**Pilot**																	
Public lighting system	Lisbon																	
UC4 - Energy management for the use of electric vehicle fleet	**Pilot**																	
Public building system	Lisbon																	
Electric Vehicles	Lisbon																	

UC5 - Electrical Vehicles (EV) local optimization and storage capacity forecasting	**Pilot**
Electric Vehicles	Lisbon
UC6 - Energy demand curve optimization based on traffic conditions	**Pilot**
Traffic lighting system	Lisbon
UC7 - Energy demand monitoring and optimization in public buildings	**Pilot**
Public building system	Societal Building
Public building system	ISA
UC8 - Smart city Energy demand curve optimization	**Pilot**
Public building system	Societal Building
Public building system	ISA
Energy generation system	University PV Park
Energy generation system	W.F. Montegordo
Electric Vehicles	Lisbon
Public lighting system	Lisbon
UC9 - Optimal Alignment of KPIs with SLAs	**Pilot**
Public building system	Societal Building
Public building system	ISA
Energy generation system	University PV Park
Energy generation system	W.F. Montegordo
Electric Vehicles	Lisbon
Public lighting system	Lisbon

UC10 - Service platform for Public Authorities and ESCO's to access to public tenders information	**Pilot**																	
Public building system	Societal Building																	
Public building system	ISA																	
Energy generation system	University PV Park																	
Energy generation system	W.F. Montegordo																	
Electric Vehicles	Lisbon																	
Public lighting system	Lisbon																	
UC12 - Measurement of the renewable energy produced and predicted in the distribution network	**Pilot**																	
Energy generation system	University PV Park																	
Energy generation system	W.F. Montegordo																	
UC13 - Predict the energy consumption on weather data	**Pilot**																	
Public building system	Societal Building																	
Public building system	ISA																	
UC14 - Measurement / control of the electric energy quality (in the distribution network)	**Pilot**																	
Public building system	ISA																	
UC15 - Preventive Maintenance Alarm	**Pilot**																	
Public building system	Societal Building																	
Public building system	ISA																	

Table 7 Lisbon City Evaluation Timeplan- 2nd phase

The focus during the 2nd evaluation period, is on testing and evaluating scenarios related to the **control capabilities** of integrated assets taking into account the integration of BESOS DSS. Due to this enhanced functionality of BESOS system, two operational modes (optimization processes) are defined (green: Cost efficient operation, yellow: Maximum RES exploitation). The metrics retrieved from Lisbon EMS Assets to support the evaluation process during the reporting period are presented:

ID	Metrics	System Component				
		EV	RES	PLS	Buildings	Forecast
1	Public/ Facility Consumption				x	
2	RES Energy Production		x			
3	Active Power {Max-Min} setting the potential generation limits of the Asset		x			
4	EVs Energy consumption	x				
5	PLS Energy consumption			x		
6	Electricity Prices/ Cost of Energy	x	x	x	x	
7	CO2 emissions	x	x	x	x	
8	Weather Conditions (Temperature)	x	x	x	x	x
9	Forecast for energy to be consumed					x
10	Forecast for energy to be produced					x
11	Usage of each entity	x	x	x	x	
12	Traffic Density (for TLS management)			x		
13	Power Factor				x	
14	Control Commands to PLS			x		
15	Control Commands to Facility Premises				x	
16	Control Commands to EV	x				
17	Estimation of the load reduction	x	x	x	x	

Table 8 Lisbon city Evaluation metrics – 2nd phase

We have to point out that for the reporting period, the main additions are the integration of EVs and PLS/TLS assets to enhance demonstration and evaluation activities. This integration further enables us to test control functionalities over these assets, towards the evaluation of the full list of use cases and business models examined in the project.

Barcelona City Demonstration - Data Summary

The same approach is followed for Barcelona pilot site. During the 2nd evaluation period, the integration of PLS system was performed (Traffic Light Systems) and along with the controllability on assets, we extended the list of use cases tested during this 2nd phase. The detailed time plan for the implementation of 2nd round evaluation activities is presented:

		06-Jun	13-Jun	20-Jun	27-Jun	04-Jul	11-Jul	18-Jul	25-Jul	01-Aug	08-Aug	15-Aug	22-Aug	29-Aug	05-Sep	12-Sep	19-Sep	26-Sep
UC1 - Visualization and Monitoring of energy data	Pilot																	
Public building system	Barcelona buildings																	
Public building system	Sodexo buildings																	
Energy generation system	W.F. VIUDO I																	
Energy generation system	Sant Guim Power Plant																	
Electric Vehicles	Barcelona																	
Public lighting system	Barcelona																	
UC2 - Data analytics on historical information of Prosumer Flexibility	Pilot																	
Public building system	Barcelona buildings																	
Public building system	Sodexo buildings																	
Energy generation system	W.F. VIUDO I																	
Energy generation system	Sant Guim Power Plant																	
Electric Vehicles	Barcelona																	
Public lighting system	Barcelona																	
UC3 - Energy demand optimization of the public lighting based on light environment	Pilot																	
Public lighting system	Barcelona																	
UC4 - Energy management for the use of electric vehicle fleet	Pilot																	
Public building system	Barcelona buildings																	
Electric Vehicles	Barcelona																	

UC5 - Electrical Vehicles (EV) local optimization and storage capacity forecasting	**Pilot**																	
Electric Vehicles	Barcelona																	
UC6 - Energy demand curve optimization based on traffic conditions	**Pilot**																	
Traffic lighting system	Barcelona																	
UC7 - Energy demand monitoring and optimization in public buildings	**Pilot**																	
Public building system	Barcelona buildings																	
Public building system	Sodexo buildings																	
UC8 - Smart city Energy demand curve optimization	**Pilot**																	
Public building system	Barcelona buildings																	
Public building system	Sodexo buildings																	
Energy generation system	W.F. VIUDO I																	
Energy generation system	Sant Guim Power Plant																	
Electric Vehicles	Barcelona																	
Public&Traffic lighting system	Barcelona																	
UC9 - Optimal Alignment of KPIs with SLAs	**Pilot**																	
Public building system	Barcelona buildings																	
Public building system	Sodexo buildings																	
Energy generation system	W.F. VIUDO I																	
Energy generation system	Sant Guim Power Plant																	
Electric Vehicles	Barcelona																	
Public lighting system	Barcelona																	

UC10 - Service platform for Public Authorities and ESCO's to access to public tenders information	**Pilot**
Public building system	Barcelona buildings
Public building system	Sodexo buildings
Energy generation system	W.F. VIUDO I
Energy generation system	Sant Guim Power Plant
Electric Vehicles	Barcelona
Public lighting system	Barcelona
UC12 - Measurement of the renewable energy produced and predicted in the distribution network	**Pilot**
Energy generation system	W.F. VIUDO I
Energy generation system	Sant Guim Power Plant
UC13 - Predict the energy consumption on weather data	**Pilot**
Public building system	Barcelona buildings
Public building system	Sodexo buildings
UC14 - Measurement / control of the electric energy quality (in the distribution network)	**Pilot**
Public building system	Barcelona buildings
UC15 - Preventive Maintenance Alarm	**Pilot**
Public building system	Barcelona buildings

Table 9 Barcelona City Evaluation Time-plan- 2nd phase

For Barcelona pilot site, two operational models are defined (cost efficient operation and max RES exploitation operation), setting the framework for the implementation of the evaluation tests. The list of metrics considered for the evaluation process during the reporting period are presented:

ID	Metrics	System Component				
		EV	RES	PLS	Buildings	Forecast
1	Public/ Facility Consumption				x	
2	RES Energy Production		x			
3	Active Power {Max-Min} setting the potential generation limits of the Asset		x			
4	EVs Energy consumption	x				
5	PLS Energy consumption			x		
6	Electricity Prices/ Cost of Energy	x	x	x	x	
7	CO2 emissions	x	x	x	x	
8	Weather Conditions (Temperature)	x	x	x	x	x
9	Forecast for energy to be consumed					x
10	Forecast for energy to be produced					x
11	Usage of each entity	x	x	x	x	
12	Traffic Density (for PLS management)			x		
13	Power Factor				x	
14	Control Commands to PLS			x		
15	Control Commands to Facility Premises				x	
16	Control Commands to EV	x				
17	Estimation of the load reduction	x	x	x	x	

Table 10 Barcelona city Evaluation metrics – 2nd phase

As mentioned above, we are focusing on the integration of controllable assets, highlighting that way the DSS functionality of BESOS platform. More specifically, the role of EVs and PLS systems is extensively presented during this period, covering that way the list of use cases and business models defined in BESOS project.

The goal of this chapter was to provide a summary of demonstration activities, as documented in WP6, focusing on the evaluation analysis. More specifically, by taking into account the evaluation plan and the ex-ante analysis, we documented the different demonstration tests and the associated metrics for the evaluation analysis. The results from the evaluation processes performed in these two periods are reported in the following sections.

3 BESOS Impact Assessment Analysis - 1st phase

Following the summary of demonstration activities, the focus is on the evaluation of the impact that BESOS platform brings at pilot sites. The next sections provide the results from impact assessment analysis, addressing the evaluation criteria defined at the initial evaluation plan and ex-ante analysis of the project.

3.1 Evaluation Indicators Taxonomy

The indicators for impact assessment of BESOS project were defined in BESOS evaluation plan. This initial evaluation plan is slightly modified to address the actual demonstration activities performed in pilot premises. The high level taxonomy of indicators considered for impact assessment analysis (based on data captured from pilot sites) is provided:

- **KPIs about Energy Savings**, i.e., reduction of energy consumption. This is a group of indicators associated with the different types of assets examined in the project (Public Buildings, residential buildings, Electric Vehicles, Public Lighting). The evaluation scenarios associated with this indicator are:
    - Increase in Building Efficiency (IBE)
    - Energy Efficiency in Neighbourhood Level (EEN)
    - Increase of Public lighting efficiency (IPLS)
    - Efficient EV Management Fleet (EEVM)
    - EVs hosting capacity (EVHC)

- **KPIs about CO2 Emissions reduction** (percentage). This is again a group of indicators calculated for the different asset types examined in the project. CO2 emissions are not measurable at local level. The reference point was calculated by taking the average energy mix for Spain and Portugal respectively. The evaluation scenarios associated with this indicator are:
    - CO2 reduction of the system (CORS)
    - CO2 reduction via EV management (COREV) ON EVs.
    - CO2 reduction through EV penetration
    - CO2 reduction due to optimal RES exploitation

- **KPIs about Energy Cost Reduction** (percentage). This indicator will determine the financial benefit for the users. This is the actual amount paid by the users before and during BESOS demonstration. The difference is due to the reduction of total consumption or due to shifting consumption at low price hours. This is a core parameter for BESOS project, as the financial viability of the proposed framework is a main requirement expressed by the system stakeholders. The associated evaluation scenarios, part of the BESOS evaluation framework, are:
    - Cost reduction (CR)
    - Peak Demand Reduction (PDR)

- **EMS Specific Operational management,** focusing on the prompt operation of the portfolio. Different evaluation criteria and indicators are considered for this case:
    - Efficient Monitoring of the Facility
    - Electrical Power Quality Factor for public buildings
    - Forecasting Performance (FOPE) for generation and building assets
    - Predictive Maintenance Accuracy Index for building assets
    - Increase RES generation utilization (IRU) for generation assets

We are providing this high level taxonomy of evaluation indicators considering the evaluation scenarios examined in the project. The results from the 1st evaluation phase are presented for each pilot site of BESOS project starting from Lisbon test site.

3.2 Lisbon Pilot Site Evaluation

Prior to impact assessment analysis, the **Efficient Monitoring of the Facility** is evaluated to ensure the reliable operation of portfolio assets. The analysis is performed for the full list of integrated assets during the reporting period and the results are presented in the next tables:

Asset ID	Energy Consumption	Energy Cost	CO2 Emissions	Power Factor
Olivais School	95.75%	96.21%	96.21%	96.17%
DRFM	94.82%	94.84%	94.84%	94.94%
Campo Grande	87.13%	87.15%	87.15%	87.85%

Table 11 Reliable Monitoring of Consumption Assets

Asset ID	Energy Generation	Forecast
TU Lisbon	95.18%	88.71%
Montegordo	89.84%	99.64%
Olivais	96.18%	-

Table 12 Reliable Monitoring of Generation Assets

The continuous and reliable monitoring of integrated assets is one of the main requirements of the projects. The integration of different types of assets with different characteristics is a heavy task and thus continuous monitoring of assets health is one of the main processes of the project. In the above tables, we presented the status per asset and metric addressed for the evaluation. A total average of **94.03%** level of reliability for data is reported. The main problem is issued for Campo Grande Building where communication issues arose during the evaluation period, blocking the uninterrupted transmission of data to BESOS platform.

The next figures depict the reliability indicator for the selected assets, showing the flow of data within a 24-hour time period.

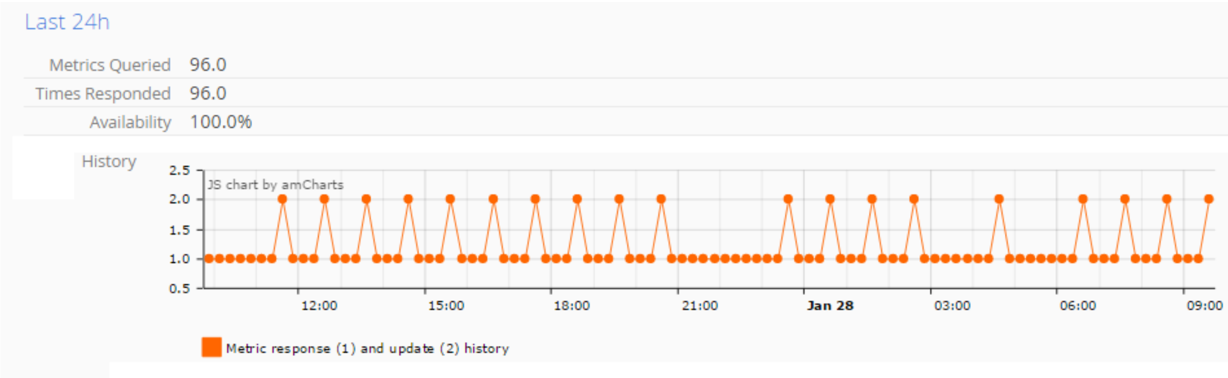


Figure 1 Daily analysis of Reliability Index- Olivais School

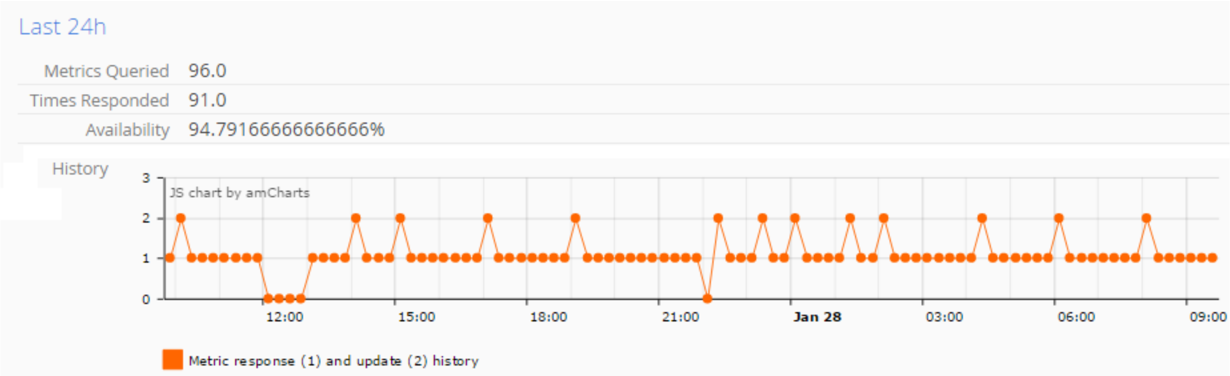


Figure 2 Daily analysis of Reliability Index - Campo Grande

From aforementioned analysis, we report a 100% reliable monitoring of Olivais school metrics (here ENERGY_CONSUMPTION metric). This is not the same for Campo Grande pilot site where a 94.79% Reliability Index is reported for Power Factor value.

The reliability on metrics gathered is enough to ensure the evaluation of the following functional use cases of the project. Though, the main task for the 2nd evaluation period is to increase the **reliability levels,** close to 100%, as this is a main prerequisite for the implementation of control strategies.

Energy demand monitoring and optimization in public buildings

In this case scenario, different pricing policies are defined for the evaluation process. The goal is to compare different tariff schemas with the main objective to be the energy cost minimization. The different pricing policies selected for the evaluation period are presented:

Tariff Schema	Timeslot 1	Timeslot 2	Timeslot 3	Timeslot 4
Tariff 1- Baseline	0.1713 Euro/KWh			
Tariff 2	0.2156	0.1265	0.0883	0.0775
Tariff 3	0.189		0.09886	
Tariff 4	0.2144	0.1704	0.0986	

Table 13 Lisbon city 1st phase – Tariff Policies

Where:

- **Timeslot 1:** 09:00-11:00, 18:00-21:00
- **Timeslot 2:** 08:00-09:00, 11:00-18:00, 21:00-22:00
- **Timeslot 3:** 22:00-02:00, 06:00-08:00
- **Timeslot 4:** 02:00-06:00

These tariff models are models available in PT market, provided by the Portuguese retailer, EDP. Some technical limitations characterize the contracts and tariff models, not taken into account in BESOS project.

We have to point out that for the 1st evaluation phase, the baseline is the current status in the different public buildings integrated in the project (Tariff 1).

	Tariff 1	Tariff 2	Tariff 3	Tariff 4
Building ID	**Total**			
Olivais	1,195.37 €	970.84 €	1,175.01 €	1,151.46 €
DRFM	1,737.94 €	1,375.23 €	1,635.74 €	1,615.37 €
Campo Grande	25,320.37 €	21,189.14 €	25,473.04 €	25,013.48 €
Building ID	**Average**			
Olivais	239.07 €	194.17 €	235.00 €	230.29 €
DRFM	347.59 €	275.05 €	327.15 €	323.07 €
Campo Grande	5,064.07 €	4,237.83 €	5,094.61 €	5,002.70 €
Building ID	**Difference from Baseline Tariff 1**			
Olivais		-19.02%	-2.03%	-3.97%
DRFM		-20.04%	-4.91%	-6.10%
Campo Grande		-16.38%	0.49%	-1.31%

Table 14 Lisbon city 1st phase – Alternative Tariffs evaluation

Table 14 presents the results for each pilot site during the reporting period. The testing period is a 5-week period and the **total** and **average** cost data are presented for the 3 pilot buildings. In all case studies, the implementation of dynamic tariff policies is beneficiary for the pilot sites. Cost reduction is significant in **Case 2** where a 4-tarrif pricing schema is adopted. An average reduction of **18.5%** on total cost is considered for that case. A lower cost reduction is reported for the other pricing policies, highlighting that way the importance of dynamic tariff policies the consumers.

This simulation scenario is useful towards the selection of the best fitted pricing policies for consumers in a deregulated energy market environment. Even with limited or no control functionality, and thus with no impact on total energy consumption, we can further establish a dynamic operational framework, affecting that way the total **energy cost**. Therefore, it is of high interest for the project to integrate a mechanism that enables a comparative analysis among the different pricing models available in the market.

Smart city energy demand curve optimization

This is the extended version of the previous use case, integrating also existing RES in the evaluation process. The goal is to cover part of energy consumption with local RES generation, minimizing that way the cost of energy and CO2 emissions. Following a preliminary analysis about the size of generation and consumption assets, we consider different evaluation scenarios for RES integration.

A **100% PV RES generation** (TU Lisbon) to cover public building energy consumption is examined as the 1st scenario. The final impact on the pilot testbed is calculated by first estimating the impact of PV generation and then evaluating the impact from alternative pricing models. Again, energy consumption is not changing, due to lack of controllability during the 1st evaluation phase, though the main differentiation is considered due to RES adaptation along with the implementation of the different price policies. The results from the evaluation process are presented, first considering only PV integration (estimation for each tariff case).

PV penetration: 100 %					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-5.64%	-4.78%	-4.06%	-3.20%	-2.40%
T2	-5.74%	-4.94%	-4.03%	-3.04%	-2.25%
T3	-6.09%	-5.30%	-4.45%	-3.61%	-2.63%
T4	-5.94%	-5.15%	-4.27%	-3.37%	-2.47%

Table 15 Cost Reduction due to PV penetration

An average **cost reduction** of **-4.5%** is reported due to PV integration, with some slight deviations per pilot case to highlight the importance of the different tariff models. The impact of PV integration at load curve is also presented for an indicative week during the reporting period.

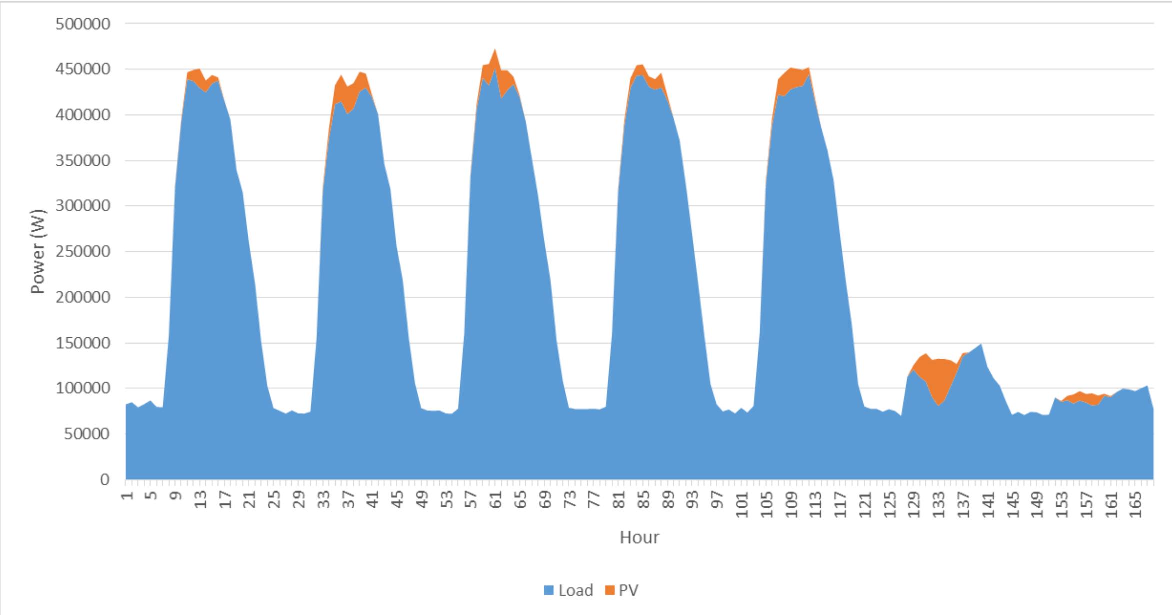


Figure 3 PV integration Curve

The next step of the evaluation process is the integrated PV & alternative pricing models scenario. This is the mixed scenario by evaluating alternative pricing policies and further integrating RES generation on energy consumption data. The results for this case scenario are presented in the next table. As a baseline we consider T1 tariff which is the actual pricing model in place.

Cost Reduction due Alternative Tariff Models with PV integration: 100 %					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-5.64%	-4.78%	-4.06%	-3.20%	-2.40%
T2	-20.84%	**-21.60%**	-19.49%	-20.48%	-18.11%
T3	-4.90%	**-5.91%**	-3.70%	-5.62%	-2.04%
T4	-6.57%	**-7.56%**	-5.23%	-6.79%	-3.59%

Table 16 Cost Reduction due to Alternative Tariff Models with PV integration

By comparing the final results, we can show an even higher impact of PV integration on total cost reduction. An even higher cost reduction is reported, supporting the assumption that by mixing RES generation and dynamic pricing models we can drastically reduce the energy cost.

Furthermore, as PV generation is available during peak demand hours, it is worth examining the impact of PV penetration in total **Peak demand**. The evaluation analysis is performed during weekdays where a higher impact on peak demand is reported:

Peak Demand Reduction					
Week	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Demand Reduction	**-9.62%**	-6.27%	-8.57%	-9.16%	-3.76%

Table 17 Peak Demand Reduction

The analysis was delivered for each day of the week, calculating the peak demand reduction due to PV integration, and a weekly average is estimated to further present the results from evaluation period. We have to point out that the maximum peak reduction during the reporting period was **-16.79%.**

Apart from energy cost reduction, special focus is delivered also on **CO2 emissions reduction** due to RES integration. The next table presents the results for the evaluation period:

CO2 Emissions					
Week	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
PV: 0%	9905.103307	12033.5329	10843.14139	4088.145468	13193.52784
PV: 100%	9307.030933	11438.91679	10396.43711	3954.900297	12863.8961
Difference	**-6.04%**	-4.94%	-4.12%	-3.26%	-2.50%

Table 18 CO2 Emissions Reduction

An average CO2 emissions reduction is reported (**-4.40%)** due to PV RES integration. An even higher increase of RES penetration will lead to even higher CO2 emissions reduction.

A 2nd case scenario is examined during the reporting period, considering penetration of wind RES generation as an alternative (Wind Farm Montegordo). The list of public buildings for this scenario remains the same and thus a comparative analysis between the two RES technologies is performed. Similar to previous case, the results for **cost reduction**, **peak demand reduction** and **CO2 Emissions reduction** are presented.

A **5% penetration** of Wind generation from Wind Farm Montegordo is considered on the evaluation process in order to set a similar case study. The results from evaluation analysis are presented:

Wind penetration: 5 %					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-6.92%	-8.38%	-13.97%	-10.16%	-4.30%
T2	-6.10%	-7.65%	-12.52%	-8.71%	-3.77%
T3	-5.90%	-7.71%	-12.64%	-8.79%	-3.74%
T4	-5.99%	-7.71%	-12.61%	-8.78%	-3.76%

Table 19 Cost Reduction due to Wind penetration

The average cost reduction for this test scenario is **-8.00%,** due to the higher availability of wind generation. A week analysis is also presented showing the impact of wind generation in load consumption.

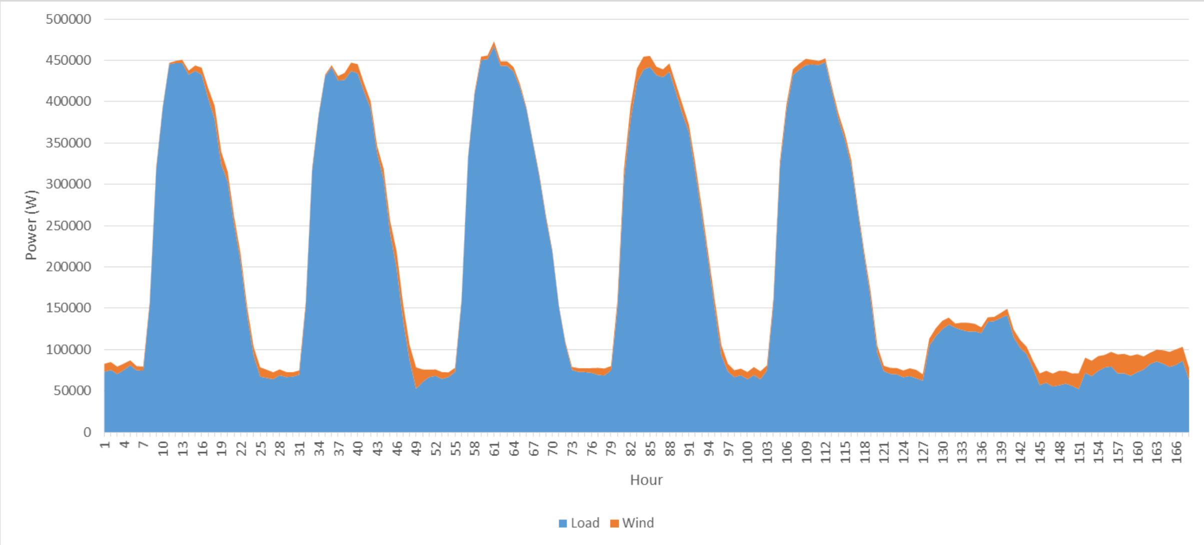


Figure 4 Wind integration Curve

The main differentiation from previous case scenario is the RES penetration even during the night hours. Wind penetration when combined with alternative tariff models leads to significant costs reduction. The integrated scenario results are presented in the next Table:

Cost Reduction due Alternative Tariff Models with Wind integration: 5 %					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-6.92%	-8.38%	-13.97%	-10.16%	-4.30%
T2	**-21.14%**	**-23.84%**	**-26.62%**	-25.14%	-19.39%
T3	-4.70%	-8.31%	-11.96%	-10.69%	-3.15%
T4	-6.62%	-10.05%	-13.48%	-12.01%	-4.87%

Table 20 Cost Reduction due to Alternative Tariff Models with Wind integration

A significant reduction on total cost is calculated for the reporting period, showing that the combined management of local RES with dynamic pricing models may be beneficial for the consumers.

On the other hand, as wind generation is available during high and low demand hours, **peak demand reduction** is rather low. The results for the reporting period are presented in the following table:

Peak Demand Reduction					
Week	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Demand Reduction	-1.31%	-6.28%	-8.84%	-9.12%	-1.59%

Table 21 Peak Demand Reduction

Again, the maximum per weekday is stored and the average weekly value is presented, showing the impact on peak demand reduction. We have to point out that in this case scenario, the maximum peak reduction during the reporting period was -13.65%, lower than the percentage reduction due to PV penetration reported in previous case scenario.

Apart from cost reduction, special focus is delivered also on **CO_2 emissions** reduction due to RES integration. The next table presents the results for the reporting period:

CO2 Emissions					
Week	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Wind: 0%	9905.103307	12033.5329	10843.14139	4088.145468	13193.52784
Wind: 100%	9271.512348	11006.8073	9229.984687	3746.641134	12622.58319
Difference	-6.40%	-8.53%	-14.88%	-8.35%	-4.33%

Table 22 CO2 Emissions Reduction

The impact on CO2 emissions is higher compared to PV integration case scenario, due to the higher penetration of wind generation. In both cases we are reporting a direct impact on CO2 emissions reduction due to RES penetration.

The integration of RES in energy systems is continuously increasing and towards this direction, there is a high interest for smart cities to invest on RES as part of their future strategy. We examined the impact of RES on total consumption focusing on the impact at energy cost and CO2 emissions. From the evaluation results, we can easily show that a combination of RES integration and implementation of different pricing policies can lead to a **significant reduction** on **energy costs** and **CO2 emissions**. By further integrating additional asset types and implementing the associated control strategies (during the 2nd evaluation period), we will show an even higher reduction for the KPI values.

Measurement of the renewable energy produced and predicted in the distribution network

This is an asset specific use case, focusing on the evaluation of BESOS forecasting engine as one of the main outcomes of the project. The evaluation of forecasting engine at generation assets is provided for the reporting period. A frequently used metric used for the evaluation of the forecasting tools is the **Mean Absolute Percentage Error (MAPE).** The mean absolute percentage error (MAPE), also known as mean absolute percentage deviation (MAPD), expresses accuracy as a percentage, and is calculated for the Lisbon site generation assets.

An average of 19.03 % of MAPE error is calculated for Lisbon site generation assets at the monitoring period. The detailed results per pilot site are presented in the following Table:

Pilot Site	MAPE Error
TU Lisbon PV park	17.58%
Olivais School	18.56%
Montegordo Wind Farm	20.96%

Table 23 MAPE Error Estimation - PT Site

We highlight the difference of the forecasting engine results for wind and PV sites. The PV forecasting data show high accuracy levels compared to wind forecasting data. This is due to the typical U-curve of PV generation, which can be easily modelled by the forecasting engine. The next figure presents a typical real time vs. forecasted generation curve for the PV in TU Lisbon:

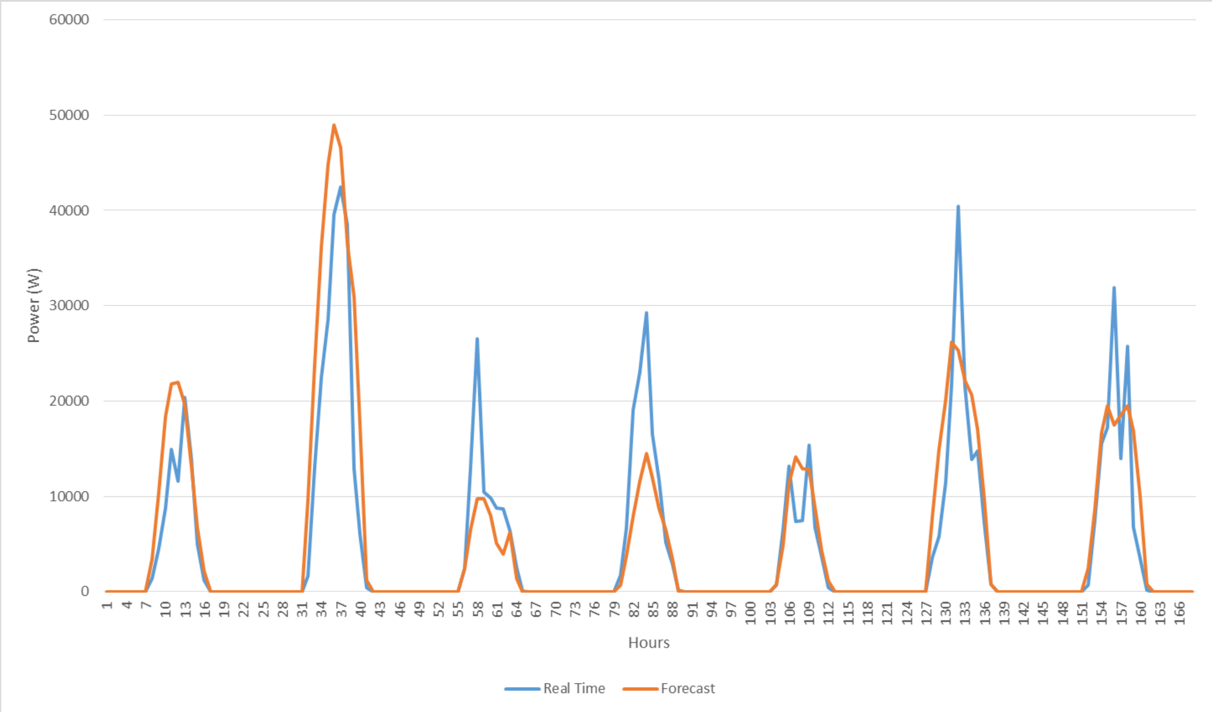


Figure 5 Lisbon Site - Real time vs. Forecasted Generation

Predict the energy consumption on weather data

This use case is focusing on the evaluation of BESOS forecasting engine for public building consumption data. Again MAPE is considered as the indicator for the evaluation of the forecasting framework. The lack of historical data at the 1st round of trials didn't enable us to evaluate this use case, and thus the demonstration was shifted to the 2nd round of trials.

Measurement / control of the electric energy quality

The goal of this use case is to calculate Power Factor for each public building, and by taking into account the baseline definition per site, to evaluate the building performance by the excess on PF value. The baseline definition is a significant parameter as it reveals the type of the consumption for each public buildings. The results from baseline definition and evaluation analysis at Lisbon public buildings are presented.

First, by consultation with pilot site managers and taking into account the data captured from pilot sites, the baseline PF is calculated. Then, and taking into account hourly data from the reporting period, we estimated the deviation of PF from baseline. The average results per pilot site monitored are presented.

Public Building	Baseline	Percentage <Baseline
Olivais School	0.89	0.60%
DRFM Building	0.9	1.79%
Campo Grande Pilot	0.95	1.79%

Table 24 PF metric analysis - PT site

As we can easily show, the power factor baseline in public buildings is >0.9, with the special case of Campo Grande (Mega Building) where the PF baseline equals to 0.95. Then, we present the deviation of PF values from baseline, which does not exceed the 2% value. The public buildings integrated in BESOS platform are commercial buildings and thus there is no high demand for reactive power (which directly affects the PF value).

It is clear that the 1st phase of evaluation is focusing only at the reporting capabilities of assets integrated in BESOS platform. Dynamic pricing models and the integration of local RES are the main parameters considered for the evaluation of the integrated BESOS scenario.

3.3 Barcelona Pilot Site Evaluation

The same approach is considered also for the evaluation of 1st integration scenario at Barcelona pilot site. First, the **reliability** of data gathered at the evaluation period is calculated for each pilot asset and the site as a whole. The results of this evaluation process are presented in the next Tables:

Building ID	Energy Consumption	Energy Cost	CO2 Emissions	Power Factor
156	99.38%	99.37%	99.24%	99.39%
158	99.38%	99.37%	99.24%	99.39%
160	99.38%	99.37%	99.24%	99.39%
161	99.38%	99.37%	99.24%	99.39%
162	99.38%	99.37%	99.24%	99.39%
163	99.38%	99.37%	99.24%	99.39%
174	99.38%	99.37%	99.24%	99.39%
175	99.38%	99.37%	99.24%	99.39%

Table 25 Reliable Monitoring of BCN Building Assets

Building ID	Energy Consumption	Energy Cost	CO2 Emissions	Power Factor
CapCervello	99.59%	99.61%	99.52%	-
CapGracia	99.59%	99.61%	99.52%	-
EoiSabadell	99.59%	99.61%	99.52%	-
Filmoteca	99.59%	99.61%	99.52%	-
IesCanMargarit	99.59%	99.61%	99.52%	-
IesSantEsteve	99.59%	99.61%	99.52%	-
IesTuro	99.59%	99.61%	99.52%	-
Infraestructures	99.59%	99.61%	99.52%	-

Table 26 Reliable Monitoring of SDX Building Assets

PLS ID	Energy Consumption	Energy Cost	CO2 Emissions	Power Factor
1/L	99.57%	99.59%	99.49%	99.57%
2/L	99.57%	99.59%	99.49%	99.56%
3/L	99.56%	99.59%	99.49%	99.56%
4/L	99.56%	99.59%	99.49%	99.59%
5/L	99.57%	99.59%	99.49%	99.59%

Table 27 Reliable Monitoring of Public Lighting Assets

EVs ID	Energy Consumption	Energy Cost	CO2 Emissions	Power Factor
PRC1	66.51%	65.30%	65.34%	-
PRC2	66.51%	65.30%	65.34%	-
PRC3	66.51%	65.30%	65.34%	-
PRC4	66.51%	65.30%	65.34%	-
PRC5	66.51%	65.30%	65.34%	-

Table 28 Reliable Monitoring of EV Assets

Asset ID	Energy Generation	Forecast
Viudo	89.84%	99.64%
Ficosa PV	82.56%	-

Table 29 Reliable Monitoring of Generation Assets

The average reliability index for the BCN pilot site is **93.80%.** On the other hand, we have to highlight some issues about EV integration, mainly due to the lack of continuous connectivity with EV charging points. For the rest of pilot assets, a high reliability index is reported during the evaluation period but it is mandatory to increase this level to 100% in order to test the control scenarios of BESOS project at the 2nd evaluation phase. For PLS assets where we tested a minimum set of control strategies, a **99.56%** reliability index was reported, supporting that way the uninterrupted communication with PLS assets. The next figures show some screenshots of reliability indicators for specific assets from the reporting period.

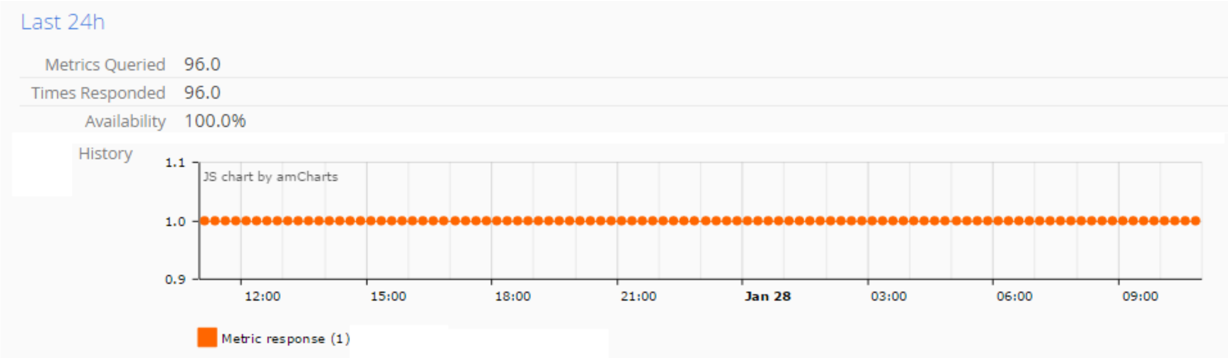


Figure 6 Daily analysis of Reliability Index- 0156 BCN Building

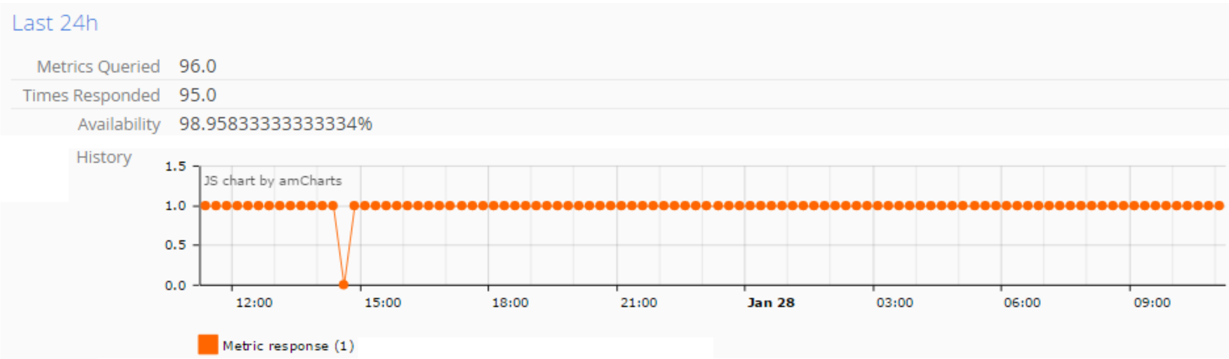


Figure 7 Daily analysis of Reliability Index- PRC1 EV Charging point

The aforementioned analysis presents a high reliability level for almost all pilot sites, enabling further evaluation of functional use cases of BESOS platform.

Energy demand optimization of the public lighting based on light environment

The integration of PLS assets in Barcelona city enables the evaluation of PLS related use cases during the 1st demonstration period. The energy, business and societal impact of PLS integration (monitoring and control) is presented for the reporting period. For the 1st evaluation period, 2 different policies are implemented in the PLS systems (2 types) integrated in the platform:

- 1st approach: Limited control functionality, fully preserving high luminance levels
- 2nd approach: Extended control functionality, stretching operation at low luminance levels

(PLS 5_L).

The results for these 2 alternative cases are presented:

KPI Reduction	Control Strategies	
	1st Approach (%)	2nd Approach (%)
Energy Consumption	1.4347	21.19
CO2 Emissions	1.4654	21.24
Energy Cost	0.9988	24.14

Table 30 PLS Control Strategies – BCN pilot site

There is a significant difference among the 2 approaches, due to the different control strategies implemented. The 1st approach focusing on control during twilight hours with a minimum impact on final results, while the 2nd approach is a simulated approach, performing control actions even during night hours. The 1st control strategy is a viable business case in the project with a limited impact on total energy consumption. Thus, we will evaluate the impact of this control scenario as part of the integrated smart city management use case.

Energy demand monitoring and optimization in public buildings

In this case scenario, different pricing policies are evaluated with the main objective of energy cost minimization. The selected policies for Barcelona pilot sites are depicted in the following Table. The different tariffs are extrapolated from the annual pricing model presented in D7.1, focusing on the time-period for the evaluation process (October 2015- January 2016). Again different timeslots are considered for the dynamic pricing models:

Tariff Schema	Timeslot 1	Timeslot 2	Timeslot 3	Timeslot 4
Tariff 1- Baseline	0.0638	0.1167	0.1368	
Tariff 2	0.12			
Tariff 3	0.098	0.1287		
Tariff 4	0.054	0.1098	0.1286	0.1784

Table 31 Barcelona city 1st phase –Tariff Policies

Where:

- **Timeslot 1:** 23:00-07:00
- **Timeslot 2:** 07:00-09:00 & 12:00-17:00 & 20:00-23:00
- **Timeslot 3:** 09:00-12:00 & 17:00-18:00
- **Timeslot 4:** 18:00-20:00

The results from the simulation process are presented:

	Tariff 1	Tariff 2	Tariff 3	Tariff 4
Building ID	**Total Cost**			
156	1,366.31 €	1,430.67 €	1,470.62 €	1,340.11 €
158	1,549.78 €	1,634.35 €	1,671.51 €	1,530.85 €
160	2,681.66 €	2,745.72 €	2,851.58 €	2,611.47 €
161	619.38 €	675.30 €	682.74 €	604.10 €
162	1,043.77 €	1,130.76 €	1,144.49 €	1,011.54 €
163	1,189.16 €	1,253.28 €	1,283.48 €	1,152.54 €
174	1,808.85 €	1,813.32 €	1,903.40 €	1,755.77 €
175	1,561.77 €	1,601.52 €	1,664.95 €	1,524.20 €
Building ID	**Average Weekly Cost**			
156	273.26 €	286.13 €	294.12 €	268.02 €

158	309.96 €	326.87 €	334.30 €	306.17 €
160	536.33 €	549.14 €	570.32 €	522.29 €
161	123.88 €	135.06 €	136.55 €	120.82 €
162	208.75 €	226.15 €	228.90 €	202.31 €
163	237.83 €	250.66 €	256.70 €	230.51 €
174	361.77 €	362.66 €	380.68 €	351.15 €
175	312.35 €	320.30 €	332.99 €	304.84 €
Building ID	**Difference from Baseline Tariff 1**			
156		4.79%	7.68%	-1.93%
158		6.37%	8.43%	-1.68%
160		2.49%	6.40%	-2.66%
161		5.88%	6.69%	-1.61%
162		8.20%	9.59%	-3.13%
163		5.54%	8.01%	-3.12%
174		0.41%	5.33%	-2.98%
175		2.67%	6.68%	-2.41%

Table 32 Barcelona city 1st phase – Alternative Tariffs evaluation

Again, different dynamic pricing policies are considered for the evaluation. In this case scenario, the baseline is not a single tariff model as dynamic tariffs are already implemented in BCN pilot sites. The baseline tariff model is **4.50%** cheaper than the equivalent single tariff model (Tariff 2) and **7.35%** cheaper than a dual tariff price model with high prices during day hours. On the other hand, an alternative tariff model (Tariff 4) lead to a cost reduction of **2.50%.**

Therefore, similar to PT site results are reported for BCN pilot site. The establishment of dynamic pricing models can be beneficial for the consumers of the buildings and thus the ESCOs, as BESOS business stakeholders, are interested to provide this service type (selection of the best fitted tariffs) to their customers.

The same evaluation analysis is performed also at SDX Public Buildings. The goal of this comparative analysis is to show the impact of the different tariffs to several case studies. The results from evaluation process are presented:

	Timeslot 1	**Timeslot 2**	**Timeslot 3**	**Timeslot 4**
	Total			
CapCervello	938.36 €	1,019.29 €	1,032.23 €	911.65 €
CapGracia	905.65 €	959.74 €	980.59 €	882.78 €
EoiSabadell	1,429.02 €	1,464.11 €	1,517.99 €	1,417.39 €
Filmoteca	12,236.67 €	12,915.79 €	13,264.22 €	11,997.74 €
IesCanMargarit	798.10 €	842.04 €	863.06 €	763.45 €
IesTuro	325.81 €	333.18 €	346.32 €	321.70 €
	Average			
CapCervello	187.67 €	203.86 €	206.45 €	182.33 €
CapGracia	181.13 €	191.95 €	196.12 €	176.56 €
EoiSabadell	285.80 €	292.82 €	303.60 €	283.48 €
Filmoteca	2,447.33 €	2,583.16 €	2,652.84 €	2,399.55 €
IesCanMargarit	159.62 €	168.41 €	172.61 €	152.69 €

IesTuro	65.16 €	66.64 €	69.26 €	64.34 €
	Difference from Baseline Tariff			
CapCervello		7.68%	9.45%	-2.65%
CapGracia		6.32%	8.49%	-2.55%
EoiSabadell		2.62%	6.34%	-0.83%
Filmoteca		5.56%	8.40%	-1.96%
IesCanMargarit		5.46%	8.12%	-4.36%
IesTuro		2.26%	6.30%	-1.25%

Table 33 SDX Buildings 1st phase – Alternative Tariffs evaluation

In this case scenario, the baseline tariff is **4.98%** cheaper than the equivalent single tariff model (Tariff 2) and **7.85%** cheaper than a 2-price model with high prices during the day. On the other hand, a variable tariff model (Tariff 4) may lead to a cost reduction by **2.27%.**

The analysis shows a higher potential of cost reduction for BCN municipality buildings. Though, in both cases we can say that the implementation of alternative tariff models can be beneficial for ESCOs and the facility managers.

The different tariff strategies are integrated at BESOS Decision Support System towards the establishment of an engine that enables the automated selection of best tariff policies. As mentioned above this is one of the main objectives of ESCOs companies, to promptly manage the assets of their portfolio by selecting the optimal pricing policy for their customers.

Smart city Energy demand curve optimization

This is the mixed scenario by integrating public lighting systems management, RES integration and optimal tariff schema selection. The impact is estimated addressing both energy, business and societal indicators. The different steps for the evaluation process are presented:

- Scenario 1: Baseline Scenario
- Scenario 2: Baseline Scenario & RES Integration
- Scenario 3: Baseline Scenario & RES Integration & PLS management
- Scenario 4: Baseline Scenario & RES Integration & PLS management & Alternative Tariff Strategies

Where we are selecting the pool of assets for the evaluation analysis:

- Public Buildings: 8 public buildings of BCN Municipality
- RES: Ficosa PV plant * 50
- PLS: CSE PLS Station * 3

First, a minimum impact on energy consumption is expected. There is limited controllability performed in pilot assets, mainly to PLS management. The main impact is expected due to RES penetration along with the evaluation of the different pricing policies. The results from the evaluation process are presented, starting from the “Smart city Energy demand curve optimization” for a week period.

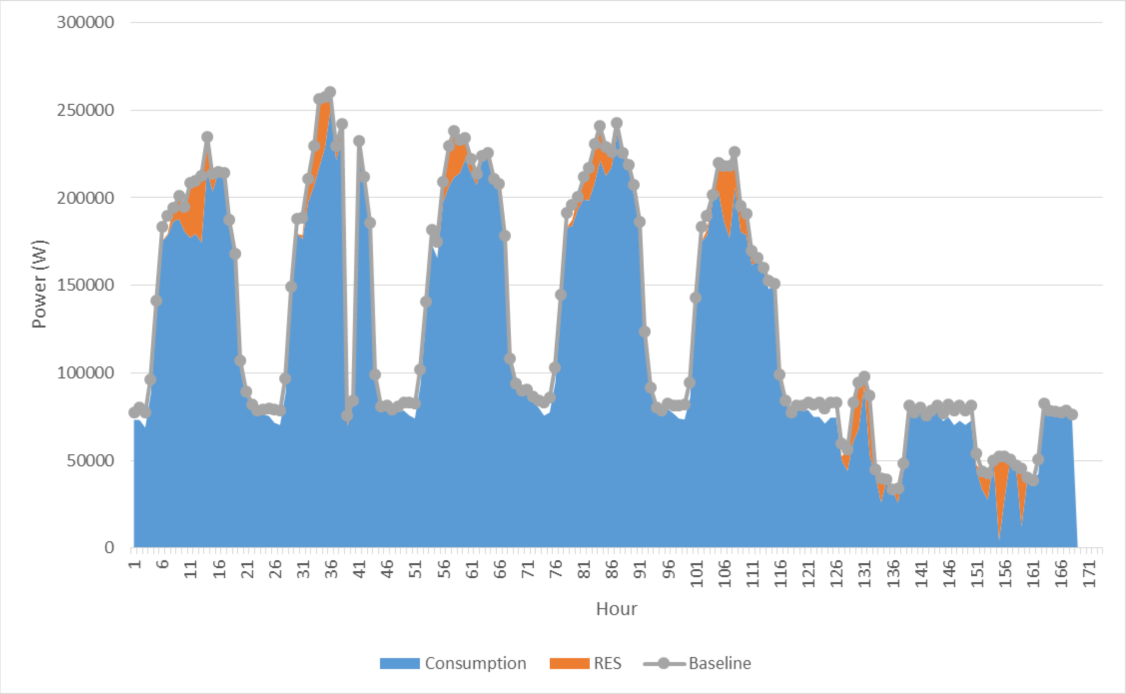


Figure 8 Smart city Energy demand curve optimization

The "gray" line is the baseline scenario where no control functionalities are considered, while the aggregate "blue & orange" curve provides the actual consumption after PLS control implementation. As we can easily report, there is a reduction on energy consumption during night hours.

Then, we consider RES penetration (orange line) towards the extraction of final energy consumption (blue line). The energy consumption indicator is presented for these 3 scenarios.

- The integration of PLS system control strategies does not affect peak power demand (as PLS are operating during low demand night hours) though a reduction of **~2%** on total energy consumption is reported.
- By further examining the penetration of RES at the evaluation process, a reduction on peak load demand is reported, also depicted in Figure 8. The results from the evaluation period are presented in the next table with an average reduction of **-7.86%**.

Peak Demand Reduction					
Week	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Demand Reduction	-10.02%	-14.32%	-8.35%	-6.06%	-0.57%

Table 34 Peak Demand Reduction

The peak demand reduction results are directly affected by RES penetration and RES generation (affected by weather conditions). This is the case of week 5, where the low PV generation (due to cloudy weather conditions) leads to a lower peak demand reduction.

Following energy consumption analysis, the impact on energy cost and CO2 emissions is examined. The tables below present the results from the evaluation process, showing first the impact of PLS control in energy cost:

Cost Reduction due to PLS Control					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-1.36%	-1.44%	-1.13%	-1.28%	-1.23%
T2	-1.94%	-2.01%	-1.58%	-1.92%	-1.71%
T3	-1.68%	-1.76%	-1.39%	-1.63%	-1.50%
T4	-1.30%	-1.39%	-1.04%	-1.17%	-1.19%

Table 35 Cost Reduction through PLS Control

An average **~1.5%** cost reduction is calculated. The PLS control framework will not provide the way for a significant cost reduction but will contribute to the total cost reduction, combined with the rest of technologies integrated in the project.

The impact of RES penetration is examined in the smart city testbed:

Cost Reduction due to PV integration					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-6.30%	-6.40%	-4.21%	-4.80%	-1.93%
T2	-6.23%	-6.32%	-4.28%	-5.05%	-2.34%
T3	-6.24%	-6.30%	-4.22%	-4.97%	-2.16%
T4	-6.09%	-6.16%	-3.99%	-4.58%	-1.86%

Table 36 Cost Reduction through PV integration

As in the case of Lisbon Site, the impact of RES penetration significantly affects total energy cost. The average cost reduction is **~ 5.4 %,** with part of this reduction to be associated with PLS control management as presented above.

Finally, we present the impact from the different pricing policies considered for the 1st evaluation period. The next table presents the impact on energy cost, compared to the baseline definition, a single tariff model.

Cost Reduction due to Alternative Tariff Policies					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-14.11%	-12.84%	-10.25%	-13.27%	-9.16%
Baseline T2	-6.23%	-6.32%	-4.28%	-5.05%	-2.34%
T3	-5.35%	-4.74%	-2.40%	-4.27%	-0.73%
T4	-16.51%	-14.50%	-12.04%	-15.54%	-11.21%

Table 37 Cost Reduction due to Alternative Tariff Policies

We can show from the results that a cost reduction up to **-16.51%,** can be expected by combining the different technologies examined in the 1st reporting period. This percentage reduction is due to the efficient PLS control, RES penetration and the establishment of dynamic tariff management framework, with the main object: to move from a static public buildings management framework to the establishment of a dynamic smart environment in large cities.

As a final step of the evaluation process for this case scenario, the impact on CO2 emissions is reported. We have to point out that CO2 emissions reduction is due to:

- PLS management with energy consumption reduction: **-1.83%,**
- RES penetration reducing the total CO2 emissions: **~ 5.29 %,**

The detailed results for the evaluation period are presented in the Table:

CO2 Emissions Reduction					
Scenario	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
PLS Control	-1.96%	-2.04%	-1.57%	-1.81%	-1.77%
PLS Control & RES	-6.05%	-6.24%	-4.32%	-4.56%	-2.41%

Table 38 CO2 Emissions Reduction

The analysis takes into account CO2 emissions ratio data as reported in D7.1.

A second evaluation analysis is performed in order to show the impact of **wind generation** in Smart city scenario. The steps of the evaluation process are again:

- Scenario 1: Baseline
- Scenario 2: Baseline & RES
- Scenario 3: Baseline & RES & PLS
- Scenario 4: Baseline & RES & PLS & Alternative Tariff Strategies

Where:

- Public Buildings: 6 SODEXO managed municipality buildings
- RES: Viudo Wind farm (part of RES generation: 50%).
- PLS: CSE PLS Station * 3

As in the 1st case scenario, a minimum impact on energy consumption is expected due to PLS management and the main differentiation is expected by RES penetration and the evaluation of different pricing policies. The results from the evaluation process are presented. An overview of the evaluation process results are presented in the next figure:

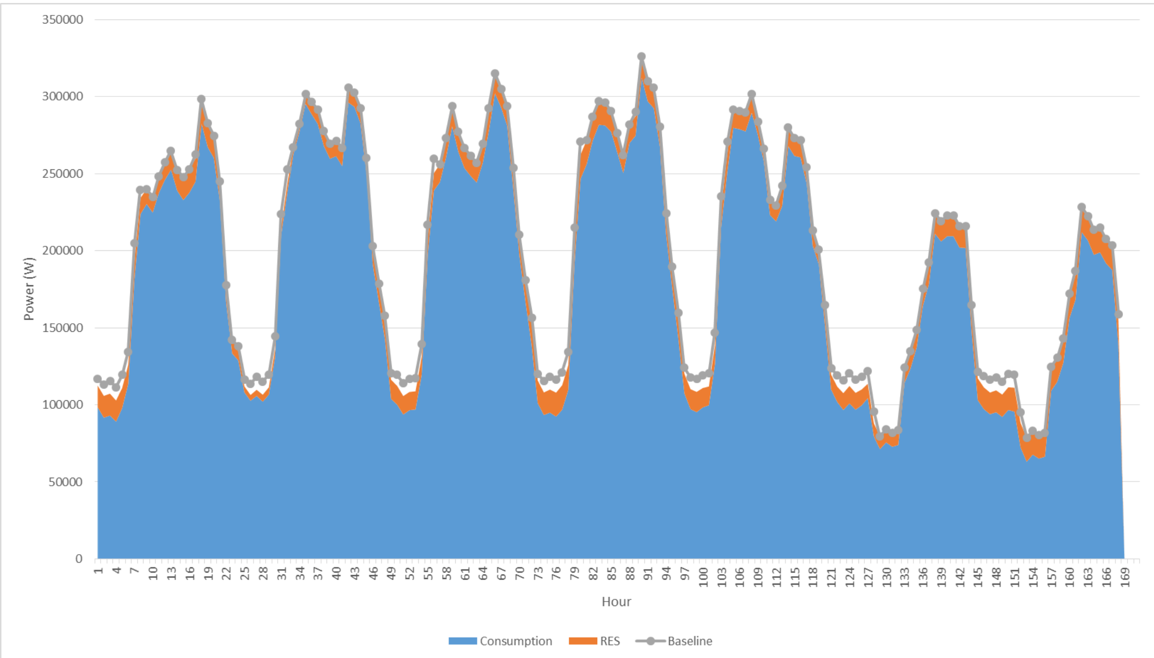


Figure 9 Smart city Energy demand curve optimization

The "gray" line defines the baseline scenario with no control functionalities, while the aggregate
"blue & orange" curve shows the energy consumption after PLS control strategies implementation. Then, we consider RES penetration (orange line) for further extraction of final energy consumption (blue line). The energy consumption data are presented for these 3 scenarios.

- The integration of PLS system control strategies will not affect peak power demand (as PLS loads are available during low demand night hours) though a reduction of **~1.85%** on total energy consumption is calculated.

- By further examining the penetration of RES (wind generation), a reduction of peak load demand is reported, depicted in Figure 8. The results are presented in the next table with an average peak demand reduction of **-1.96%**.

Peak Demand Reduction					
Week	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Demand Reduction	-0.13%	-1.14%	-4.23%	-3.22%	-1.10%

Table 39 Peak Demand Reduction

The low peak reduction is mainly due to the type of RES technology integrated, wind generation. The impact of wind RES is not that significant during peak hours, comparted to PV generation scenario examined in previous case study.

Following the analysis about energy consumption, the impact on energy cost and CO2 emissions is presented. The next tables shows the results from evaluation process. First the impact of PLS control in energy cost is:

Cost Reduction due to PLS Control					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-0.93%	-1.07%	-1.04%	-0.78%	-0.91%
T2	-1.33%	-1.48%	-1.43%	-1.18%	-1.27%
T3	-1.15%	-1.29%	-1.26%	-1.00%	-1.11%
T4	-0.89%	-1.03%	-0.95%	-0.70%	-0.88%

Table 40 Cost Reduction due to PLS Control

An average **~1.08%** cost reduction is calculated. Compared to previous evaluation analysis, the lower reduction is due to the higher energy consumption at SODEXO Building assets. Then the impact of RES penetration is examined in the smart city test site:

Cost Reduction due to wind integration					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-1.15%	-3.94%	-6.69%	-4.93%	-1.89%
T2	-1.58%	-4.54%	**-7.45%**	-5.63%	-2.36%
T3	-1.38%	-4.27%	**-7.12%**	-5.32%	-2.15%
T4	-1.10%	-3.85%	-6.50%	-4.77%	-1.83%

Table 41 Cost Reduction due to PV integration

The impact of RES penetration significantly affects the total cost. An average cost reduction is **~ 3.92 %,** with part of this reduction due to PLS control as presented in previous section. We have to point out that wind generation integration may lead to reduction of up to **7.45%**, showing that way the high impact of wind generation.

As a final case scenario, we are presenting the results from the different pricing policies considered at the 1st evaluation phase. The next table presents the energy cost KPI, compared to the baseline definition, a single tariff schema.

Cost Reduction due to Alternative Tariff Policies					
Tariff	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
T1	-10.51%	-12.69%	-14.96%	-13.26%	-10.47%
T2	-2.61%	-5.82%	-8.88%	-7.12%	-3.88%
Baseline T3	-1.38%	-4.27%	-7.12%	-5.32%	-2.15%
T4	-12.75%	-14.38%	-16.46%	-14.77%	-12.24%

Table 42 Cost Reduction due to Alternative Tariff Policies

We show that an energy cost reduction up to **-14.12%,** is expected through a coordinated management process. The results may be due to the efficient PLS control, RES penetration and the establishment of dynamic tariff management framework.

As a last step of the evaluation process, the impact on CO2 emissions is calculated. We have to point out that CO2 emissions reduction is due to:

- PLS management with energy consumption reduction: **-1.34%,**
- RES penetration reducing the total CO2 emissions: **~ 4.27 %,** with a maximum reduction value of **7.46%**

The detailed results for the reporting period are presented in the next Table:

CO2 Emissions Reduction					
Scenario	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
PLS Control	-1.35%	-1.51%	-1.40%	-1.14%	-1.31%
PLS Control & RES	-1.57%	-4.82%	-7.46%	-5.14%	-2.37%

Table 43 CO2 Emissions Reduction

The main differentiation of this case scenario is the non-typical operation of wind generation, compared to PV generation analysis performed in previous case study. On the other hand, the higher production yield of this type of technology (wind generation) is considered as an added value towards integrating wind RES in asset management platforms.

This scenario is the holistic Smart city management scenario covering all functionalities examined in BESOS project during the 1st evaluation period. In the 2nd evaluation period, we are integrating additional asset types with controllability, enabling that way the establishment of a more flexible management framework.

Measurement of the renewable energy produced and predicted in the distribution network

The evaluation of BESOS forecasting engine is provided for BCN site generation assets. The MAPE results are presented. The average MAPE indicator for the RES assets at the reporting period is 19.30 %.

The next table provides the average results per pilot site:

Pilot Site	MAPE Error
Viudo Wind Farm	21.35%
Ficosa PV Plant	17.24%

Table 44 Generation Forecasting Evaluation

While a limited number of generation assets is integrated at the reporting period, we are covering both types of RES technology examined in the project, enabling that way the evaluation of generation forecasting engine in different case studies.

Predict the energy consumption on weather data

As in Lisbon pilot site, the demonstration and evaluation of energy consumption forecasting engine was not performed at the 1st phase due to lack of historical data. Thus, the evaluation analysis was shifted for the 2nd period of demonstration and evaluation.

Measurement / control of the electric energy quality

As in Lisbon pilot site, the Power Factor analysis is performed for Barcelona Municipality Buildings (where PF metric data are available). The baseline definition of PF quality indicator is presented in the next table along with the deviation of PF actual data from the baseline.

Public Building ID	Baseline	Index (Percentage<Baseline)
156 - Biblioteca Collserola	0.9	5.95%
158 - Biblioteca Francesc Candel	0.7	7.34%
160 - Seu Districte Sants	0.80	5.51%
161 - Seu Districte Sarrià	0.9	8.33%
162 - Seu Districte Sant Andreu	0.30< PF<0.50	0.89%
163 - Seu Districte Gracia	0.95	4.02%
174 - Palau de Foronda	0.83	1.34%
175 - CEIP Pau Vila	0.9	0.60%

Table 45 Power Factor Index Analysis

We first define the Power Factor baseline taking into account the historical data from pilot sites. In most of the cases, the PF limit is 0.9, a typical PF value for commercial buildings. Though, there are some exceptions in pilot sites:

ID 158: In this case a lower PF indicator is calculated. This is a common situation in cases with large HVAC installations.

ID 162: In this case, the Power factor values between 0.30 and 0.50. This is an abnormal situation but this is an industrial pilot site where heavy loads are performing.

The focus during the 1st reporting period was at the evaluation of the **reporting functionalities** by EMS, though a limited controllability of PLS enables us to further evaluate mixed scenarios towards the establishment of a smart city energy demand optimization framework.

The previous section presented the results of impact assessment analysis for the 1st evaluation period in both pilot sites. A limited number of BESOS use cases where tested and further evaluated as the fully scale evaluation analysis of BESOS use cases is performed at the 2nd evaluation period.

4 BESOS Impact Assessment Analysis - 2nd Phase

Following the presentation of results from the 1st evaluation period, the evaluation of BESOS platform at the end of the project is presented (2nd evaluation period). The goal of this section is to provide the impact of BESOS platform at the full list of project use cases. We define the three main layers (similar to the 1st evaluation period) that consist of the holistic impact assessment analysis of the project:

Energy Impact: impact to energy usage and management will be investigated. We are considering different types of control strategies and following the baseline definition, we calculate the impact of BESOS platform in energy savings.

CO2 emissions Impact: impact to energy usage and the associated CO2 emissions. This analysis is focusing mainly at the integration of RES along with the dynamically updated CO2 emissions ratio values.

Financial/ Business Impact: impact to the cost of energy for the different types of assets examined in BESOS project. This analysis is focusing at the impact of different tariff policies, along with the implementation of control strategies that affect the system operation.

Further to these high level evaluation criteria, we are examining individual scenarios that are of high interest for the business stakeholders. Therefore, an extra evaluation layer is defined, including the standalone evaluation scenarios performed during the reporting period.

The results from the evaluation process are presented following the same approach as in 1st evaluation phase (evaluation results per use case). We are starting the analysis with Lisbon pilot site.

4.1 Lisbon Pilot Site Evaluation

The main differentiation from the 1st reporting period is the integration of PLS, TLS and EVs assets in BESOS platform. This extended list of assets also affects the final list of use cases evaluated during the reporting period.

Prior to impact assessment analysis, the **Efficient Monitoring of each Facility** is evaluated to ensure the reliable operation of portfolio assets. The analysis is delivered for the full list of assets integrated at the reporting period:

Asset ID	Energy Consumption	Energy Cost	CO2 Emissions	Power Factor	Forecast
Olivais School	99.04 %	99.04 %	99.04 %	99.04 %	x
DRFM	96.93 %	96.93 %	96.93 %	96.93 %	x
Campo Grande	97.98 %	97.98 %	97.98 %	97.98 %	98.11%
LMIT	99.61%	99.61%	99.61%	99.61%	x
Public Lighting System	x	x	x	x	x
Traffic Lighting System	100%	x	x	x	x
EV platform	75.87%			x	x

Table 46 Reliable Monitoring of Consumption Assets

Asset ID	Energy Generation	Forecast
TU Lisbon	x	87.5%
Montegordo	95.23%	87.5%
Olivais	99.04%	87.5%

Table 47 Reliable Monitoring of Generation Assets

The continuous and reliable monitoring of integrated assets is one of the main requirements of the projects. The integration of different types of assets with heterogeneous characteristics is a critical tasks for project demonstration. In the above tables we presented the reliability level for each asset during the evaluation process with an average of **96.04%** level of reliability for the metrics selected for analysis. The major problem is reported for TU Lisbon EMS system where the hardware EMS gateway adapted in BESOS project is provided by a company which does not support any update on the firmware of the gateway and this affects the prompt operation of the device.

Energy demand optimization of the public lighting based on light environment

A main objective of the project is to examine the impact of BESOS DSS in PLS assets, by taking as input parameter daylight environmental conditions. The integration of Lisbon Public Lighting EMS does not enable this evaluation analysis as notifications are the only data values reported from Philips PLS platform. A snapshot of the values reported by PLS platform is presented in the following figure.

MRID:	CityTouch_S1_PL10	
Name:	PoL10	
Normally In Service:	true	
Po L Type:	LED	
Priority:	MEDIUM	
Status:		
	Reason:	after installation
	Resource Status:	ACTIVE
	Value:	operational

Figure 10 Snapshot of values from PLS platform

Therefore, the lack of energy consumption data does not enable the evaluation of this case scenario. Though, and in order to proceed with a concrete evaluation of BESOS platform in Lisbon pilot site, a simulation test bed is established (by taking into account configuration parameters from BCN pilot sites) and the results from the evaluation process are presented as part of Annex C.

Energy management for the use of electric vehicle fleet

The goal of this use case is to proceed with a combined “EV charging process and public building consumption management” scenario towards the delivery of a coordinated energy management framework. This use case is evaluated in a small test bed, focusing on the management of EVs in conjunction with public building characteristics. Data gathered from LMIT public building (REFECTORY) and EV management platform (5 EV groups) are considered for the evaluation along with the selection of the criteria for optimization:

Baseline definition: This is the case where EV charging process is performed when plugged. In LMIT pilot site, this happens at morning hours when EV owners operate the vehicles’ fleet.

Charging during night: This is the case where EV charging process is performed during night hours with low energy consumption. The main objective of this case scenario is to perform a smooth charging process taking into account public building characteristics.

The results from the evaluation process are presented. We are starting the analysis with overall results, while further analysis is performed for a week period.

Energy Optimization						
Percentage Reduction (%)	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**	**Average**
Total Cost	-28.31%	-26.54%	-17.19%	-18.77%	-23.90%	-22.94%
CO2 Emissions	-2.66%	1.21%	-3.47%	1.18%	-1.71%	-1.09%
Peak Demand Reduction	13.6%-26.2%	19.4%-39.5%	13.6%-26.2%	31.6%-54.2%	11.6%-16.2%	11.6%-54.2%
EV charging Optimization Parameters						
EV Charging (KWh)	12.0525	25.02	122.15	69.24	48.07	55.31
EV/Public Building	5.87%	10.71%	48.04%	28.39%	22.14%	23.03%

Table 48 EV & Public Building Coordinated Management

The coordinated management process significantly impacts total energy cost. By shifting charging process during overnight hours, this affects total energy cost (lower prices during overnight hours). The same goes for Peak Demand reduction at public building as the main objective of this scenario is to smooth charging process in order to avoid peak demand values. However, this is not the case for CO2 emissions, as a higher CO2 ratio is considered for night hours (data from PT energy mix). Therefore, a slight increase of total amount of CO2 emissions is reported.

The above table presents the detailed input parameters considered for the evaluation process (charging requirements and public buildings consumption). In this case scenario, the public consumption (LMIT Building) is rather low and thus we are examining the impact of mass EV charging process in total energy cost and peak demand management.

The next figure presents the results from analytics process for a week period.

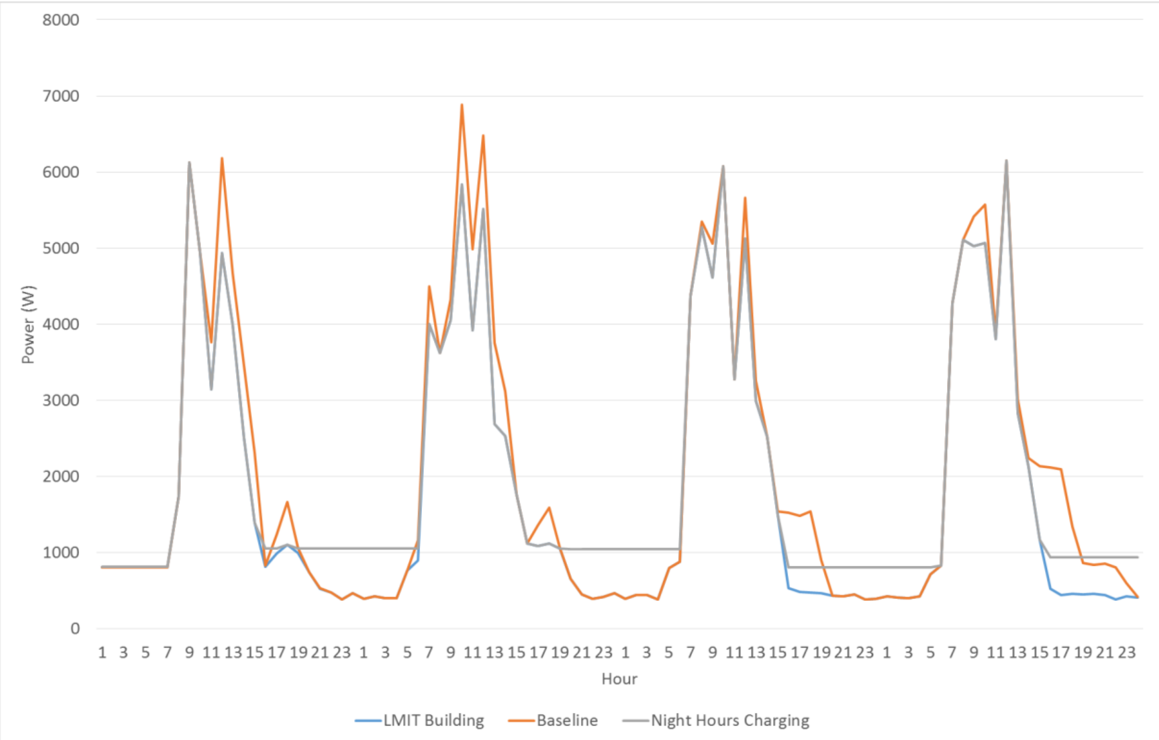


Figure 11 EV & Building optimization charging process

While the baseline charging process (charging when plugged), may or may not lead to charging during peak hours, this is not the case for charging during night hours. As depicted in figure above, the impact on charging process during value hours leads to an optimal management of EV fleet. It is clear that EV charging process may be performed in an optimal way, taking into account the high level settings from the facility manager of the building. We have to point out that on this case scenario the main objective is EV charging process taking into account public building demand curve. By shifting the charging process during night hours, we are getting a direct impact by smoothing energy consumption curve. The flexibility of EV charging process can be further exploited for the establishment of a sustainable environment as presented in the next use case.

Electrical Vehicles (EV) local optimization and storage capacity forecasting

This is the case scenario about electrical vehicles (EV) management plan, where the focus is on the management of the fleet of Electric Vehicles in an optimal way. Different types of optimization scenarios are examined (taking also into account technical constrains of the integrated platform) and the evaluation indicators for the case scenario are presented:

- Maximum EV fleet charging capacity
- Cost minimization for charging process
- CO_2 Emissions Reduction by charging during night hours

For that reason we are taking into account Input/configuration parameters for the case scenario which are:

- Maximum EV fleet charging capacity
- CO_2 emissions level
- Electricity Tariffs

For this case scenario we consider the full portfolio of EVs integrated in the platform. The results from the evaluation process are presented:

Cost Optimization						
Percentage Reduction (%)	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**	**Average**
Total Cost	-50.02%	-48.35%	-27.48%	-35.09%	-44.18%	-41.02%
CO2 Emissions	-3.46%	5.62%	-1.90%	2.73%	-0.10%	0.58%
Energy Optimization						
Percentage Reduction (%)	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**	**Average**
Total Cost	-35.21%	-33.66%	-21.08%	-30.96%	-33.80%	-30.94%
CO2 Emissions	-3.36%	1.10%	-3.29%	-1.14%	-1.14%	-1.57%

Table 49 Electrical Vehicles (EV) local optimization Scenario

The cost minimization scenario leads to a drastic decrease on total cost for charging process compared to baseline scenario. This differentiation is mainly affected by the cost of energy and the implementation of dynamic pricing models in pilot site. Therefore, it is of high importance to highlight the establishment of an optimization framework for the management of EV fleet. Similar results are also considered for the energy management scenario (shifting during night hours). Even the total cost reduction is lower (compared to cost optimization scenario), this case scenario does not require the installation of expensive hardware equipment. The goal of the “shifting during night hours” scenario is to shift the charging process at night hours (after 22:00), by triggering the charging process following a typical pattern (and thus only a timer switch is required for the establishment of this framework). The results from charging process at these 2 scenarios, compared to the baseline scenario are presented for an indicative week period.

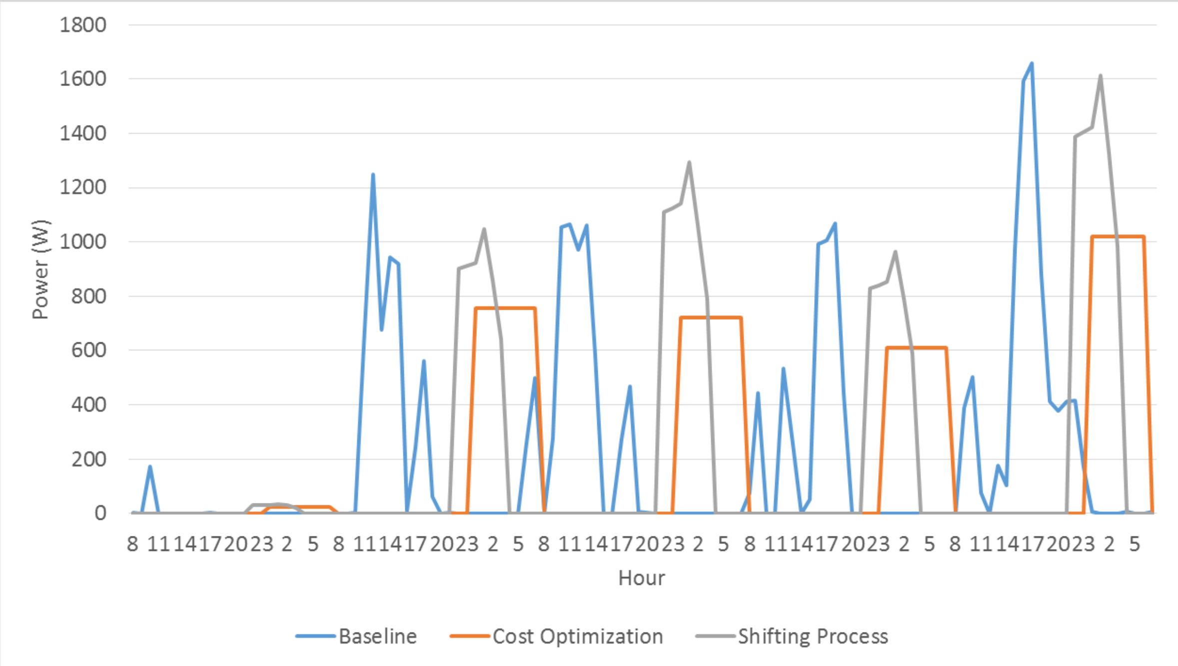


Figure 12 Electrical Vehicles (EV) local optimization Scenario

From the figure above, we highlight the impact of cost optimization process in overall charging process. While the baseline scenario shows demand peaks at critical peak hours, the demand shifting scenario manages charging process at night hours, without avoiding the peaks on charging process and further cost optimization scenario manages a charging process at night hours, handling also the issue with peak demands. In other words, the cost optimization scenarios further smooths the charging process at low tariff operational period.

In contrary to significant cost reductions due to charging process at nigh hours, this is not the case for CO2 emissions reduction. Taking into account data coming from PT site about CO2 emissions ratio, this is higher during night hours. Therefore, and proceeding with CO2 emissions calculation, we report an increase in total CO2 emissions. However, the difference in CO2 emissions ratio during day and night hours is rather low and thus the final impact on CO2 emissions is negligible.

The first part of this analysis is focusing on the evaluation of cost optimization process (either by the establishment of an optimization framework or by shifting charging process during night hours). Following to this, we are reporting also the impact on storage capacity of each EV charging park. Nowadays, the cost for charging infrastructures is high and remain as a main boundary for mass usage of EVs.

Therefore, it is of high importance to examine scenarios that optimally manage the charging process in existing infrastructures avoiding that way the cost for extra investments. In this case scenario, we are considering the optimization process where the goal is the maximum exploitation of existing infrastructures (mainly during night hours). The maximum capacity for charging process is defined as 20 KW, taking into account EV operational scenarios in PT pilot site and the optimization process is performed during night hours in order to ensure the maximum capacity usage. Therefore, this case scenario is considered as an extension of energy optimization scenario presented in previous use case, and the results from optimization process are presented in the following table:

Percentage Change (%)	Period 1	Period 2	Period 3	Period 4	Period 5	Total
Baseline Scenario						
Max Number of EVs	**25**	**12**	**6**	**5**	**7**	**55**
EV Max Host Capacity						
Max Number of EVs	**40**	**18**	**9**	**7**	**7**	**81**
Total Cost	-34.84%	-33.81%	-20.69%	-30.58%	-32.58%	-30.50%
CO2 Emissions	-2.44%	2.24%	-2.14%	3.43%	-0.79%	0.06%

Table 50 Electrical Vehicles (EV) Storage Capacity Scenario

The case scenario in PT pilot site enables us to examine different situations as there are different charging patterns defined. One way or another, and by optimally managing the charging process during night hours, we establish a framework for mass EV management. The table presents the impact on charging process which leads to a 47% increase on exploitation of charging capacities (if EVs available for charging process).

In addition, and due to charging process during night hours, we manage to decrease total cost for charging process (as we did in previous case scenarios where we also examine the impact of charging process at night hours). Following the common way of presenting the data from the different optimization processes, we also report a slight increase on total CO2 emissions due to the increased CO2 emissions ratio at night hours.

As a last step of this case scenario, we further evaluate the impact of replacing conventional vehicles with electric vehicles in terms of CO2 emissions. For this case, we are considering the following parameters for the analysis. The results for the specific case scenario examined in PT pilot site are presented in the following table:

Period	Wh	KWh	Equivalent Distance (km)	gCO2 passenger	gCO2 electric	% Difference
Period 1	12052.5	12.0525	60.2625	7436.3925	3310	-55.49%
Period 2	25020	25.02	125.1	15437.34	3343	-78.34%
Period 3	122150	122.15	610.75	75366.55	24430	-67.59%
Period 4	69240	69.24	346.2	42721.08	18285	-57.20%
Period 5	48070	48.07	240.35	29659.19	14693	-50.46%
Average	**55306.5**	**55.3065**	**276.5325**	**34124.1105**	**12812.2**	**-61.82%**

Table 51 Electrical Vehicles (EV) replacement of conventional vehicles

As expected, the replacement of conventional vehicles with EV cars leads to a high decrease of CO2 emissions. This is actually one of the main objectives for electrical transportation in large cities, as the way to minimize the impact of CO2 emissions by using electric vehicles.

From aforementioned analysis, we can show the impact of EV charging towards the establishment of a sustainable environment in district level, addressing energy costs, CO2 emissions and RES maximum exploitation. The incorporation of EV charging process as part of an integrated scenario (addressing also energy consumption data) will be examined in the holistic smart city management scenario.

Energy demand curve optimization based on traffic conditions

The integration of traffic lighting EMSs in Lisbon pilot site does not enable the evaluation of this case scenario. Only aggregated energy consumption data are available, while we are missing information about traffic density; key parameter for the evaluation of this test scenario. A snapshot from a 2-month period of energy consumption data is presented in the following schema.

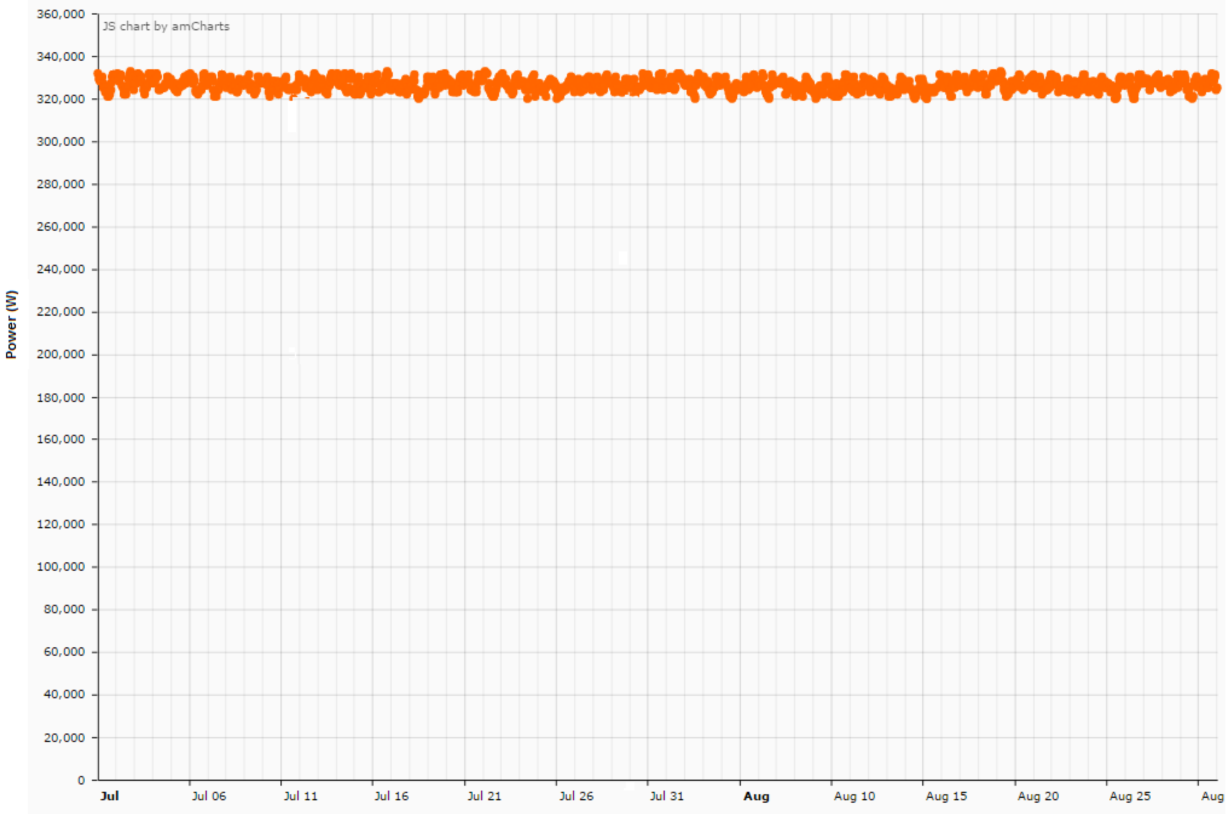


Figure 13 TLS consumption data from Lisbon Pilot site

The figure above shows a constant value for total energy consumption, considering also the non-controllability of the TLS solution installed in premises. In order to provide a concrete evaluation of BESOS platform in Lisbon pilot site, a simulation scenario was conducted (following the same approach as in "Energy demand optimization of the public lighting based on light environment" use case). Input data required for the evaluation of this use case were retrieved from BCN pilot site. The results from this simulation scenario are presented in Annex C.

Energy demand monitoring and optimization in public buildings

Following the first round of evaluation, and due to lack of controllability at building EMSs, the objective remains as: to provide a framework for optimal management of public buildings taking also into account the implementation of dynamic pricing schemas. During the 2nd reporting period, we have extended the number of building assets, enabling that way a more concrete evaluation of public buildings management process.

In this case scenario, the same tariff policies and baseline scenarios are considered for evaluation. The goal is to compare different tariff schemas with the main objective of energy cost minimization. The results from simulation process are presented per pilot site.

	Tariff 1	Tariff 2	Tariff 3	Tariff 4
Building ID	Total			
Olivais	€ 808.66	€ 619.70	€ 757.62	€ 739.73
DRFM	€ 628.86	€ 522.55	€ 631.32	€ 619.10
Campo Grande	€ 26,355.19	€ 22,111.63	€ 26,566.02	€ 26,094.75
LMIT	€ 197.69	€ 163.05	€ 196.47	€ 192.75
Building ID	Average Week			
Olivais	€ 161.73	€ 123.94	€ 151.52	€ 147.95
DRFM	€ 125.77	€ 104.51	€ 126.26	€ 123.82
Campo Grande	€ 5,271.04	€ 4,422.33	€ 5,313.20	€ 5,218.95
LMIT	€ 39.54	€ 32.61	€ 39.29	€ 38.55
Building ID	Difference from Baseline Tariff 1			
Olivais		-23.84%	-7.06%	-9.18%
DRFM		-17.03%	0.71%	-1.44%
Campo Grande		-16.12%	0.77%	-1.01%
LMIT		-17.46%	-0.53%	-2.42%

Table 52 Lisbon city 2nd phase – Alternative Tariffs evaluation

The table above presents the results for each pilot site evaluated during the reporting period. Again, a 5-week testing period is considered for evaluating the **total** and **average** energy cost. Compared to the 1st round of trials, the implementation of dynamic pricing policies is not beneficiary for all pilot sites. In some case scenarios (energy consumption profiles), a dynamic pricing policy may lead to an increase in total energy cost. Special interest is delivered also on the comparative analysis among the different pilot sites examined (e.g. Campo Grande energy cost reduction is significantly lower compared to Olivais site energy cost reduction).

Once again we highlight the impact of the 2nd tariff schema where an 18.61% energy cost reduction is reported.

This simulation analysis is useful for the selection of optimal pricing policies in a deregulated energy market environment. Even with limited or no control, and thus with no impact in total energy consumption, we can establish a dynamic management framework, evaluating the impact of different pricing schemas in energy cost. Therefore, one of the main innovations brought by the project is this tool to examine the different tariff policies and how these affect the overall system operation.

Smart city Energy demand curve optimization

This is a mixed scenario where the objective is the coordinated management of the different types of assets towards the optimal management of the portfolio. More specifically we consider:

- PLS management taking into account environmental conditions and traffic density data (for Traffic PLS)
- EVs assets taking into account the flexibility of charging process
- RES penetration though integration of different generation types
- Alternative pricing policies for public buildings.

This is a complex scenario where the different types of services developed in BESOS project are integrated under a common evaluation framework. The steps for the optimization process are presented:

- Step 1: Impact of PLS and TLS management process and further evaluation of alternative pricing policies considering also public buildings consumption

- Step 2: Impact of RES penetration
- Step 3: Coordinated management of EVs taking into account alternative pricing policies

The testbed for evaluation includes:

- Public Buildings: Olivais & DRFM & LMIT buildings taking into account data about maximum power consumption
- EV fleet: A total number of 25 EVs is selected for simulation, by extrapolating the data from available EVs
- PLS portfolio, considering simulated data as coming from BCN municipality pilot site (as we are not retrieving energy data from Lisbon PLS pilot site)
- 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)
- RES integration, considering integration of Olivais PV (3 x) and Montegordo (0.1 x) wind park in order to examine an integrated case scenario.
- For the list of alternative pricing policies as presented above, we are selecting for our evaluation process, **Tariff 4**, as the one with the maximum impact on energy cost.

The results from the evaluation process are presented, highlighting the impact of each specific strategy at the final results. We are starting the presentation analysis considering the impact of integrated PLS and TLS management framework. As presented above, we have a direct impact on total energy consumption, concerning that dimming control strategies are performed. This affects also the total energy cost as the dimming process is delivered mainly at twilight hours where the cost of energy is even higher. In addition, we are reporting also the impact of dynamic pricing models that affect the cost of energy for total demand (considering TLS, PLS and Public Buildings). Furthermore, a direct impact on CO2 emissions is reported, considering also the amount of energy reduction.

The results from analysis are presented:

	Week 1	Week 2	Week 3	Week 4	Week 5
Total Load					
Consumption (KWh)	6029.227095	4978.773645	5304.403895	5396.165645	4993.467645
Cost (euro)	1032.806601	852.8639254	908.6443873	924.363175	855.3810076
CO2 Emissions(gr)	1688.755047	1391.802042	1481.611597	1509.631552	1395.475349
Total Load with TLS & PLS Management					
Consumption (KWh)	5275.521825	4223.933375	4550.698625	4639.380375	4239.762375
Cost (euro)	792.1606344	613.3211795	666.8725307	689.9242236	615.4389653
CO2 Emissions (gr)	1479.271958	1181.980313	1272.188195	1299.28387	1185.99226

Table 53 Total Load with TLS & PLS Management

The potential from LS system is high, considering that limited control strategies are implemented in existing premises. The impact is even higher considering that both PLS & TLS system pose a significant load at city level. On the other hand, we highlight also the impact of dynamic pricing schemas in total energy load (TLS, PLS and public Buildings). The next figure presents a typical week period, highlight the implementation of PLS &TLS control strategies.

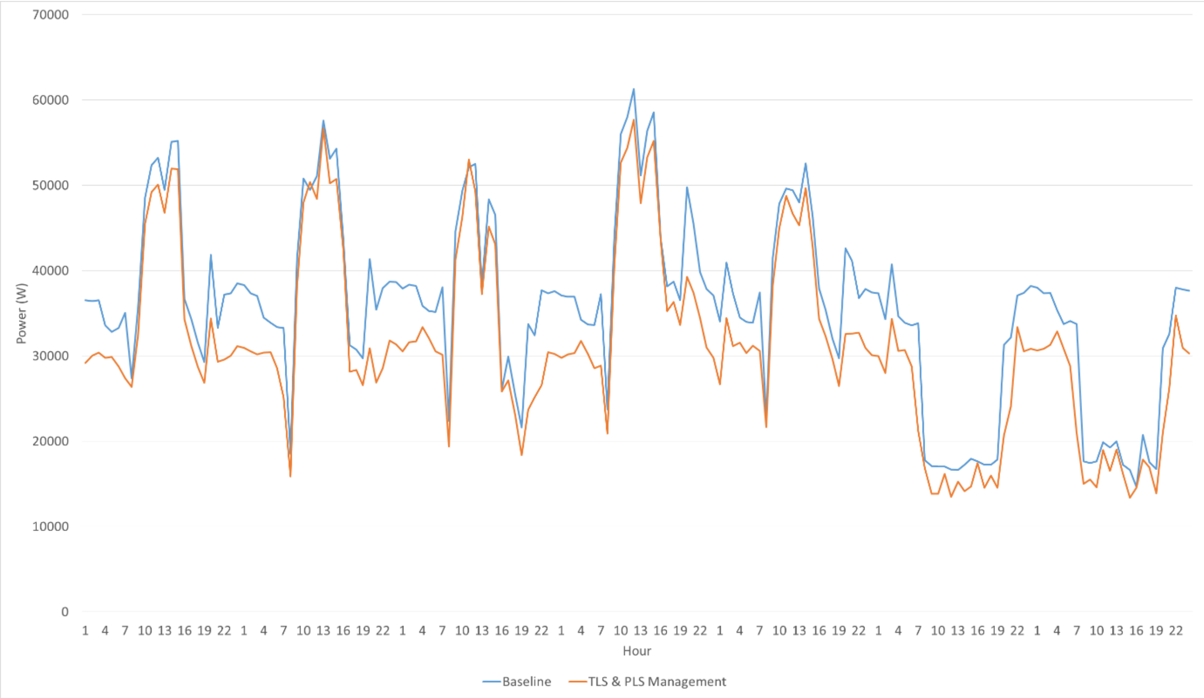


Figure 14 PLS &TLS Management Scenario

A demand shedding is reported for the reporting period, with an even higher impact at night hours mainly affected by the low traffic density data. Following the analysis of PLS & TLS systems, we are further integrating RES generation in the holistic framework. Nowadays, there is an increasing investment on RES units for self-consumption coverage and thus we are examining the direct impact of these units in total energy consumption. The analysis is performed for both wind and PV generation, covering that way both technologies incorporated in BESOS project. The results from the mixed scenario are presented:

	Week 1	Week 2	Week 3	Week 4	Week 5
Total Load					
Consumption (KWh)	6029.227095	4978.773645	5304.403895	5396.165645	4993.467645
Cost (euro)	1032.806601	852.8639254	908.6443873	924.363175	855.3810076
CO2 Emissions(gr)	1688.755047	1391.802042	1481.611597	1509.631552	1395.475349
Total Load with TLS & PLS Management & RES Integration					
Consumption (KWh)	4798.882425	3554.418175	4082.789925	4110.476675	3811.762675
Cost (euro)	714.351975	503.2976097	588.8042623	602.7770497	541.0377048
CO2 Emissions (gr)	1344.417856	992.4914453	1139.366334	1149.145845	1064.035964

Table 54 Total Load with TLS & PLS Management& RES Integration

It is clear that by integrating RES technologies in smart city environment we manage to reduce both energy consumption and CO_2 emissions, as we are introducing a new technology with zero impact on CO_2 generation. In the aforementioned analysis, we are not considering the cost of investment for this technology, as the installations are already in place. Therefore, the impact at energy cost is reported, proportional to energy consumption reduction. The next figure presents the impact of RES technology for a week period, compared to the previous case scenario and the implementation of TLS & PLS Control Strategies.

Figure 15 RES Integration Management Scenario

A reduction in energy consumption is reported, focusing on the impact at day hours due to PV penetration. On the other hand, a slight reduction is reported also at the rest of hours of the time period, considering also the impact from wind generation integrated in this case scenario.

The last step of the optimization process is the analysis of shiftable loads considering the rest of the assets and control strategies already implemented. There are 2 types of shifting procedures examined in the project:

- EV charging process taking into account energy cost and consumption curve
- Pseudo-shifting process through the evaluation of alternative pricing models, which was examined above through the evaluation of energy cost in different pricing schemas.

The integration of EV technology is examined as part of the integrated analysis, considering the optimization based on energy cost (pricing schema). The results from optimization process are presented.

	Week 1	Week 2	Week 3	Week 4	Week 5
Total Load					
Consumption (KWh)	6029.227095	4978.773645	5304.403895	5396.165645	4993.467645
Cost (euro)	1032.806601	852.8639254	908.6443873	924.363175	855.3810076
CO2 Emissions(gr)	1688.755047	1391.802042	1481.611597	1509.631552	1395.475349
Holistic Management Scenario					
Consumption (KWh)	4798.882425	3554.418175	4082.789925	4110.476675	3811.762675
Cost (euro)	709.2684328	493.2379648	562.9605118	584.2534605	524.8650402
CO2 Emissions (gr)	1344.110882	991.7359038	1139.920269	1148.2169	1063.65675

Table 55 Holistic Management Scenario

It is clear that the total consumption remains the same (as demand shifting process does not affect the total consumption) with an impact in total energy cos (by shifting loads at low tariff hours). The next schema presents the impact of EV charging process, compared to the previous case scenario and RES integration.

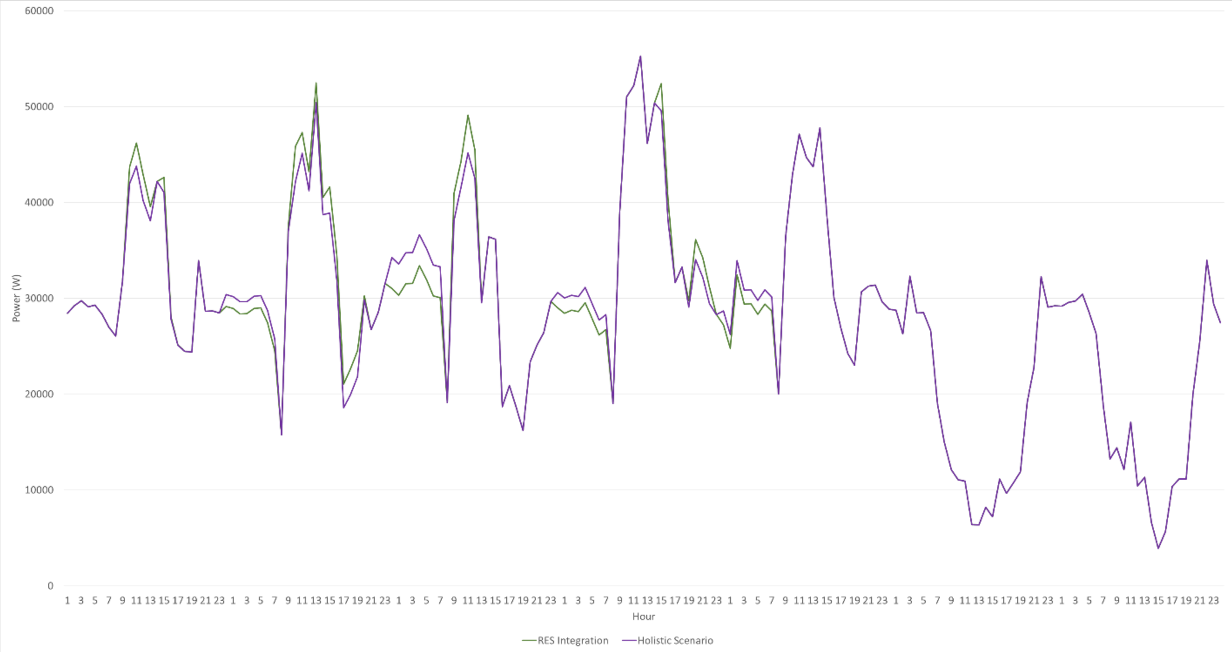


Figure 16 Holistic Management Scenario

The figure above shows the results from demand shifting process through charging at night (low cost) hours. Therefore, we are showing a demand reduction at peak day hours and further increase of consumption at low demand night hours.

The overall impact (baseline → holistic management framework) is presented in the following figure.

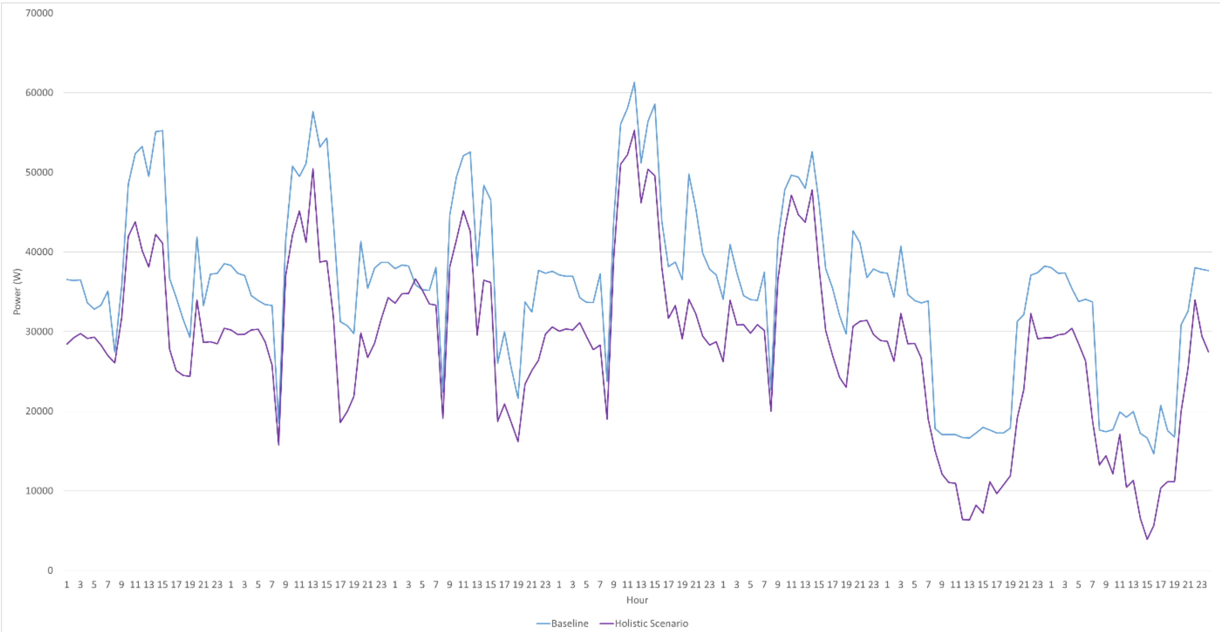


Figure 17 Holistic Management Scenario_A

While the impact from each separate asset type, when integrated in the platform is rather low, this is not the case for the integrated scenario. By coupling different types of technologies, we increase the level of flexibility for the system, enabling that way the optimal management of integrated assets. A summary of the impact from the different control strategies towards the delivery of the holistic management scenario is presented in the following table:

	Week 1	Week 2	Week 3	Week 4	Week 5	Average
Total Load						
Baseline	-	-	-	-	-	-
Total Load with TLS & PLS Management						
Consumption	-12.50%	-15.16%	-14.21%	-14.02%	-15.09%	**-14.20%**
Cost	-23.30%	-28.09%	-26.61%	-25.36%	-28.05%	**-26.28%**
CO2 Emissions	-12.40%	-15.08%	-14.13%	-13.93%	-15.01%	**-14.11%**
Total Load with TLS & PLS Management & RES Integration						
Consumption	-20.41%	-28.61%	-23.03%	-23.83%	-23.67%	**-23.91%**
Cost	-30.83%	-40.99%	-35.20%	-34.79%	-36.75%	**-35.71%**
CO2 Emissions	-20.39%	-28.69%	-23.10%	-23.88%	-23.75%	**-23.96%**
Holistic Management Scenario						
Consumption	-20.41%	-28.61%	-23.03%	-23.83%	-23.67%	**-23.91%**
Cost	-31.33%	-42.17%	-38.04%	-36.79%	-38.64%	**-37.39%**
CO2 Emissions	-20.41%	-28.74%	-23.06%	-23.94%	-23.78%	**-23.99%**

Table 56 Holistic Management Scenario- Summary

From aforementioned analysis, we highlight the impact in total energy consumption and CO2 emissions considering the implementation of different control strategies that directly affect the KPI values (TLS&PLS management, RES penetration).

Even higher is the impact in energy cost, considering the implementation of additional control shifting strategies that do not affect modify consumption but directly affect energy cost (alternative pricing models and EV charging at low price hours). This differentiation is reported in all case scenarios and time periods examined during the evaluation process.

We have to point out that during this reporting period, the full list of assets is integrated in the platform. By enabling controllability at electric vehicles and traffic lighting systems we can provide flexibility to the system towards the optimal portfolio management. Actually, this is the main objective of BESOS platform: *to enhance existing neighbourhoods with decision support system to provide coordinated management of public infrastructures in Smart Cities.*

Modification of user behaviour

The initial plan was to evaluate the impact of BESOS behavioural triggering framework by analyzing energy consumption data. Though, (1) the lack of sub metering data on the selected zones where BMA application was demonstrated and (2) the mandate to enhance citizens' participation on BESOS project activities, led us to proceed with end users experience evaluation by conducting questionnaire surveys. Therefore, the results for the evaluation of this use case (modification of user behaviour) are provided in the next section through citizens' questionnaires analysis.

Measurement of the renewable energy produced and predicted in the distribution network

The forecasting engine, integrated in BESOS project, is considered as a big data analytics engine, performing analytics over historical data towards the extraction of accurate forecasts. During the 2nd evaluation period and following a long training period, the results of forecasting engine operation are 16.51% on average. The next table shows the results about RES forecasting engine evaluation:

Pilot Site	MAPE Error
TU Lisbon PV park	14.96 %
Olivais School	15.31 %
Montegordo Wind Farm	19.25 %

Table 57 Generation Forecasting Evaluation

A screenshot from a 5-days period is presented in the following figure:

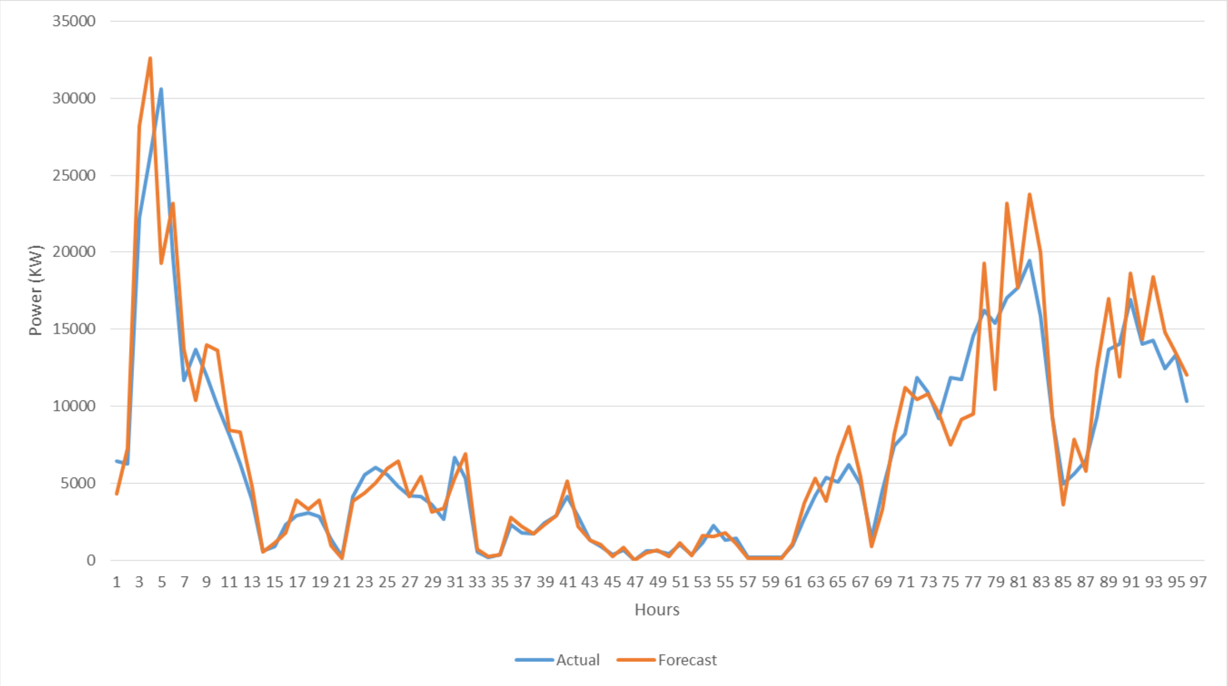


Figure 18 Montegordo Wind Farm forecasting

The main differentiation from the 1st reporting period is the different weather conditions. The 1st round of evaluation was conducted during winter period, while the 2nd evaluation process is performed at summer period. This differentiation does not affect the results of the engine, as the seasonal aspects are inherent in the calculation framework of BESOS forecasting engine. On the other hand, we can show a higher level of accuracy at forecasted data, compared to 1st evaluation period, due to the longer training period of data analytics engine.

Predict the energy consumption on weather data

Following the evaluation of energy production forecasting engine, the evaluation of consumption forecasting engine is presented. The details of energy consumption forecasting engine are reported in WP4, though we highlight that the service is available for HVAC consumption forecasting. This is one of the main innovations of BESOS project, integrated at the reporting period, delivering the service for the list of public buildings with HVAC main loads. The table presents the results from evaluation process:

Pilot Site	MAPE Error
Campo Grande I	29.13 %
Campo Grande II	30.57 %
Campo Grande III	27.11%

Table 58 Consumption Forecasting Evaluation

An average MAPE Error 28.94% period is reported. A screenshot from Campo Grande I device type is presented in the following figure:

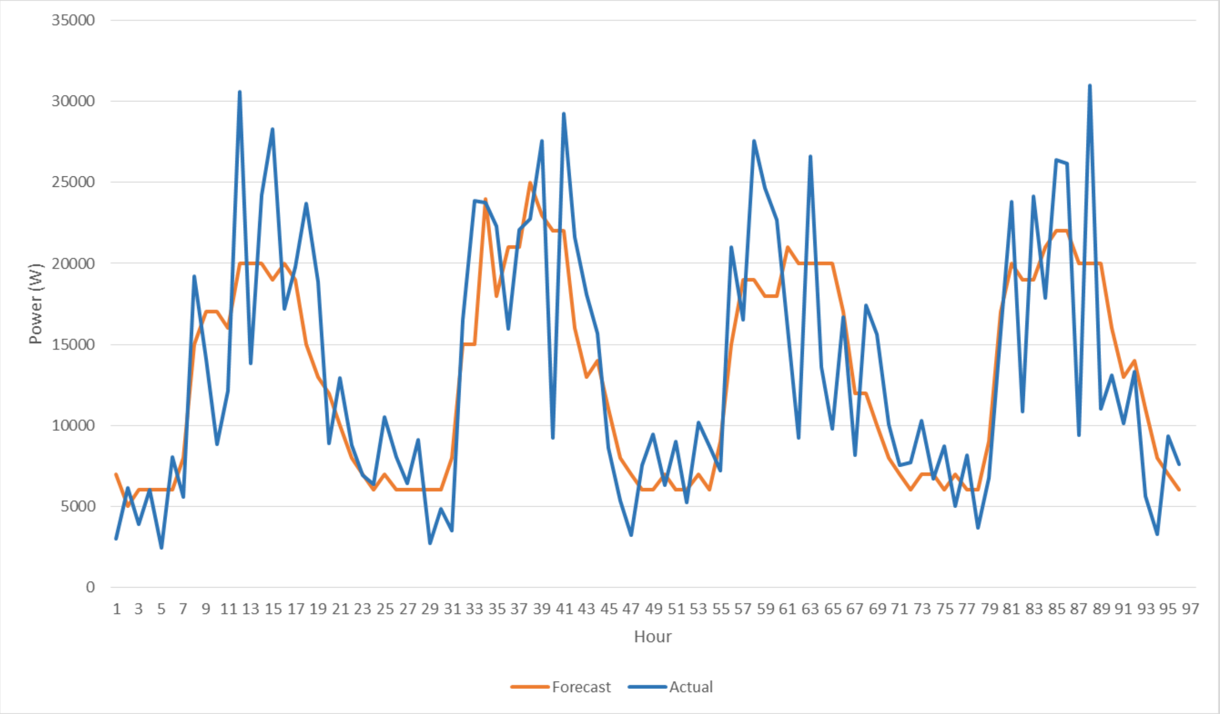


Figure 19 Campo Grande I Consumption Forecasting

Towards providing accurate energy consumption forecasts, different input parameters (static and dynamic parameters) are considered in the model, presenting that way a framework to perform accurate forecasts even at device level.

Measurement / control of the electric energy quality

The scope of this scenario is to evaluate the performance of portfolio assets taking into account power factor data captured by the different EMSs types integrated, mainly public buildings. We have already defined the baseline for power factor (during 1st evaluation period), and thus the analysis is focusing on the level of fulfilment of the different public buildings integrated in BESOS.

Pilot Site	Percentage deviation
Olivais School	1.24 %
DRFM	3.25 %
Campo Grande	4.68%
LMIT	1.78 %

Table 59 Power Factor Index Analysis

There are no significant outliers on power factor values to be reported. The evaluation analysis is performed in commercial (non-industrial) public buildings where typical business processes are taking place and thus the power factor values are mainly based on active power consumption data (low reactive power demand). Considering the integration of LMIT building during the 2nd round of trials, we are defining the baseline for this asset type (0.65: the baseline value considering the high demand for reactive power). A typical screenshot from a week period showing the pattern on PF values is presented.

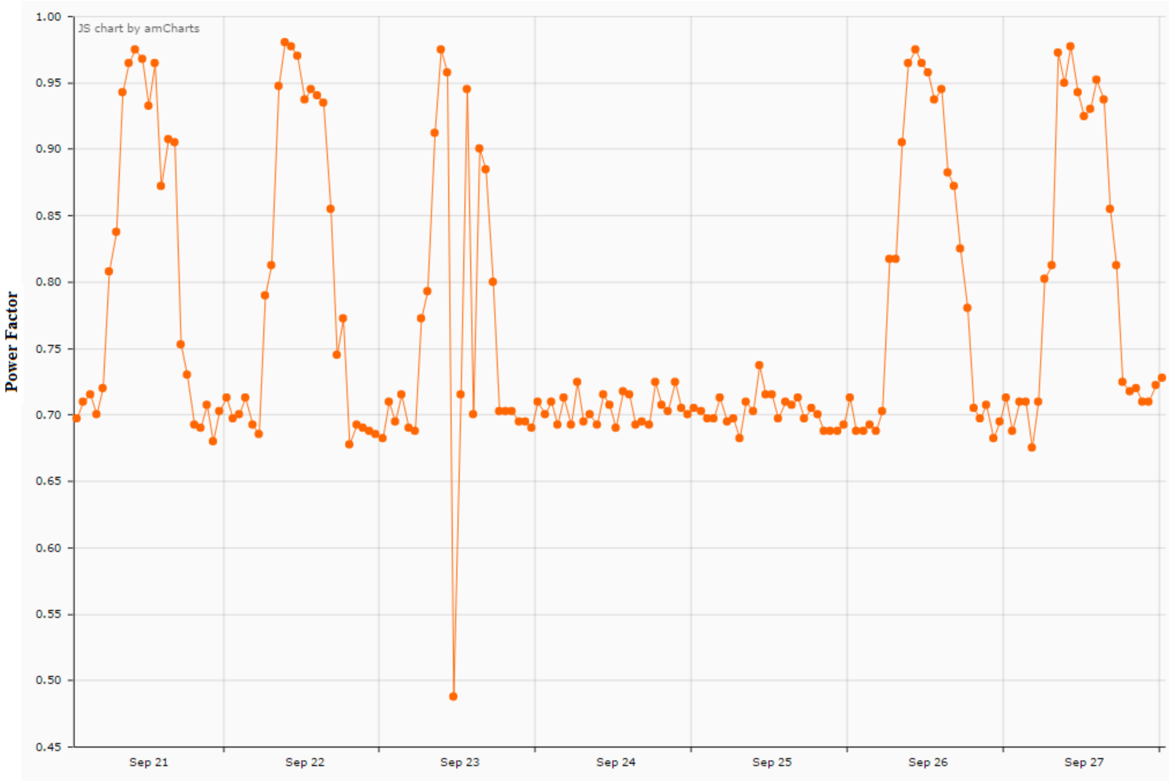


Figure 20 LMIT Building Power Factor Values

We are reporting high power factor values at working days, with low power factor values at non-working days (weekends & night hours). Also an outlier is detected (PF=0.50), further defined as a deviation point in Table 59.

Preventive Maintenance Alarm

Following previous use case analysis, where the focus is on monitoring power factor indicator, the goal on this scenario is to evaluate the performance of DSS “Alarm Service” in case of abnormal conditions. Taking into account PF indicator limits, BESOS DSS triggers prompt control strategies in order to minimize PF outliers. The results from demonstration period are presented for assets providing energy power quality data.

Pilot Site	Successful Triggering Alarm
Olivais School	100%
DRFM	100%
Campo Grande	100%
LMIT	100%

Table 60 Preventive Maintenance Alarm Analysis

We have to point out that due to non- controllability at public buildings, we are evaluating the reliability of alarms triggered by BESOS DSS. As expected, BESOS DSS triggers an alarm message when an abnormal situation occurs, further enabling the implementation of optimal control strategies.

For the 2nd evaluation period, the main objective was to extend the list of integrated assets in order to address the full set of use cases examined in the project. Especially for Lisbon pilot site, the focus is on the adaptation of assets and systems integrated during the 2nd evaluation period (Public Lighting System, Traffic Lighting System, Electric Vehicles, Consumption Forecasting Engine) towards the establishment of a sustainable energy management framework.

4.2 Barcelona Pilot Site Evaluation

During the 2nd iteration, the focus is on the adaptation of the full list of EMSs at Barcelona pilot site, along with the evaluation of the use cases defined in the early phase of the project. Again, the evaluation analysis is performed per use case, following the evaluation plan and the selected evaluation criteria/indicators.

Prior to impact assessment analysis, the **Efficient Monitoring of each Facility** is evaluated to ensure the reliable operation of BESOS assets. The analysis is performed for the full list of assets integrated during the reporting period:

Asset ID	Energy Consumption	Energy Cost	CO2 Emissions	Power Factor	Forecast
BCN Buildings	98.36%	98.36%	98.36%	98.36%	98.11%
SDX Buildings	95.02%	95.02%	95.02%	95.02%	98.11%
Public Lighting System	96.23%	96.23%	96.23%	96.23%	x
Traffic Lighting System	x	x	x	x	x
EV platform	99.04%	99.04%	99.04%	x	x

Table 61 Reliable Monitoring of Consumption Assets

Asset ID	Energy Generation	Forecast
Viudo	95.23%	87.5%
Ficosa PV	96.6%	87.5%
BCN PV	98.36%	x

Table 62 Reliable Monitoring of Generation Assets

Again a high level of reliability is reported for BESOS assets. OTESP, acting as the central middleware for BESOS system, ensures high level stability while the integrated assets are continuously feeding energy and contextual information to the system. Special interest is delivered for the analysis of the new assets integrated in the platform (public lighting, traffic lighting, additional RES), as this is the focus during the 2nd evaluation period. By ensuring a high level of reliability on assets integration, we further proceed with the evaluation of the core BESOS functionalities.

Energy demand optimization of the public lighting based on light environment

During the 2nd reporting period, the public lighting assets from BCN municipality were integrated in BESOS platform. Therefore, the evaluation process is performed in actual contributions, considering real time and historical data retrieved from the associated EMSs. The list of PLS assets integrated in the platform is presented

Id	GIS_Lat	GIS_Lon	Area	Nominal power W	Total Point of Lamps
1192	41.406	2.190	CORTS CATALANES, G.V.	11760	90
1996	41.408	2.184	VALENCIA, C	7530	32
2032	41.415	2.199	SELVA DE MAR, C	4814	100
2304	41.442	2.186	MERIDIANA, AV	29450	63
6568	41.400	2.201	LLULL, C	9620	71
6870	41.403	2.155	DIAMANT, PL	6145	91

7894	41.392	2.163	GRACIA, PG	4735	47
7895	41.393	2.161	GRACIA, PG	6065	70
7896	41.392	2.162	GRACIA, PG	4613	45
7897	41.394	2.161	GRACIA, PG	6307	64
7913	41.390	2.165	GRACIA, PG	7820	69
7914	41.390	2.165	GRACIA, PG	7675	71
7927	41.396	2.171	SANT JOAN, PG	9111	54
7937	41.451	2.187	SA TUNA, C	4657	60
7960	41.404	2.188	CORTS CATALANES, G.V.	14398	112

Table 63 List of PLS cabinets

The list of data available per cabinet integrated in the platform is:

- Local date and time
- Tension (V)
- Active power (W)
- Reactive power (VAr)
- Power factor (%)
- Accumulated (active) energy consumption (kWh)
- Accumulated inductive reactive energy (kVArh)
- Accumulated capacitive reactive energy (kVArh)

We have to point out that as the total installation is 135KW and thus PLS EMS is a significant load integrated in BESOS platform. Active power data are further considered during the evaluation process, taking also into account the potential of controllability of PLS assets. The results from the evaluation process (through simulation of control in PLS assets) are presented in the following table:

Evaluation Indicator	KPI Reduction
Energy Consumption	5.92 %
Energy Cost	8.51 %
CO2 Emissions	6.09 %

Table 64 PLS Control Strategies – BCN pilot site

We can show an even higher impact on total energy consumption, compared to the 1st evaluation period, mainly due to the different data values and control strategies examined during the evaluation process. A snapshot from a 2-day period for ID 7937 cabinet is presented in the following schema, highlighting actual vs. baseline consumption values at transition periods.

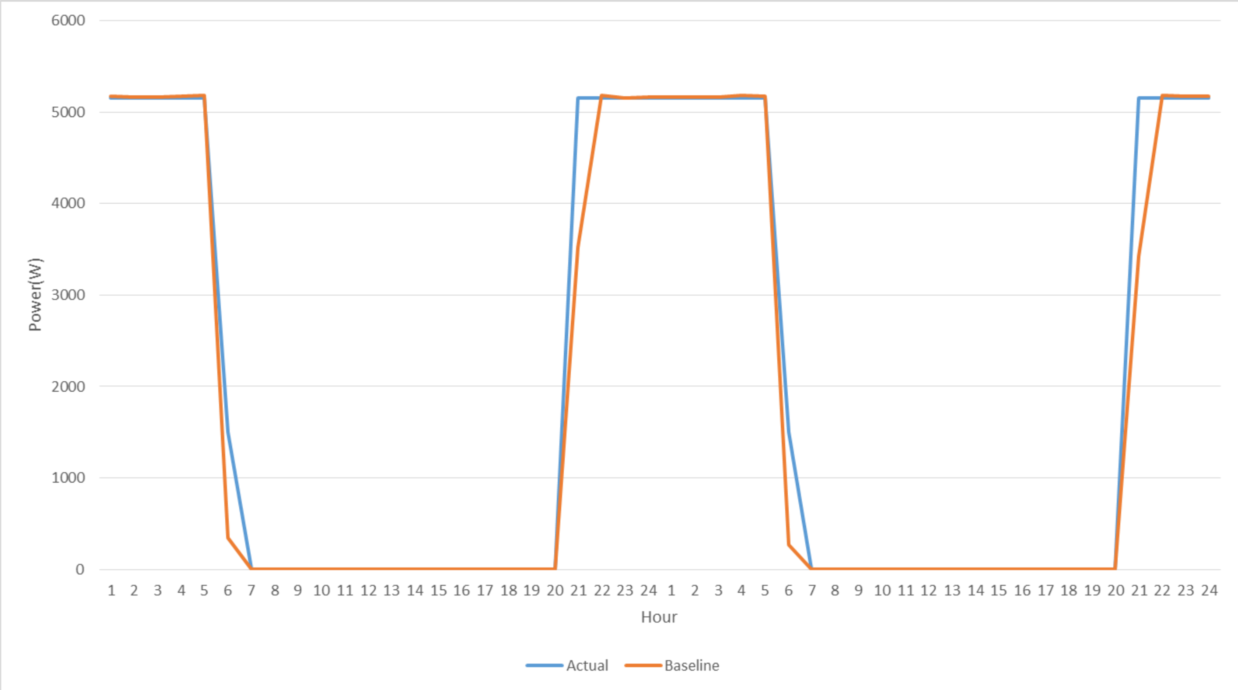


Figure 21 PLS Management- BCN scenario

Once again to point out the higher impact at energy cost reduction, as control strategies are implemented during twilight period where the cost of energy is even higher. This is not the case for CO2 emissions reduction which are equal to energy consumption reduction. Compared with the management of other city asset types, the impact at Energy Consumption of PLS is rather low. However, and towards the establishment of a holistic smart city framework, we will examine the integration of PLS assets as part of the common management framework.

Energy management for the use of electric vehicle fleet

During the 2nd round of trials, the integration of EV assets enables the evaluation of this use case. In this specific use case, we examine EVs in conjunction with public buildings and thus electric vehicle management process is delivered taking into account public building characteristics (virtually coordinated pilot asset). The public building asset and the associated EVs considered for the evaluation scenario are presented:

- **“IES Turó”** public building managed by SODEXO
- **Four electric vehicles (EVs)** consisting of the EV fleet for this case scenario
  - SRC301
  - SRC302
  - SRC601
  - SRC602

The main objective of this use case is to manage EV charging process taking into account public building energy consumption curve. More specifically, the objective is to avoid charging during high demand hours by shifting the charging process during overnight hours. The results from evaluation process are presented, focusing on the final impact at energy cost and CO2 emissions (total energy consumption remains the same as the priority is to fulfil charging requirements).

Percentage Reduction (%)	Period 1	Period 2	Period 3	Period 4	Average
Total Cost	-14.44 %	-12.63 %	-27.86 %	-21.10 %	-19.01 %
CO2 Emissions	2.42 %	3.42 %	5.67 %	1.76 %	3.32 %
Peak Demand	-10.54 %	-5.97 %	-8.95 %	-1.23 %	-6.67 %
EV Charging Process Parameters					
EV Charging (KWh)	37.9	37.3	41.7	11	31.98
EV/Public Building (%)	6.90 %	5.56 %	6.46 %	2.66 %	5.40 %

Table 65 EV & Public Building Coordinated Management

The coordinated management process significantly impacts total energy cost. By shifting charging process during overnight hours, this affects total energy cost (lower prices during overnight hours). The same goes for Peak Demand reduction at public building as the main objective of this scenario is to smooth charging process in order to avoid peak demand values. However, this is not the case for CO2 emissions, as a higher CO2 ratio is considered for night hours (data from Spanish energy mix). Therefore, a slight increase of total amount of CO2 emissions is reported.

In Table 65 , we also presented the EV charging parameters considered for the evaluation process and the EV consumption compared to building demand curve.

An average of 31.98 KWh about EV energy consumption for the reporting period (weekly period) is considered. The average energy consumption demand is rather low, showing the limited impact (usage) of EVs in Barcelona pilot site compared to public building energy consumption, showing a potential for installing additional charging points (charging capacity will be examined in the next scenario). The next screenshot depicts the impact of EV charging optimization process in public building demand curve (for a week period):

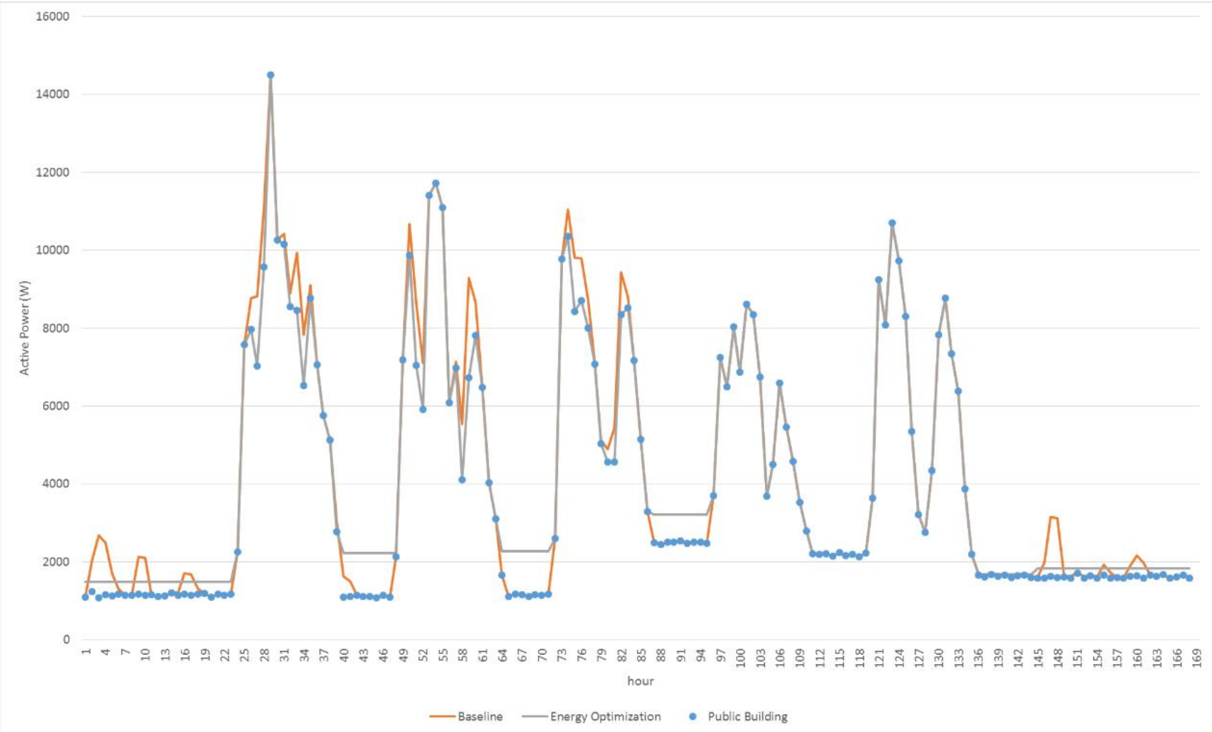


Figure 22 EV & Public Building Coordinated scenario

By promptly managing EV charging process taking into account public building characteristics, we can shift charging process at low consumption-valley hours and therefore eliminate peak demand points. The aforementioned analysis is focusing on the evaluation of control strategies taking into account public building load characteristics. This case scenario is referred as "private charging management scenario" towards the coordinated management of building and EV parameters (compared to "public charging management scenario" presented in the following section).

Electrical Vehicles (EV) local optimization and storage capacity forecasting

The main objective of this use case is the management of different charging points from a central entity (EVs aggregator) towards the implementation of optimal charging strategies. As presented at the ex-ante analysis, 2 types of control strategies (apart from baseline) are performed within BESOS charging framework (charging during night hours - CO2 emissions, charging during low prices). Taking into account the low penetration of electric vehicles in BCN city (and thus limited data from assets integrated in BESOS platform), a selection of charging points is considered to set the vehicles fleet. The results from BESOS DSS operation are presented.

Percentage Change (%)	Period 1	Period 2	Period 3	Period 4	Average
Shifting During Night Hours					
Total Cost	-16.73%	-14.68%	-25.31%	-21.91%	-19.66%
CO2 Emissions	5.04%	8.16%	4.44%	0.25%	4.47%
EV Cost Minimization Process					
Total Cost	-20.60%	-18.38%	-39.13%	-48.03%	-31.54%
CO2 Emissions	3.98%	8.45%	4.03%	3.63%	5.02%

Table 66 Electrical Vehicles (EV) local optimization

The 1st case is a simplified case where the charging process starts during night hours (shifting charging process during night hours). This process directly affects total energy cost and CO2 emissions values. More specifically, an average decrease (-20%) in total energy cost is foreseen due to low electricity prices during night. On the other hand, an increase in total CO2 emissions is anticipated due to higher CO2 emissions ratio values at night.

The 2nd case requires an optimization framework towards the minimization of charging results. An even higher impact in energy cost reduction is foreseen (average -31.54%). On the other hand, a 5.04% increase in CO2 emissions value is considered.

The aforementioned analysis shows that both control strategies lead to similar results. While "EV Cost Minimization Process" scenario requires the establishment of a complex algorithmic framework, the implementation of "Shifting during Night Hours" does not require a sophisticated management process and a low cost hardware installation (a relay timer operating at night hours) is required.

A screenshot with results from EV charging process is presented below:

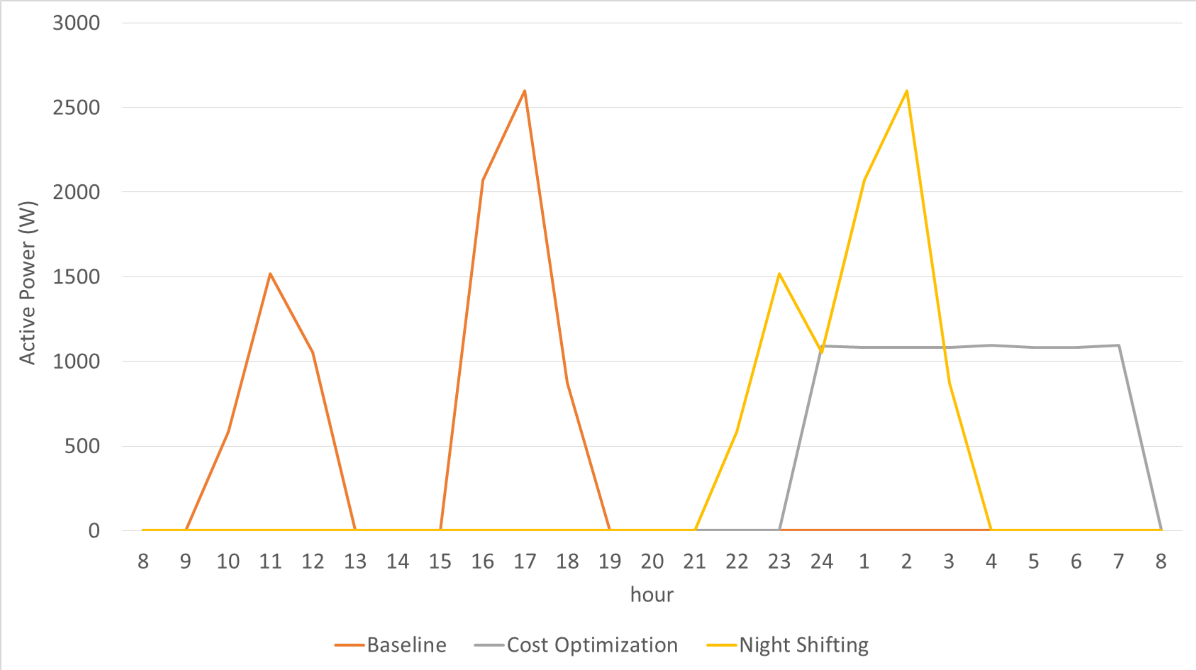


Figure 23 EVs local optimization scenario

From aforementioned analysis we can show that cost optimization scenario leads to a smooth and coordinated charging process. In this case, apart from energy cost reduction we also eliminate peak demands in daily curves. This is not the case for "Shifting during Night Hours" process as the synchronous EV charging may lead to critical grid conditions (e.g. rebound effect)

Apart from CO2 emissions and energy cost, additional indicators (**EV hosting capacity**, **CO2 reduction through EV penetration**) are calculated. For EV hosting capacity, a maximum demand capacity (20 KW total capacity with a max. 2KW per charging point) is specified for the evaluation process. The assumption is that the charging process is performed during night hours (22:00-06:00). The results from simulation analysis are presented:

Percentage Change (%)	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Total**
Baseline Scenario					
Max Number of EVs	**8**	**8**	**8**	**11**	**8**
EV Max Host Capacity					
Max Number of EVs	**17**	**18**	**17**	**26**	**17**
Total Cost	-17.67%	-15.39%	-31.54%	-36.36%	-25.24%
CO2 Emissions	3.99%	8.21%	5.04%	2.37%	4.90%

Table 67 Electrical Vehicles (EV) hosting capacity optimization

The coordinated charging process may lead to a significant increase on the number of EVs supported by existing infrastructures. This is a main objective of the industry in order to minimize or even eliminate the required installation costs for charging premises. As a side effect for this case scenario, we may also highlight the impact in total energy cost (significant reduction), while also a minor increase in total CO2 emissions. This scenario is an alternative to “Shifting during Night Hours” scenario presented above, considering as main objective the maximum exploitation of EV hosting capacity.

In addition, CO_2 reduction through EV penetration is a meta-indicator, considering the transition from fuel to electric vehicles. By taking into account specific configuration parameters (travelled distance: 0.20 kWh/km, emissions level: 123.4 g CO_2/km), we further estimate the final impact in CO_2 emissions.

Period	KWh	Equivalent Distance (km)	gCO2 passenger	gCO2 electric	% Difference
Period 1	37.909	189.5450016	23389.85319	12259.41676	-47.59%
Period 2	37.375	186.8750002	23060.37502	10805.69692	-53.14%
Period 3	41.719	208.5950008	25740.6231	16277.36071	-36.76%
Period 4	10.989	54.94499905	6780.212883	4038.75322	-40.43%
Average	31.998	159.9900004	19742.76605	10845.3069	-44.48%

Table 68 CO2 reduction through EV penetration

An average of **44.48%** CO_2 reduction due to EV penetration (compared to conventional vehicles) is foreseen for the case study examined. This is actually one of the main reasons to promote the mass EV penetration in large European cities, supporting that way the drastic reduction of CO_2 emissions.

The aforementioned analysis about “energy management for the use of electric vehicle fleet” is focusing explicitly at the optimal management of EV fleet. The integration of EV management framework to the holistic BESOS platform is evaluated in the next business scenario about “Smart city Energy demand curve optimization”.

Energy demand curve optimization based on traffic conditions

The integration of traffic lighting systems along with traffic density data enables the evaluation of this use case. The main objective of this use case is to optimally operate PLS systems, taking into account traffic density patterns. The level of lighting of a given point of light *p* in a road segment *r* will only depend on the following parameters:

- The minimum level of user comfort set by legislation
- The size of road
- The density of the traffic in the considered time slot t (scale 1..5)

For BCN pilot site, the demonstration is performed as:

Taking the length of each road lane, we are considering a point of light every 50 meters and 100 W per point of light. We consider a typical baseline curve as defined by the PLS solutions integrated in the platform. This is the main differentiation from TLS in Lisbon system where a flat energy consumption is considered for the whole evaluation period. We again defined three types of road:

- Low speed road, where speed <= 30 km/h
- Moderate speed road, where 30 < speed <= 60 km/h
- High speed road, where speed > 60km/h

All roads (80 streets are selected for demonstration analysis) are defined as moderate speed by default, except the ones which ID contain any of the following strings:

- Carmel-Ramiro de Maeztu, Ronda Dalt, Ronda Litoral, Passeig Valldaura, Passeig de la Zona Franca→ High speed road
- A mixing of moderate and low speed road for the rest of the streets selected for

Barcelona test site.

Based on the type of road and the traffic density, the following table is defined. Values represent the percentage of dimming to be set:

Traffic density	Low speed road	Moderate speed road	High speed road
Very light traffic (1)	0.6	0.5	0.4
Light traffic (2)	0.65	0.6	0.5
Heavy traffic (3)	0.7	0.9	0.9
Very heavy traffic (4)	0.75	0.8	0.9
Traffic jam (5)	0.8	0.5	0.4

Table 69 Traffic density data in BCN pilot site

Taking into account these rules, we proceed with the evaluation of BESOS DSS for TLS in Barcelona site, integrated in BESOS platform. The results from the demonstration of this use case are further presented for the 4 week testing period:

	Week 1	Week 2	Week 3	Week 4
Energy Consumption (KWh)	14937.105	14960.870	14803.470	14876.230
Energy Cost (euro)	1106.381	1108.112	1096.635	1101.907
CO2 Emissions (gr)	4189.789	4196.533	4152.047	4172.711
Actual vs. Baseline				
Energy Consumption	0.743	0.744	0.739	0.741
Energy Cost	0.751	0.752	0.747	0.750
CO2 Emissions	0.745	0.746	0.741	0.744

A time series analysis for a week period is provided, showing the impact of DSS control engine in Barcelona TLS assets.

Figure 24 Energy demand curve optimization based on traffic conditions

The figure above presents the results from simulation process. We are highlighting not only the lack of controllability taking into account traffic density data but even the lack of adequate lighting when required. Then a summary of the demonstration analysis results is provided highlighting the impact in BESOS evaluation indicators.

Evaluation KPI	KPI Reduction
Energy Consumption	- 25.84%
CO2 Emissions	- 24.99%
Energy Cost	- 25.59%

Table 70 TLS demand curve optimization

It is obvious that the impact in energy cost and CO2 emissions is mainly affected by the traffic density data and the dimming functionality implemented by TLS DSS. In addition, and as part of an integrated framework, TLS decision support tool could provide added value towards the establishment of a unified management framework.

Energy demand monitoring and optimization in public buildings

Following the 1st round of trials, the goal of the 2nd reporting period is on evaluating the impact of different pricing policies in public buildings, considering the different weather conditions (evaluation during summer period compared to the 1st round where the evaluation was performed during winter). The next table presents the results from the evaluation of different tariff schemas:

	Tariff 1	Tariff 2	Tariff 3	Tariff 4
Building ID	**Total Energy Cost**			
156	€ 1,310.54	€ 1,360.08	€ 1,405.62	€ 1,277.65
158	€ 2,388.77	€ 2,477.99	€ 2,552.19	€ 2,368.90
160	€ 2,885.79	€ 2,980.08	€ 3,086.20	€ 2,790.96
161	€ 764.61	€ 828.36	€ 839.51	€ 742.27
163	€ 1,274.38	€ 1,337.04	€ 1,374.54	€ 1,228.77
174	€ 1,925.97	€ 1,971.60	€ 2,054.22	€ 1,839.22
175	€ 1,407.87	€ 1,460.04	€ 1,508.08	€ 1,361.50
Building ID	**Average Weekly Cost**			
156	€ 262.11	€ 272.02	€ 281.12	€ 255.53
158	€ 477.75	€ 495.60	€ 510.44	€ 473.78
160	€ 577.16	€ 596.02	€ 617.24	€ 558.19
161	€ 152.92	€ 165.67	€ 167.90	€ 148.45
163	€ 254.88	€ 267.41	€ 274.91	€ 245.75
174	€ 385.19	€ 394.32	€ 410.84	€ 367.84
175	€ 281.57	€ 292.01	€ 301.62	€ 272.30
Building ID	**Difference from Baseline Tariff 1**			
156		3.84%	7.27%	-2.47%
158		4.27%	7.10%	-0.84%
160		3.30%	6.97%	-3.28%
161		8.54%	9.92%	-2.95%
163		5.04%	7.90%	-3.60%
174		2.51%	6.74%	-4.49%
175		3.70%	7.11%	-3.31%

Table 71 BCN Municipality Buildings demand optimization

The baseline for this case scenario is not a static tariff model as dynamic tariffs are already in place in BCN pilot buildings. The baseline tariff is on average **4.46%** cheaper than the equivalent single tariff (Tariff 2) and 7.57% cheaper than a dual tariff model with high prices during day. On the other hand, an alternative dynamic tariff model (Tariff 4) lead to a cost reduction by 3.00%.

The results are similar to the 1st reporting period, highlighting the impact of different tariff models in total energy cost. The establishment of dynamic tariffs may be beneficial for the consumers of the buildings and thus ESCOs show interest at providing this type of service (selection of the best fitted tariff model) to their customers.

The same evaluation approach is provided also for SDX Public Buildings. The goal of this comparative analysis is to show the impact of different tariff schemas for different case studies. The results from the evaluation process are presented:

	Timeslot 1	**Timeslot 2**	**Timeslot 3**	**Timeslot 4**
	Total Energy Cost			
CapCervello	€ 1,643.38	€ 1,793.28	€ 1,812.83	€ 1,574.37
ArxiuMunicipal	€ 6772.03	€ 7589.76	€ 7584.10	€ 6478.69
TomasaCuevas	€ 1252.86	€ 1319.76	€ 1360.34	€ 1237.65
Filmoteca	€ 12,316.55	€ 13,100.74	€ 13,402.93	€ 11,954.78
IesCanMargarit	€ 684.42	€ 786.12	€ 776.33	€ 648.90
UpCampusNord	1152.48	1225.02	1247.54	1081.64
	Average Weekly Cost			
CapCervello	€ 328.68	€ 358.66	€ 362.57	€ 314.87
ArxiuMunicipal	€ 1354.41	€ 1517.95	€ 1516.82	€ 1295.74
TomasaCuevas	€ 250.57	€ 263.95	€ 272.07	€ 247.53
Filmoteca	€ 2,463.31	€ 2,620.15	€ 2,680.59	€ 2,390.96
IesCanMargarit	€ 136.88	€ 157.22	€ 155.27	€ 129.78
UpCampusNord	€ 230.50	€ 245.00	€ 249.51	€ 216.33
	Difference from Baseline Tariff			
CapCervello		9.19%	10.35%	-4.20%
ArxiuMunicipal		12.08%	11.99%	-4.33%
TomasaCuevas		5.34%	8.58%	-1.21%
Filmoteca		6.36%	8.82%	-2.94%
IesCanMargarit		14.78%	13.39%	-5.12%
UpCampusNord		6.29%	8.25%	-6.15%

Table 72 SDX Buildings demand optimization

Similar results are presented for SDX buildings, with the implementation of variable tariff models. The baseline tariff is **10.11%** cheaper than the equivalent single tariff model (Tariff 2) and **10.85%** cheaper than a dual tariff model with high prices during day hours. On the other hand, the alternative tariff model (Tariff 4) lead to a cost reduction by **4.60%.** Therefore, the selection of optimal tariff models is a complex task, requiring the analysis of different parameters (load profiles, timeslots, and tariffs) for the selection of optimal tariff schemas.

The aforementioned dynamic tariff analysis will be further integrated in BESOS Decision Support System towards the establishment of an engine that will automatically enable the selection of best fitted pricing policies. As mentioned above, this is one of the main services offered by ESCOs companies to public building managers, to manage assets of the portfolio by selecting the most beneficial tariffs for their customers.

Smart city Energy demand curve optimization

This is the integrated scenario where the goal is the coordinated management of the different types of assets of the portfolio. More specifically we consider as part of the integrated scenario:

- PLS management taking into account environmental conditions
- TLS management taking into account traffic density data
- EVs charging engine taking into account their flexibility at charging process
- RES penetration by integrating of different generation types
- Alternative tariff policies for Public Buildings

The different steps of the optimization process are reported:

- Step 1: Impact of PLS and TLS management (load shedding) as this operation is independent from the rest of case scenarios
- Step 2: Impact of RES penetration , towards covering part of energy demand by exploiting RES generation
- Step 3: Coordinated management of EVs (load shifting) taking into account alternative pricing policies, considering that the cost of energy is lower during night hours.

In order to establish a concrete scenario, we are selecting part of the assets for the optimization process, setting a common scale for the different assets integrated in the platform. The testbed for evaluation includes:

- Public Buildings: 4 Barcelona Municipality public buildings with aggregated power demand at 210 KW and an average of 70 KW.
- EV fleet: A list of 250 EVs by extrapolating the data gathered from the existing charging points with a maximum charging point at 32 KW and an average of 9.8 KW
- PLS portfolio : A total number of 5 PLS cabinets with a nominal power at 25 KW
- TLS assets: Part of the transport zone (20 zone areas) integrated in the project, taking into account the available traffic patterns. The nominal power for the selected zone is 25 KW.
- RES integration: Both PV and Wind integration, considering also the PV units integrated in BESOS platform at this reporting period. An average of 18 W nominal power of RES is examined covering that way ~ 15% of energy consumption from RES generation.

We have to point out that the data for the evaluation analysis are coming from the actual pilot sites for all asset types selected. Therefore, we are addressing the main goal of the project, towards integrating heterogeneous asset types (RES, Public Buildings, Public &Traffic Lighting Systems, and Electric Vehicles) under a common management framework. The results from the evaluation process are presented, starting from TLS/PLS management. The impact of TLS/PLS is direct to the load curve, as we are performing control strategies on the two asset types. Special interest is delivered for the management of TLS through to integration of traffic density data at the reporting period. The results from the optimization process are presented.

	Week 1	Week 2	Week 3	Week 4	Week 5
Total Load					
Consumption (KWh)	16169	18763	16545	18383	20781
Cost (euro)	1859.411	2157.721	1902.691	2114.046	2389.828
CO2 Emissions(gr)	3066.305	3580.039	3124.869	3512.589	3967.837
Total Load with TLS & PLS Management					
Consumption (KWh)	15237.8	17789	15583	17420	19803
Cost (euro)	1684.0899	2002.5243	1737.7177	1934.7317	2225.7904
CO2 Emissions (gr)	2900.5591	3407.2634	2953.9777	3340.5127	3794.4004

Table 73 Total Load with TLS & PLS Management Scenario

The impact at energy consumption, cost and CO2 emissions is rather low, as presented also during the evaluation of the individual asset types. Though, we are performing load shed control strategies with a direct impact in all KPIs presented above.

As part of the evaluation process, we examine the impact of dynamic pricing policies. The implementation of dynamic pricing schemas directly affects the cost of energy (for TLS, PLS and Public Buildings) leading to an even higher reduction of energy cost compared to energy consumption reduction.

The next figure presents a screenshot of optimization process for a week period.

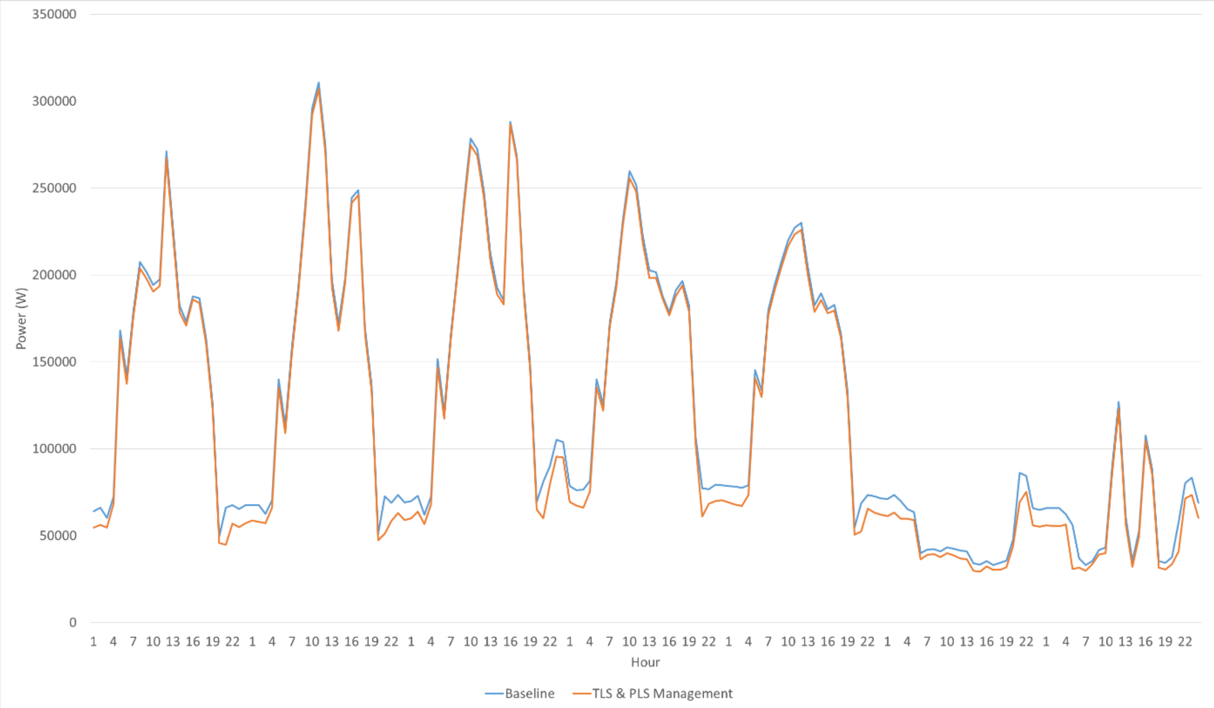


Figure 25 TLS & PLS Management Scenario

The TLS &PLS management curve is below the baseline curve with a significant different at twilight and night hours, as we are implementing the control strategies in TLS &PLS load types.

Moving forward, we are examining the impact of RES integrated in the platform. RES integration directly affects total load curve as part of the energy consumption is covered by RES generation. We are addressing both types of RES technology examined in the project, considering for PV generation the assets integrated in BESOS platform at the reporting period.

	Week 1	Week 2	Week 3	Week 4	Week 5
Total Load					
Consumption (KWh)	16169	18763	16545	18383	20781
Cost (euro)	1778.567	2063.907	1819.966	2022.131	2285.922
CO2 Emissions(gr)	3066.305	3580.039	3124.869	3512.589	3967.837
Total Load with TLS & PLS Management & RES Integration					
Consumption (KWh)	10652	15341	13257	15025.3	16204.4
Cost (euro)	1152.956	1715.414	1454.243	1644.997	1800.213297
CO2 Emissions (gr)	2066.282	2975.117	2532.715	2908.946	3118.632881

Table 74 Total Load with TLS & PLS Management & RES Integration Scenario

In BCN pilot site we are examining a case scenario of mass RES generation, leading to a higher impact on energy consumption and energy cost (compared to Lisbon pilot site). A 15 % RES integration scenario is examined as part of the overall management scenario, with the proportional impact in KPI values. The next figure presents the impact of RES integration as a sequence of previous case scenario (TLS&PLS integration)

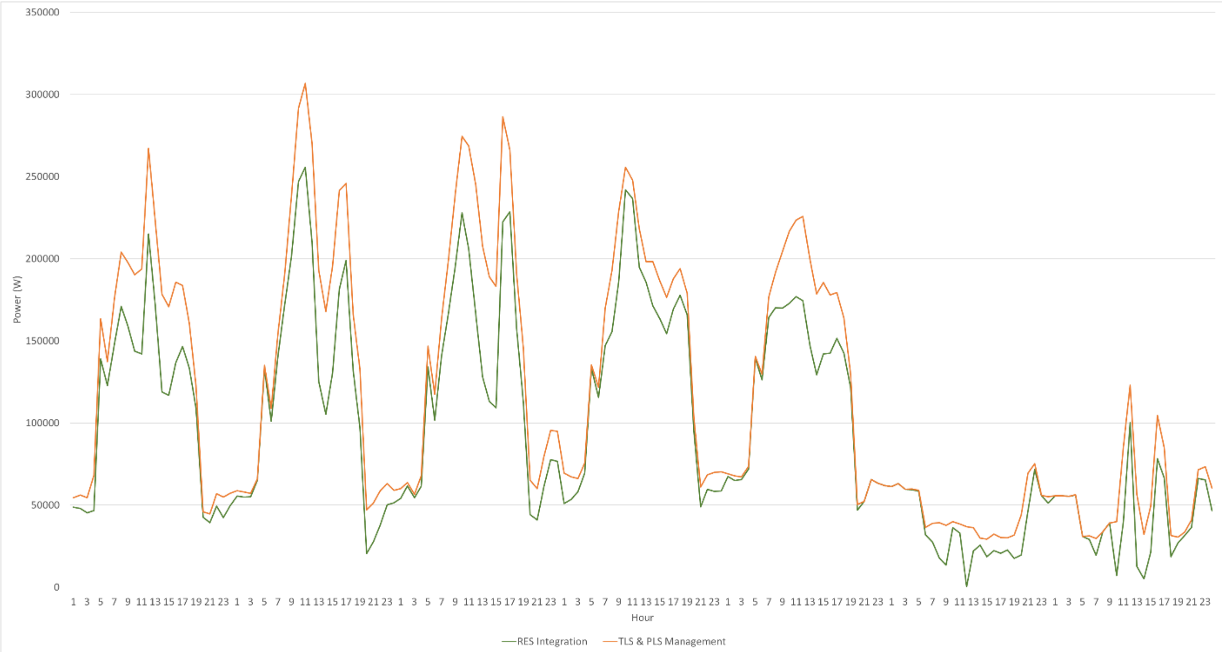


Figure 26 TLS & PLS Management & RES Integration

The figure above shows the high impact of PV generation (this is the RES type with a high penetration in BCN case scenario) at midday hours, leading to a significant energy consumption (and subsequently energy cost and CO2 emissions) reduction.

As a last step of the evaluation, we are presenting the impact of EV demand shifting process. The main objective of the optimization process is cost minimization and towards this direction we are considering the implementation of dynamic pricing schemas in pilot sites. The results from this step of the algorithmic process are presented.

	Week 1	Week 2	Week 3	Week 4	Week 5
Total Load					
Consumption (KWh)	16169	18763	16545	18383	20781
Cost (euro)	1778.567	2063.907	1819.966	2022.131	2285.922
CO2 Emissions(gr)	3066.305	3580.039	3124.869	3512.589	3967.837
Holistic Management Scenario					
Consumption (KWh)	10652	15341	13257	15025.3	16204.4
Cost (euro)	1047.131	1610.287	1349.404	1616.414	1707.234
CO2 Emissions (gr)	2099.455	3003.211	2576.574	2906.152	3143.024

Table 75 Holistic Management Scenario

The energy consumption and CO2 emissions values remain the same (as demand shifting strategies are performed for the management of EV fleet) but we are reporting a significant cost reduction by charging EVs at night hours (where the cost of energy is low). The next figure presents the impact of EV charging process compared to previous case scenario (TLS& PLS management and RES integration).

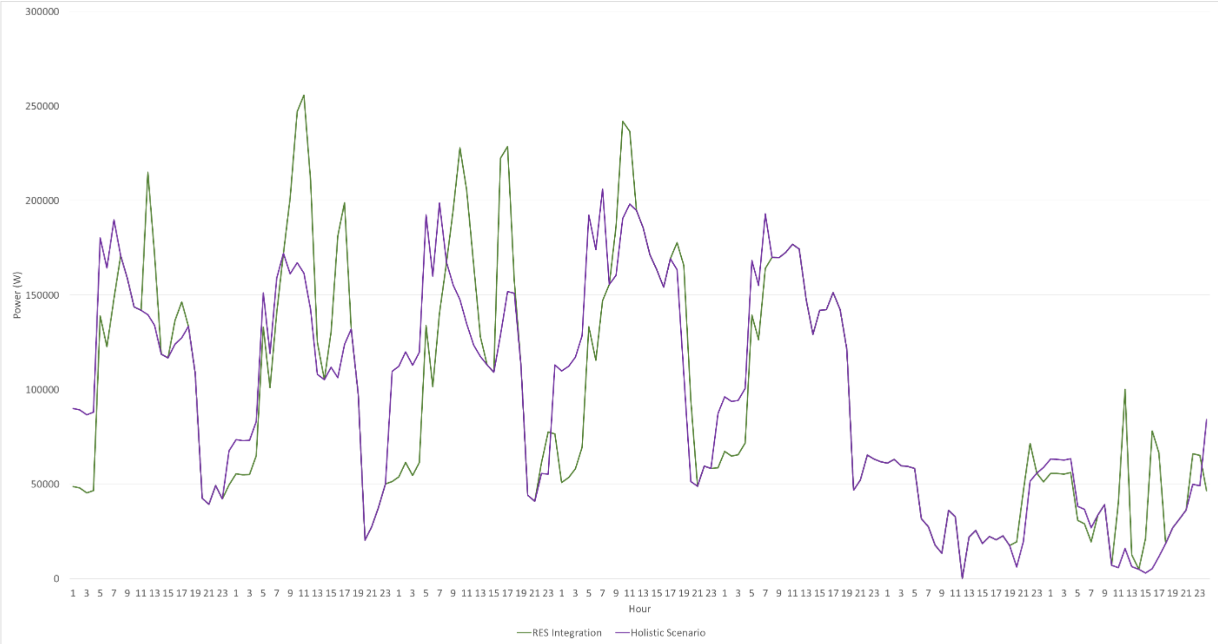


Figure 27 Holistic Management Scenario

The figure above shows load shifting at night hours (EV charging at night hours), which directly affects the cost for energy, as we are evaluating dynamic pricing schemas with high prices at day hours and low prices at night hours.

We are presenting in summary the results for the different steps of this integrated management framework. We are first examining the impact of PLS & TLS control strategies along with the evaluation of alternative pricing models. Then, we consider RES assets integration as part of the integrated scenario and as a final step we are examining the impact of EVs penetration.

	Week 1	Week 2	Week 3	Week 4	Week 5	Average
Total Load						
Baseline	-	-	-	-	-	**-**
Total Load with TLS & PLS Management						
Consumption	-5.76%	-5.19%	-5.81%	-5.24%	-4.71%	**-5.34%**
Cost	-9.43%	-7.19%	-8.67%	-8.48%	-6.86%	**-8.13%**
CO2 Emissions	-5.41%	-4.83%	-5.47%	-4.90%	-4.37%	**-5.00%**
Total Load with TLS & PLS Management & RES Integration						
Consumption	-34.12%	-18.24%	-19.87%	-18.27%	-22.02%	**-22.50%**
Cost	-37.99%	-20.50%	-23.57%	-22.19%	-24.67%	**-25.78%**
CO2 Emissions	-32.61%	-16.90%	-18.95%	-17.19%	-21.40%	**-21.41%**
Holistic Management Scenario						
Consumption	-34.12%	-18.24%	-19.87%	-18.27%	-22.02%	**-22.50%**
Cost	-43.68%	-25.37%	-29.08%	-23.54%	-28.56%	**-30.05%**
CO2 Emissions	-31.53%	-16.11%	-17.55%	-17.26%	-20.79%	**-20.65%**

Table 76 Smart city Energy demand curve optimization Scenario

As mentioned above, we are reporting a significant energy consumption and CO2 emissions reduction due to TLS & PLS Management along with the integration of RES. In addition, the optimal EV management leads to an even higher energy costs reduction (~30%), showing that way the potential of the integrated management framework as presented in BESOS project.

A screenshot from a week period, comparing baseline scenario with holistic management scenario is presented in the following diagram:

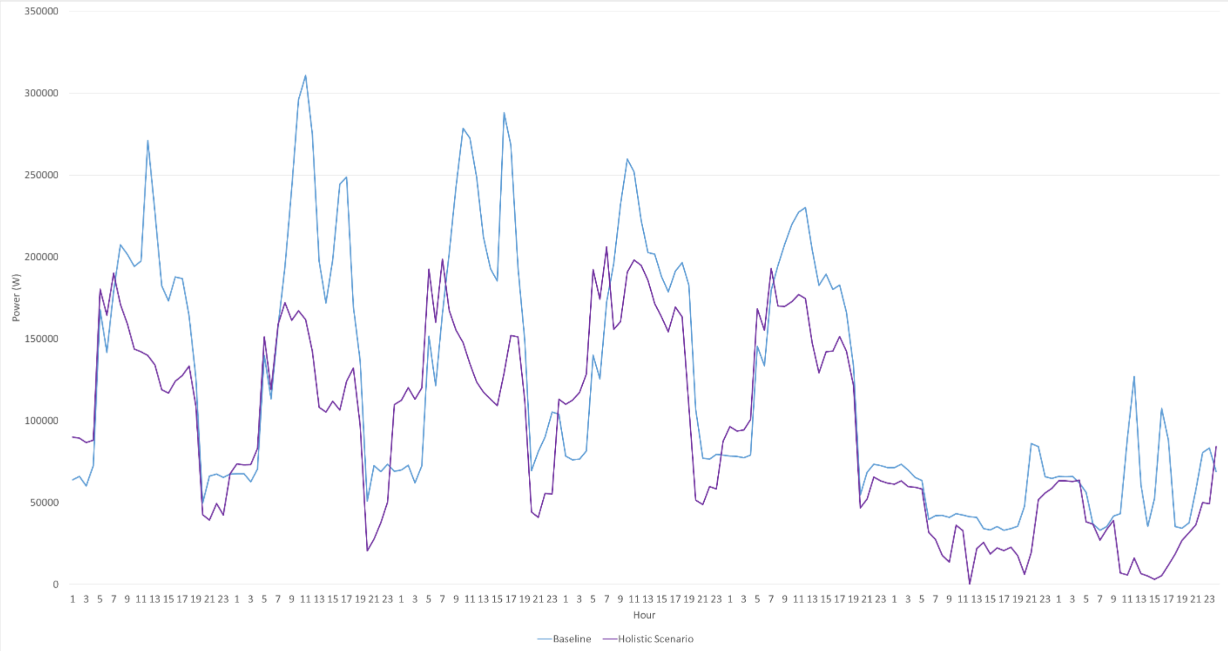


Figure 28 Baseline vs. Holistic Management Scenario

By combining different control strategies (load shedding and shifting control) at the different asset types, we establish a flexible framework that enables the coordinated management of the different loads. It is clear that this scenario is the main scenario for BESOS evaluation as it combines the different asset types integrated in the project. Actually, this scenario implements the overall objective of the project towards the establishment of a coordinated management framework at district level.

Measurement of the renewable energy produced and predicted in the distribution network

The forecasting engine, integrated in BESOS project, is considered as a big data analytics engine, performing analytics over historical data towards the extraction of accurate forecasts. During the 2nd evaluation period and following an extended training period, the average data from forecasting engine are 17.75 %. The next table presents the results per generation asset integrated in Barcelona test site:

Pilot Site	MAPE Error
Viudo Wind Farm	19.27%
Ficosa PV Plant	16.23 %

Table 77 Generation Forecasting Evaluation

A screenshot from Ficosa PV Plant for a short period of time is presented:

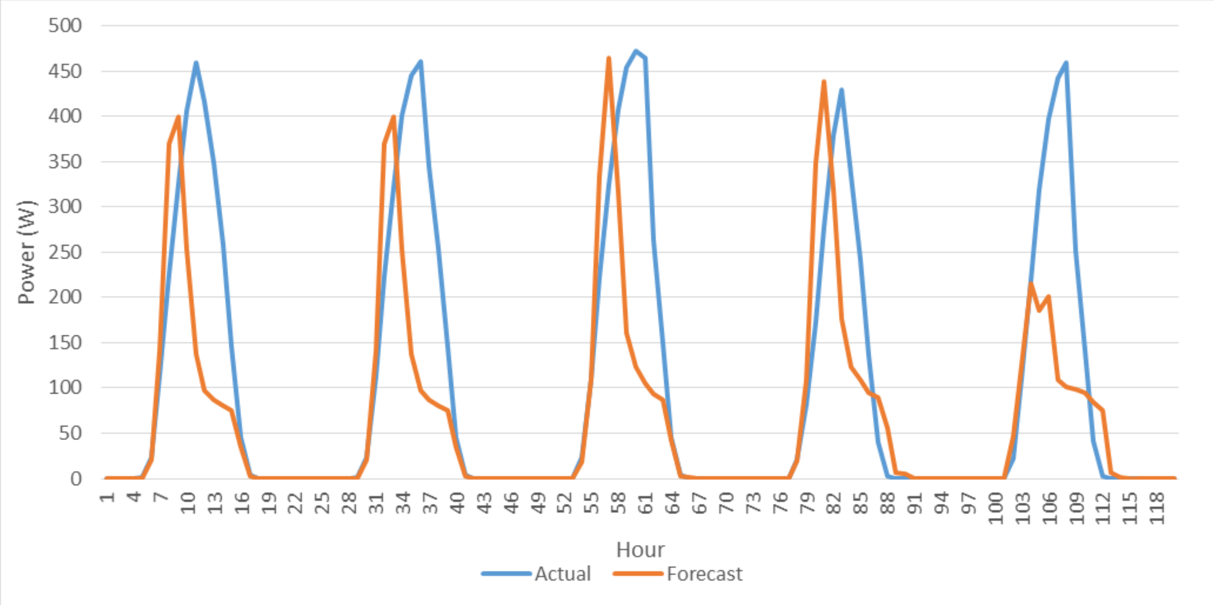


Figure 29 Ficosa PV Generation Forecasting

We have to point out that BESOS forecasting engine provides during this 2nd evaluation period more accurate results compared to the 1st evaluation period due to an extended training process performed.

Predict the energy consumption on weather data

Following the evaluation of energy production forecasting engine, the results from the evaluation of consumption forecasting engine are presented. The analysis is focusing on public buildings consumption forecasting where HVACE devices are available and the results from the selected public buildings are presented:

Pilot Site	MAPE Error
Building ID	**BCN Municipality**
160 - Seu Districte Sants	27.43%
160 - Seu Districte Sants	28.21%
Building ID	**SDX Municipality**
CapCervello	32.65%
CapGracia	31.86%
EoiSabadell	34.75%
Filmoteca	30.56%

Table 78 Consumption Forecasting Evaluation

The full list of public buildings with HVAC devices is selected for demonstrating consumption forecasting engine results. This enables the concrete evaluation of the forecasting engine under different building types and operational conditions. An average MAPE= 30.91% is reported as the main output from the evaluation process.

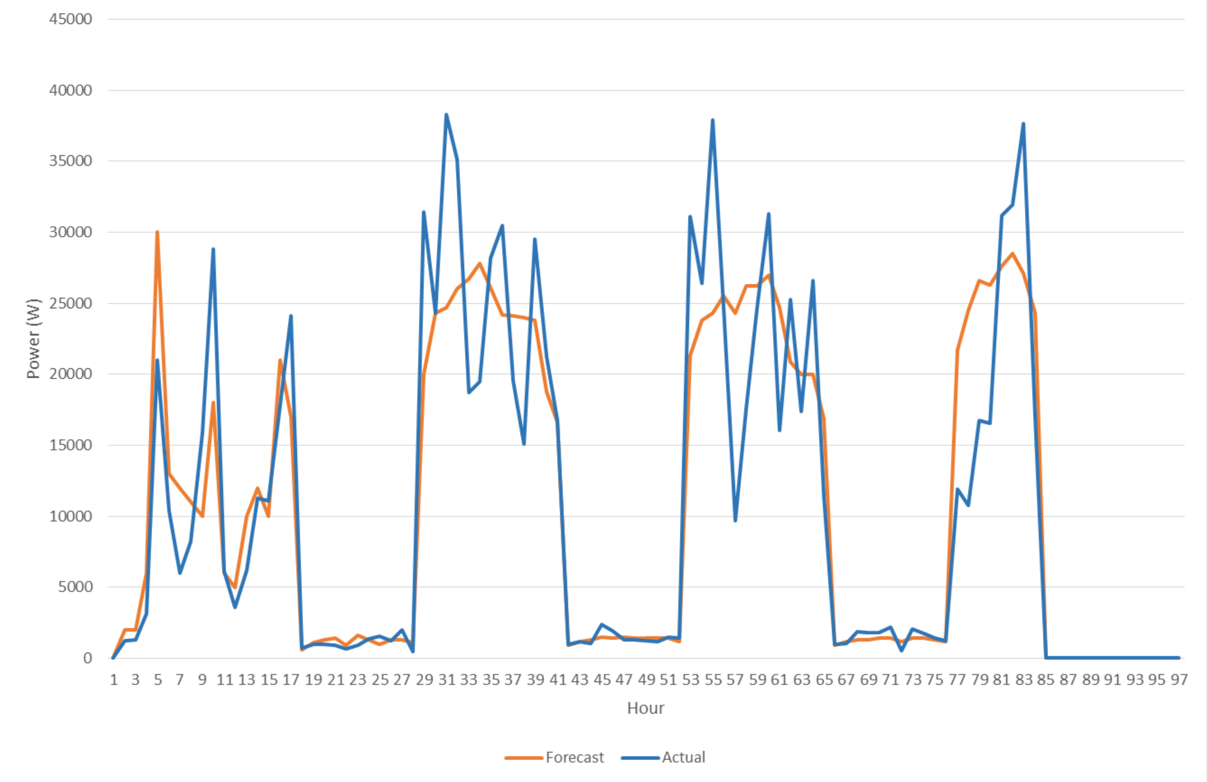


Figure 30 160 - Seu Districte Sants consumption Forecasting

The continuous training process is a main prerequisite for the extraction of accurate forecasting data and thus one of the objectives of ENERCAST (the provider of the consumption forecasting engine) is to proceed with further analytics over the data retrieved from pilot premises towards the commercialization of BESOS consumption forecasting engine.

Measurement / control of the electric energy quality

The goal of this scenario is to evaluate the performance of portfolio taking into account power factor data. The baseline of public buildings PF Indicator has been defined (1st evaluation period), and thus the analysis is focusing on evaluating the level of fulfilment for each pilot asset.

Public Building ID	Baseline	Index (Percentage<Baseline)
156 - Biblioteca Collserola	0.9	3.27%
158 - Biblioteca Francesc Candel	0.85	1.34%
160 - Seu Districte Sants	0.80	8.21%
161 - Seu Districte Sarrià	0.9	3.78%
163 - Seu Districte Gracia	0.95	1.67%
174 - Palau de Foronda	0.83	1.24%
175 - CEIP Pau Vila	0.93	0.24%

Table 79 BCN City energy quality evaluation

An indicative screenshot of Power Factor values for a half month period from 158 - Biblioteca Francesc Candel is presented in the following figure:

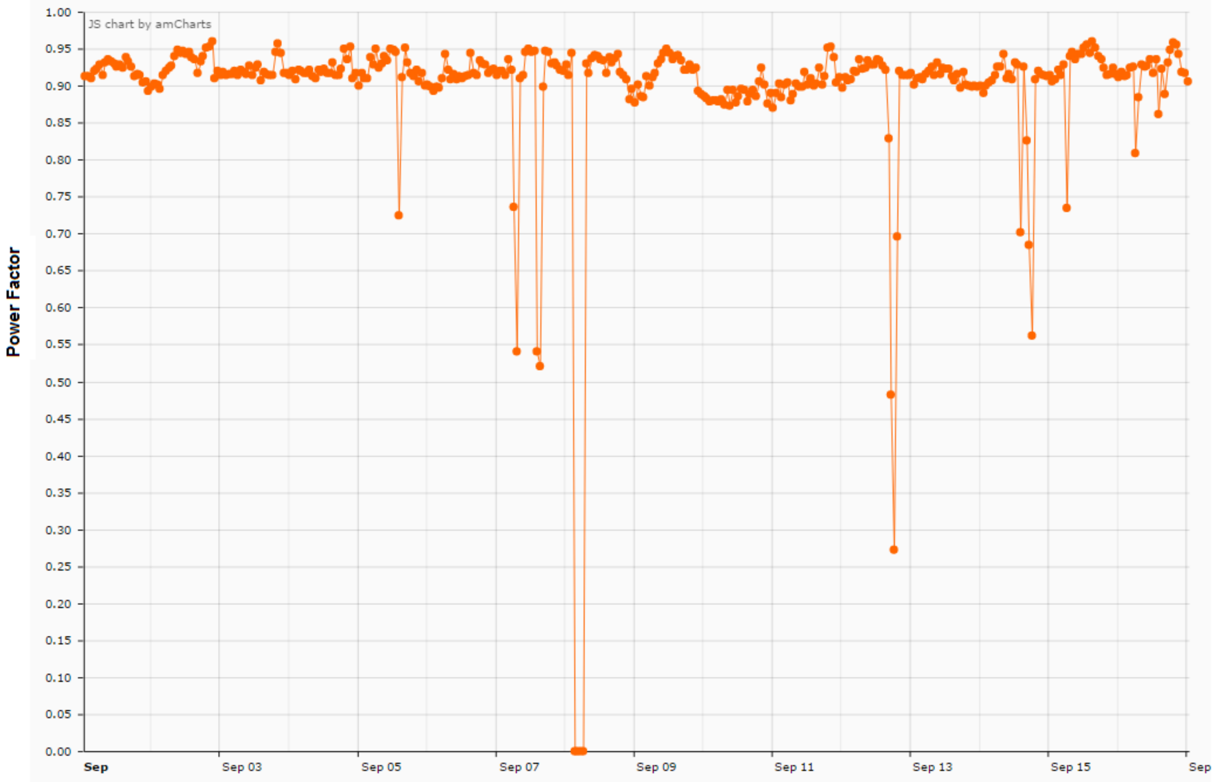


Figure 31 BCN City energy quality values

Along with data analysis in BCN energy quality data, we proceed with the analysis of data from SDX buildings. We have to point out that a limited number of assets provides energy quality data, presented in the following table:

Public Building ID	Baseline	Index (Percentage<Baseline)
ArxiuMunicipal	0.95	1.12%
BibliotecaRoquetes	0.91	5.24%
Cap Cervello	0.89	4.32%
Can Margarit	0.94	6.52%

Table 80 SDX buildings energy quality evaluation

The evaluation analysis is performed for building assets, able to report power quality data to BESOS platform. The accuracy level for PF values is the accuracy on monitoring PF values form the asset types integrated in BESOS platform.

Preventive Maintenance Alarm

Following previous case analysis, where the goal is at monitoring PF indicator, the objective of this scenario is to evaluate the performance of predictive maintenance engine. This is an add-on service in BESOS DSS, triggering best fitted control strategies in case of PF values outliers' detection. The analysis is performed in public building assets reporting power quality data, and the results of the evaluation process are presented:

Public Building ID	Successful Triggering Alarm
156 - Biblioteca Collserola	100 %
158 - Biblioteca Francesc Candel	100 %
160 - Seu Districte Sants	100 %
161 - Seu Districte Sarrià	100 %
162 - Seu Districte Sant Andreu	100 %
163 - Seu Districte Gracia	100 %
174 - Palau de Foronda	100 %
175 - CEIP Pau Vila	100 %

Table 81 BCN City Preventive Maintenance Engine evaluation

Due to non-controllability in public building assets, the main goal of the evaluation is to trigger the prompt alarms when deviations in baseline PF occur. Therefore, we evaluate the functional performance of BESOS DSS on triggering alarms when abnormal conditions occur.

The main focus of the evaluation process during the reporting period is on the coordinated management of the different types of BCN assets integrated in BESOS platform. Towards this direction, special interest is delivered for use case "Smart city Energy demand curve optimization" where heterogeneous types of assets are integrated under a common management framework. Actually, this is the main objective of BESOS project, "to promote a framework that enables the coordinated management of the different types of assets in smart city level."

4.3 Impact Assessment analysis Summary

The goal of this section is to provide a summary of BESOS impact assessment, for each of the evaluation periods. The analysis is performed per pilot site considering the list of evaluation criteria and the association with the use cases as presented above. We are presenting first the impact assessment analysis for Lisbon Pilot site

Criteria ID	Evaluation Criteria	1st Evaluation Period	2nd Evaluation Period	Description
1	Efficient Monitoring of the Facility (EMF)	94.03%	96.04%	The evaluation is directly associated with UC-1 about efficient and reliable monitoring of assets
2	Increase RES generation utilization (IRU)	5.0%	9.71%	Smart City management scenario considering integration of different asset types
3	Cost reduction (CR)	-21.60%	**-37.39%**	Smart City management scenario considering integration of different asset types
4	Peak Demand Reduction (PDR)	-	- 12.32%	Smart City management scenario considering integration of different asset

				types
5	Increase in Building Efficiency (IBE)	- 18.5%	- 23.84%	Public Buildings Management Scenario considering alternative tariff models
6	Energy Efficiency in Neighbourhood Level (EEN)	-	**- 23.91%**	Smart City management scenario considering integration of different asset types
7	Energy Efficiency via Behavioural Triggering	-	-	Evaluation of this Indicator is performed through end users questionnaire analysis
8	Increase of Public lighting efficiency (IPLS)	-	-13.34% & - 26.90% **(Simulation)**	PLS & TLS management scenarios considering different contextual parameters at the optimization process
9	Efficient EV Management Fleet (EEVM)	-	- 22.94%	Energy management for the use of electric vehicle fleet for coordinated EV & Building Management
10	EVs hosting capacity (EVHC)	-	147%	Electrical Vehicles (EV) local optimization and storage capacity forecasting for EV fleet management
11	CO2 reduction of the system (CORS)	-6.09%	**- 23.99%**	Smart City management scenario considering integration of different asset types
12	CO2 reduction via EV management (COREV)	-	0.58%	Electrical Vehicles (EV) local optimization and storage capacity forecasting for EV fleet management
13	CO2 reduction through EV penetration	-	- 61.82%	Electrical Vehicles (EV) local optimization and storage capacity forecasting for EV fleet management
14	CO2 reduction due to optimal RES exploitation	-6.09%	- 9.85%	Smart City management scenario considering integration of RES assets
15	Electrical Power Quality Factor	98 %	97.26%	Measurement / control of the electric energy quality evaluation scenario

16	Forecasting Performance (FOPE)	19.03 %	16.51% & 28.94%	Generation and Consumption Forecasting Engine Evaluation
17	Predictive Maintenance Accuracy Index	-	100%	Predictive Maintenance Analysis Evaluation Scenario

Table 82 Impact Assessment Analysis Summary- Lisbon Pilot Site

Peak Demand Reduction and Energy Efficiency in Neighbourhood Level (EEN) indicators are not calculated during the 1st evaluation phase as the smart city management scenario incorporates only "RES penetration" and "evaluation of alternative tariffs" strategies which don't affect the KPI values. We highlight the impact on total energy cost and consumption due to integration of different asset types in Smart City management scenario. The same analysis is presented also for Barcelona Pilot site.

Criteria ID	Evaluation Criteria	1st Evaluation Period	2nd Evaluation Period	Description
1	Efficient Monitoring of the Facility (EMF)	93.80%	96.23%	The evaluation is directly associated with UC-1 about efficient and reliable monitoring of assets
2	Increase RES generation utilization (IRU)	5.4%	17.16%	Smart City management scenario considering integration of different asset types
3	Cost reduction (CR)	-10.51%,	**-30.05%**	Smart City management scenario considering integration of different asset types
4	Peak Demand Reduction (PDR)	-	-26.32%	Smart City management scenario considering integration of different asset types
5	Increase in Building Efficiency (IBE)	-2.50%	- 3.10%	Public Buildings Management Scenario considering alternative tariff models
6	Energy Efficiency in Neighbourhood Level (EEN)	- 2.0%	**- 22.5%**	Smart City management scenario considering integration of different asset types
7	Energy Efficiency via Behavioural Triggering	-	-	Evaluation of this Indicator is performed through end users questionnaire analysis
8	Increase of Public lighting efficiency	- 1.43%	-5.92% & -25.84%	PLS & TLS management scenarios considering different

	(IPLS)			contextual parameters at the optimization process
9	Efficient EV Management Fleet (EEVM)	-	-19.01 %	Energy management for the use of electric vehicle fleet for coordinated EV & Building Management
10	EVs hosting capacity (EVHC)	-	210 %	Electrical Vehicles (EV) local optimization and storage capacity forecasting for EV fleet management
11	CO2 reduction of the system (CORS)	-6.05%	**-20.65 %**	Smart City management scenario considering integration of different asset types
12	CO2 reduction via EV management (COREV)	-	4.47%	Electrical Vehicles (EV) local optimization and storage capacity forecasting for EV fleet management
13	CO2 reduction through EV penetration	-	-44.48%	Electrical Vehicles (EV) local optimization and storage capacity forecasting for EV fleet management
14	CO2 reduction due to optimal RES exploitation	- 5.29 %	- 16.41%	Smart City management scenario considering integration of RES assets
15	Electrical Power Quality Factor	95.75 %	97.22%	Measurement / control of the electric energy quality evaluation scenario
16	Forecasting Performance (FOPE)	19.30%	17.75% & 30.91%	Generation and Consumption Forecasting Engine Evaluation
17	Predictive Maintenance Accuracy Index	-	100%	Predictive Maintenance Analysis Evaluation Scenario

Table 83 Impact Assessment Analysis Summary- BCN Pilot Site

For the 1st reporting period, no Peak Demand Reduction (PDR) calculation is provided as the implementation of the associated control strategies (alternative tariffs and PLS management during night hours) is not affecting peak demand values.

Along with the summary of impact assessment process, a comparative analysis with ex-ante evaluation is also presented in this section. The simulation based ex-ante analysis was performed in D7.1 in order to a-priori simulate the impact of BESOS platform. Following the evaluation of BESOS in pilot sites during the demonstration period, we further compare the simulated vs. actual impact of BESOS platform.

Criter	Evaluation Criteria	Ex-Ante	Ex-Post	Description

ia ID		Analysis	Analysis	
1	Increase in Building Efficiency (IBE)	- 7%	- 3.10%	Public Buildings Management Scenario considering alternative tariff models
2	Increase of Public lighting efficiency (IPLS)	-8.5% to - 14%	-5.92% & -25.84%	PLS & TLS management scenarios considering different contextual parameters at the optimization process
3	Efficient EV Management Fleet (EEVM)	-16.5%	-19.01 %	Electrical Vehicles (EV) local optimization and storage capacity forecasting for EV fleet management
4	CO2 reduction via EV management (COREV)	1.2%	4.47%	Electrical Vehicles (EV) local optimization and storage capacity forecasting for EV fleet management
5	CO2 reduction due to optimal RES exploitation	-5%	- 16.41%	Smart City management scenario considering integration of RES assets
6	Energy Efficiency in Neighbourhood Level (EEN)	-5%	- 22.5%	Smart City management scenario considering integration of RES assets
7	Cost reduction (CR)	-4%	-30.05%	Smart City management scenario considering integration of RES assets
8	CO2 reduction of the system (CORS)	-2.4%	-20.65 %	Smart City management scenario considering integration of RES assets

Table 84 Ex-ante vs. Ex-post evaluation analysis (BCN pilot site)

The analysis is performed addressing the main BESOS key performance indicators, considering the integration of different asset types. There are several factors affecting the final impact during the evaluation process (scale of pilot site, input parameter values, control strategies implemented, etc.). Though, similar results are reported for both evaluation processes. To this end, BESOS evaluation framework is presented as an end-to-end methodological framework where the ex-ante analysis is initially performed to accurately simulate the impact of each control strategy in the different city asset types.

During this period, we evaluated BESOS ecosystem under different case scenarios, addressing the evaluation criteria and indicators identified during the initial evaluation plan. The analysis is focusing in **Smart city Energy demand curve optimization scenario**, where the integration of different types of assets increases the flexibility of the system towards the implementation of optimal management strategies. This is actually the main innovation brought by BESOS platform: *to examine the integration of heterogeneous types of devices in district/municipality level enabling that way the demonstration of smart city concept.*

5 User applications Assessment Analysis

Based on the evaluation plan and in order to proceed with the evaluation of BESOS platform, we take also into account end users feedback. The goal of this section is to present the results from ex-post questionnaires analysis as provided by the main stakeholders of the platform. We have to point out, that we extended the list of BESOS stakeholders covering also the EV users as stakeholders affected by BESOS management tool. In addition, as BESOS is a platform for smart cities optimal operation, we took into account citizens' feedback about BESOS supported functionalities (in order to cover the scenario about Behavioural Triggering which was not evaluated through impact assessment analysis). Therefore, two extra versions of ex-post questionnaires were created to receive end users valuable feedback.

The evaluation analysis takes into account the results from ex-ante analysis as reported in D7.1. While this analysis highlighted the weaknesses of existing management tool, in ex-post evaluation process we are reporting the impact that BESOS platform and services bring to the different business stakeholders of the project.

The next section presents the results from end users questionnaires analysis. The focus is on the evaluation of functionalities offered by the tools but also on look and feel, accuracy, latency, responsiveness of each application, as a main prerequisite for the development of user responsive and intuitive interfaces.

5.1 User Acceptance Evaluation Plan

An overview of the initial "User Acceptance Evaluation Plan" is provided in this section. Special treatment on the evaluation process, apart from the evaluation of the system functionalities, is the evaluation of penetration of IT technology, like the one developed in the project, to daily activities of system stakeholders. Therefore, as part of the User Acceptance evaluation we need to evaluate the willingness of end users to accept or reject the IT applications, to use it or misuse it, to incorporate it into their routine or work around it. In other words, the evaluation "*whether BESOS information systems are 'successful' or not is decided on the work floor".*

There are numerous frameworks for this evaluation process. Perhaps, the most notable is the **Technology Acceptance Model** (TAM) for the prediction and explanation of end-user reactions to IT solutions. A summary of this methodological framework is provided here, while the detailed analysis of **TAM methodology** was reported as part of the evaluation plan.

TAM was developed back in the 1980's, in light of concern that workers were not using IT made available to them. Its originators reasoned that the key to increasing use was to first increase acceptance of IT, which could be assessed by asking individuals about their future intentions to use the IT. Knowing the factors that shaped one's intentions would allow organizations to manipulate those factors in order to promote acceptance, and thus increase IT use. Therefore, in BESOS project we define the evaluation factors that consist of the user evaluation framework.

The quantification of **user acceptance** (UA) is based on a "***5-point rating scale***" as addressed by Van der Laan, Heino and De Waard ([6]). The whole principle is quite simple and consists of a list of actors as presented below:

1. useful / useless
2. pleasant / unpleasant
3. flexible/ inflexible
4. effective / superfluous
5. responsive/ unresponsive
6. assisting / worthless
7. enhancing alertness / reducing alertness

These factors are further addressed to the questionnaires generated for the system stakeholders in order to get their direct feedback on the aforementioned criteria. The overall evaluation framework is provided:

1. The stakeholder's feedback on questionnaires is based on the aforementioned factor analysis.
2. The final score is estimated by averaging the scores on the aforementioned factors that consist of the evaluation process.
3. The final score for each application about the usefulness and pleasantness are based on the average value of the factors of point 2.

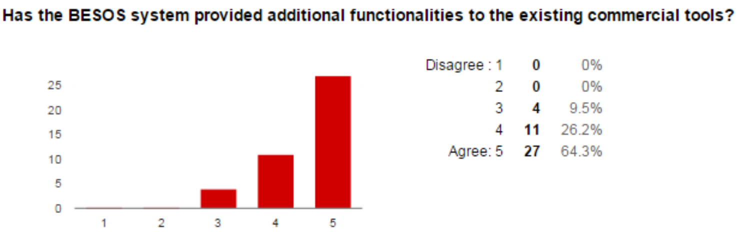
The evaluation of **user acceptance** is of high interest on BESOS project and is performed by the end of the project demonstration in pilot sites of Barcelona and Lisbon. The stakeholders enrolled during the evaluation process are coming from the consortium partners and therefore have direct interaction with the business applications developed during the project period. The details for questionnaire analysis as performed during the evaluation period are provided in the next section.

5.2 Municipalities and Asset Owners Questionnaire Analysis

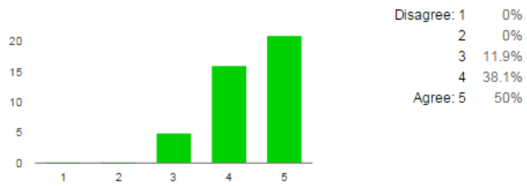
The ex-post questionnaire template for Municipalities and Asset Owners is available in Annex B. More than **40 asset owners** and **public authorities** were participated at the evaluation process, with the main focus to evaluate BESOS BSSC and the SLA management functionality. The results from Questionnaire Analysis are presented starting from an overall review of BESOS BSSC tool based in TAM methodology. The usefulness and user satisfaction is presented:

	1	2	3	4	5
Useful	0%	0%	9.30%	16.30%	**74.40%**
Pleasant	0%	0%	11.60%	34.90%	**53.50%**
Bad	**65.10%**	**30.20%**	2.30%	2.30%	0%
Nice	0%	0%	14%	41.90%	**44.20%**
Effective	0%	0%	20.90%	37.20%	**41.90%**
Likeable	0%	2.30%	14%	39.50%	**44.20%**
Assisting	0%	0%	7%	41.90%	**51.20%**
Undesirable	**76.20%**	21.40%	2.40%	0%	0%

The BBSC application is evaluated as a very useful and assisting tool for the stakeholders of the platform. Going to further details to the evaluation of BESOS BSSC, the end users of the platform highlighted the functionalities offered by BESOs platform in contrary to available commercial tools.



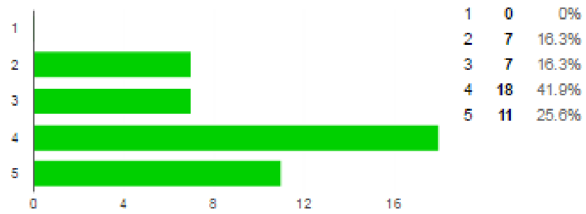
The analytics tool provides added value on the management of the portfolio?



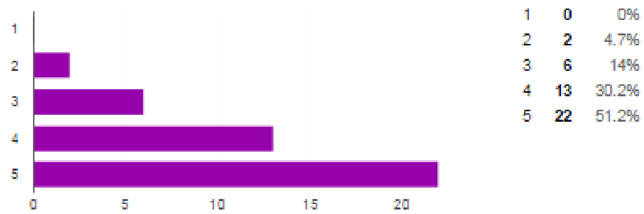
More specifically, BESOS BSC is evaluated by the end users, as a tool that may enable the better management of heterogeneous asset types and therefore lead to significant cost and energy consumption reduction.

Could you manage to get benefits from the BESOS Balance Scorecard (BESOS BSC) applications?

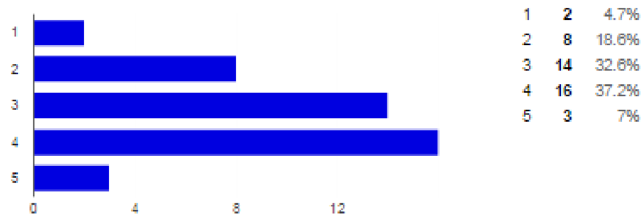
Energy Reduction



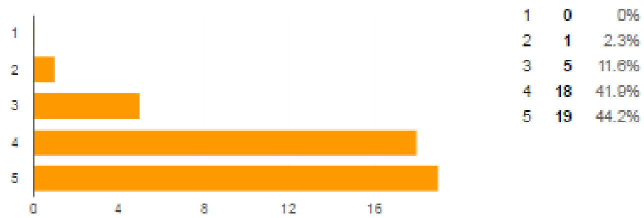
Better usage of resources



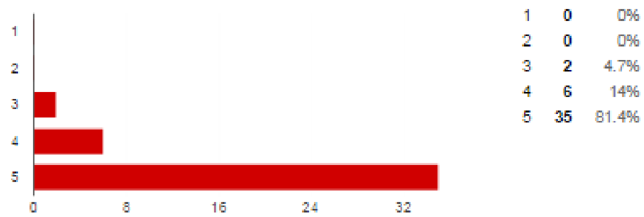
Increase of environmental awareness



Better Management of SLA contracts

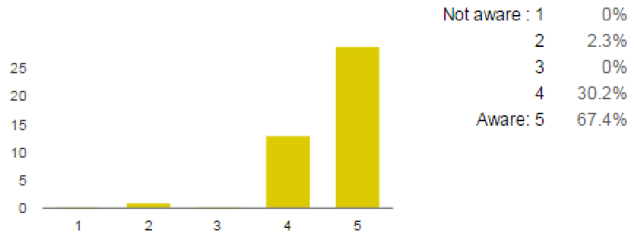


Easier view of all EMSs

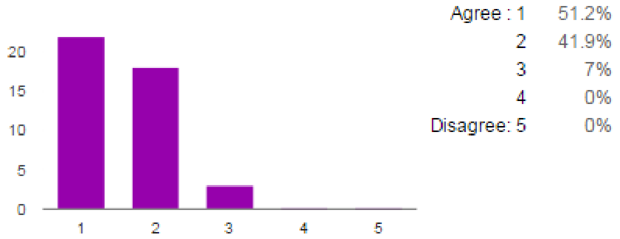


Special remarks about the potential of establishing, operating and renegotiating dynamic SLAs. This is actually one of the main innovations brought by the project, the potential to establish customized contractual agreements and further monitor the performance of SLAs. In addition, the potential of implementing business strategies under different business objectives (energy consumption, CO_2 emissions, and cost reduction) is an added value of the tool.

The integrated SLA management framework has optimized the management of SLAs vs. KPIs?

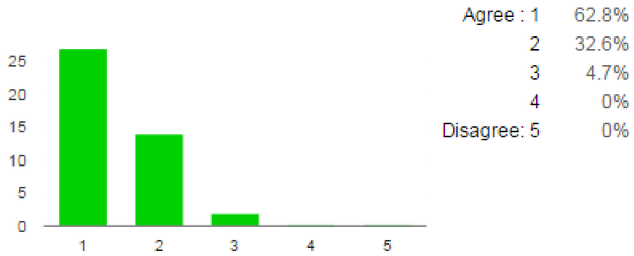


The renegotiation of SLAs functionality provides an added value of BESOS platform?



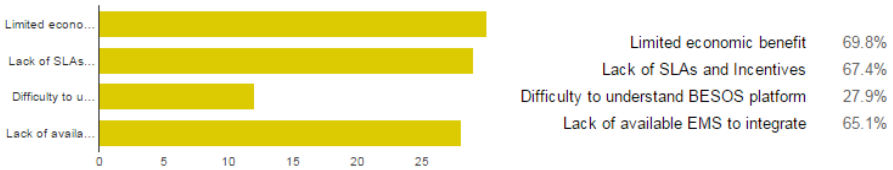
What related to the evaluation of BESOS Visual Analytics tool, the end users highlighted the functionalities offered by the platform, enabling the optimal management of the portfolio considering different metric and KPI values.

The system provides the metrics and KPIs needed for optimal EMS management?



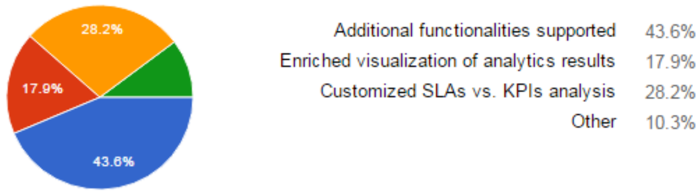
On the other hand, the end users of BESOS BSC tool highlighted the weaknesses and threads for the business application. The lack of a viable market environment and open EMS solutions are highlighted as critical factors that affect the viability of the tool.

What are the limitations of the current model from an Authority perspective in order to have a mass penetration of the system's application?

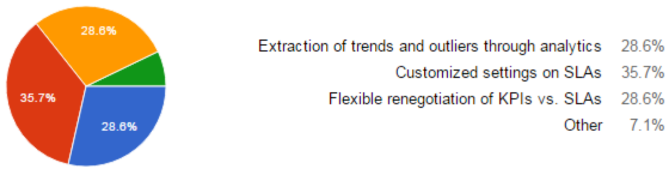


Furthermore, the tool may be further enhanced by adding additional functionalities and a more appealing UI as potential extensions of the current version of the tool.

Do you have any ideas to improve the system (either visual interface or the information provided)?

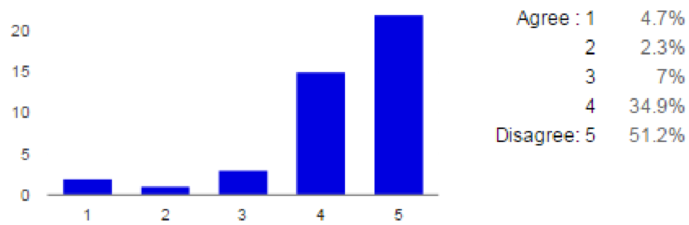


Do you think that there should be any additional information or functions on the screen that is currently missing?



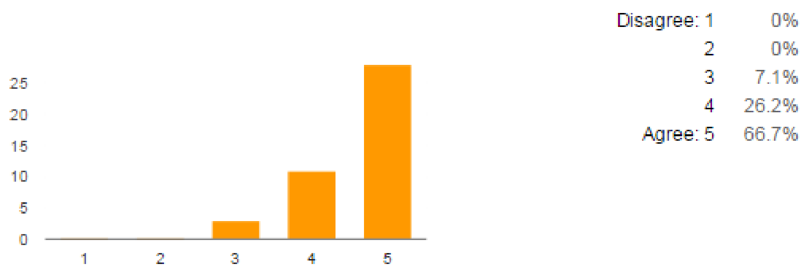
A main aspect of the project is the coverage of security and privacy requirements by BESOS tool. The end users of the platform didn't express special concerns about privacy and security, as an authentication mechanism is supported by the tool.

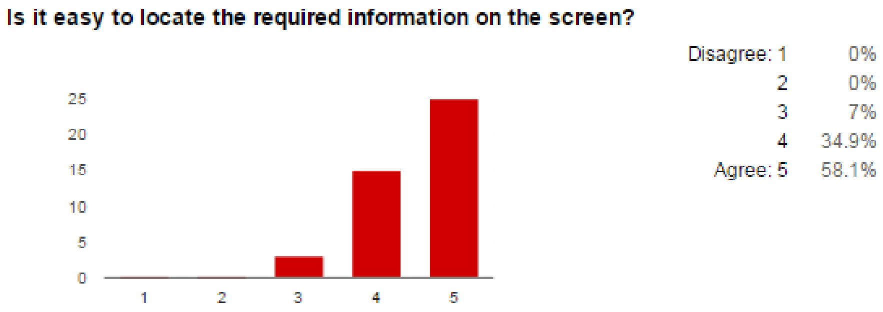
The overall system is characterized by lack of privacy?



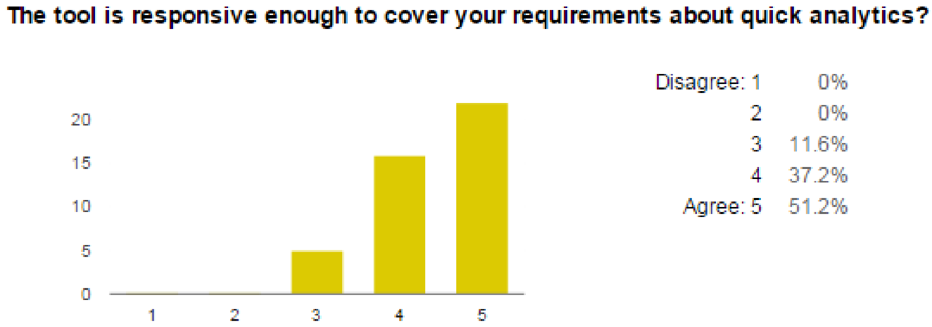
Moving forward to the look and feel evaluation of BESOS BSSC, the end users of the tool highlighted the simplicity and the user friendliness of both BESOS VA and Balanced Scorecard applications. The latency on interaction with the tool is not significant, while the flexibility offered by the platform enables the evaluation of different business scenarios.

Do you think that the visual interface of the application is appealing





Finally, it is worth noticing that BESOS BSSC is a web application with high availability/reliability level (as reported by the different business stakeholders participating in the evaluation process), with some minor issues related to the connectivity of EMSs in BESOS platform.



Overall, the technical and pilot users involved in the evaluation of BESOS BSC tool, provided positive feedback about the functionalities offered by the tools and the visualization of analytics information, encouraging the partners of the consortium to further extend the functionalities offered by the tool and further commercialize this as a standalone solution for assets management.

The aforementioned analysis presented the results from business evaluation of BESOS BSC, the tool provided to ESCOs and Public Authorities for a high level business wise management of the portfolio. The next section is focusing on the evaluation of the DSS platform, considering that way the detailed evaluation of the different optimization processes examined in the project.

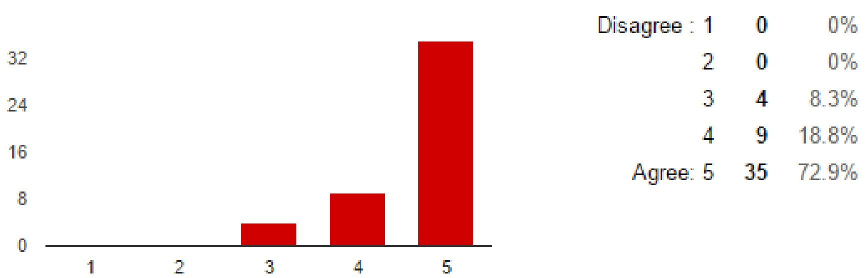
5.3 Facility managers and ESCOs Questionnaire Analysis

The ex-post questionnaire for Facility managers and ESCOs is available in Annex B. More than 45 Facility managers and ESCOs participated at the evaluation process, with the main goal to evaluate BESOS DSS and the optimal management framework for EMSs taking into account business objectives and SLAs. The results from Questionnaire Analysis are presented, starting from overall BESOS tool evaluation following TAM methodology. The usefulness and user satisfaction rating are presented:

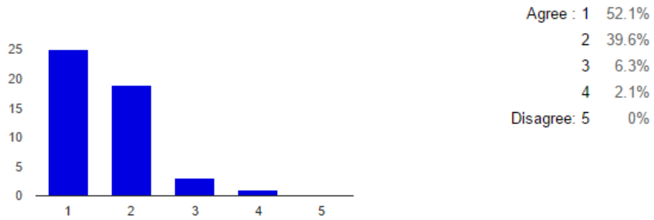
	1	2	3	4	5
Useful	0%	0%	6.30%	35.40%	**58.30%**
Pleasant	0%	0%	4.20%	**52.10%**	**43.80%**
Bad	39.60%	**54.20%**	6.30%	0%	0%
Nice	0%	0%	18.80%	25.00%	**56.30%**
Effective	0%	0%	19.10%	27.70%	**53.20%**
Likeable	0%	0%	12.50%	**47.90%**	39.60%
Assisting	0%	0%	16.70%	16.70%	**66.70%**
Undesirable	**87.50%**	8.30%	4.20%	0%	0%

The end users of the platform were evaluated the BESOS DSSC as a useful and assisting application, highlighting the functionalities offered by the tool as the decision making tool for the management of the different asset types. Moving to the focused review of BESOS DSS application, the evaluation is mainly performed in the extended functionalities offered by BESOS DSS compared to commercial solutions.

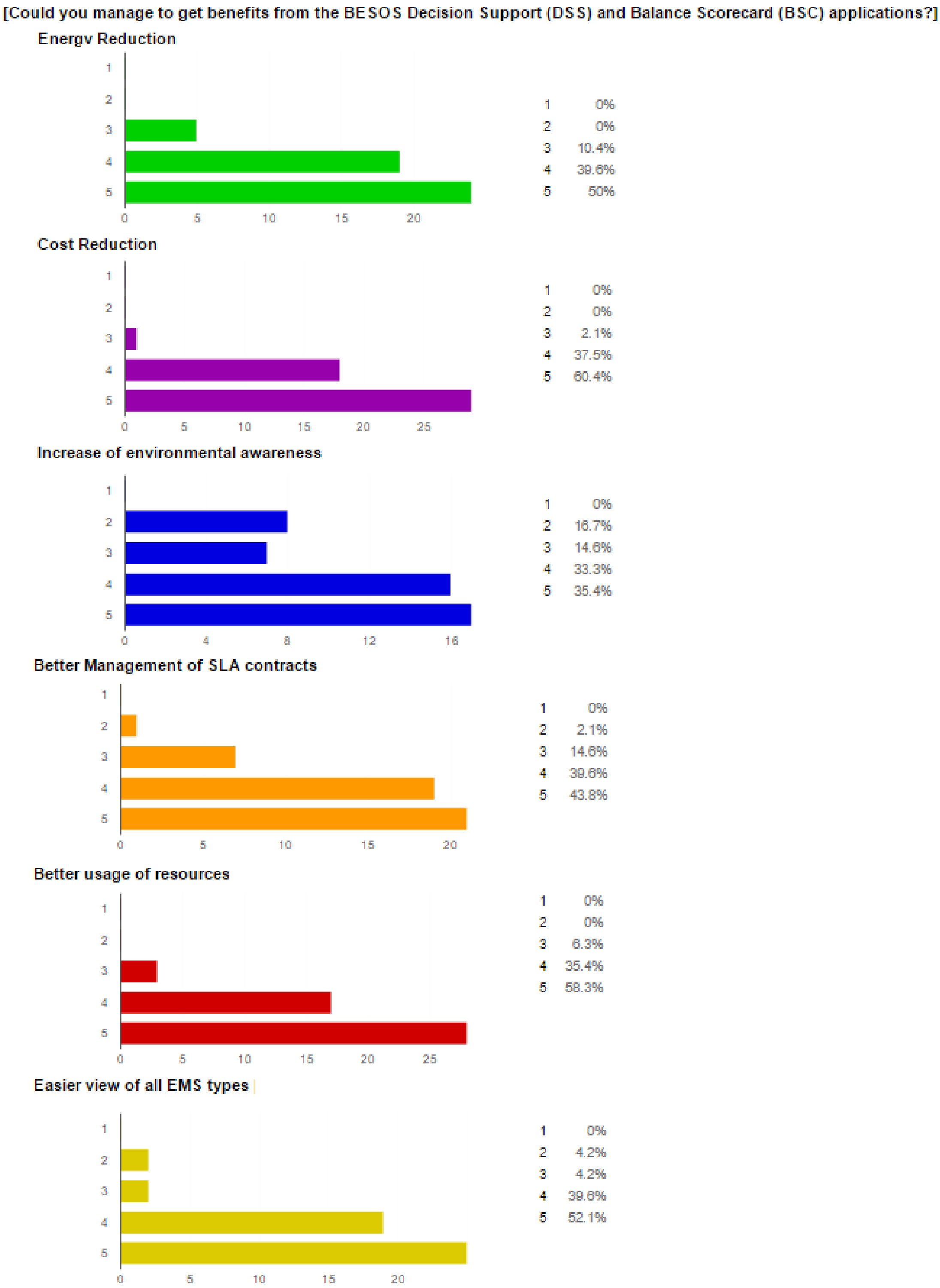
Has the BESOS system provided additional functionalities to the existing commercial tools?



Do you think that monitoring and control functionality through BESOS DSS is an added value of BESOS platform?

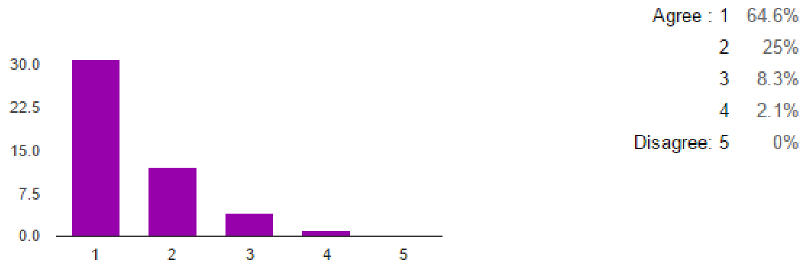


The majority of pilot stakeholders also highlighted the main innovation of BESOS platform to provide a framework for optimal management of SLA contracts and the ability to set different control objectives during the optimization process (CO2 emissions reduction, Cost reduction, etc.).



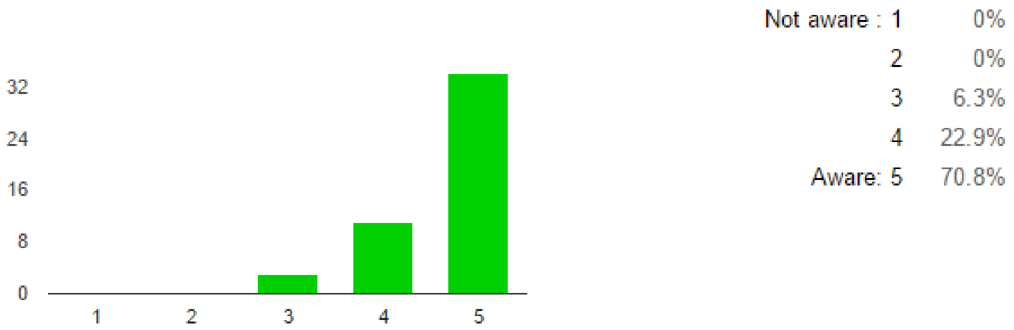
We have to mention also as an added value of BESOS DSS applications, the integration of heterogeneous types of assets, providing metrics and KPIs that enable the coordinated management under a unified framework.

Do you think that the overall system provides the metrics and KPIs needed for optimal EMS management?



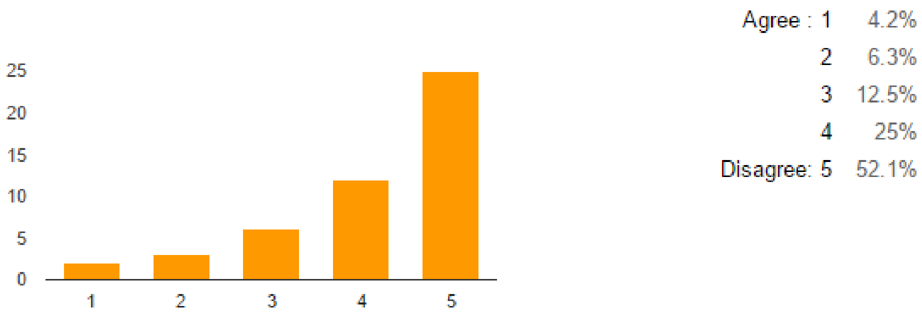
In addition, the forecasting engine as an add-on for BESOS DSS provides accurate results and further facilitates business stakeholders for triggering the optimal strategies via DSS.

The integrated forecasting engine has affected your overall management process?



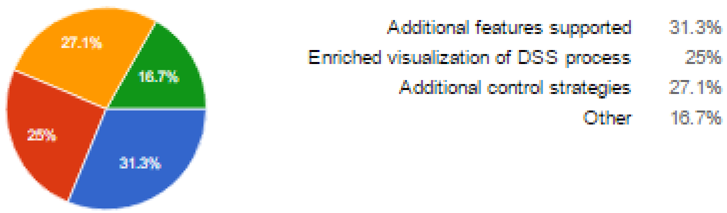
A main aspect of the project is the alignment with security and privacy requirements. The end users of the platform didn't express special concerns about security and privacy, as an authentication mechanism is supported by the tool in a similar way supported for Municipalities and Asset Owners. The end users of the platform receive classified access to the data, taking into account their role in BESOS management framework.

Do you think that the overall system is characterized by lack of privacy?

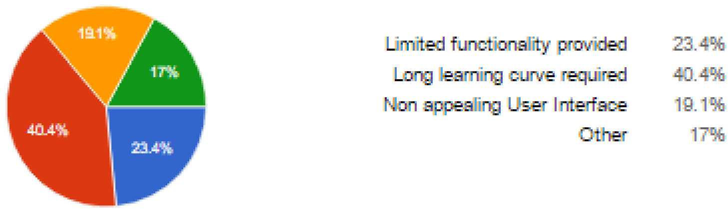


On the other hand, the business stakeholders highlighted also some missing points from the current status of the application and mentioned further extensions that may facilitate the easy deployment of the application in similar case studies. Special interest should be delivered on the simplification of functionalities offered by the tool and further on support for additional/customized control strategies to the different asset types managed by the platform.

Do you have any ideas to improve the system (either visual interface or the information provided)?

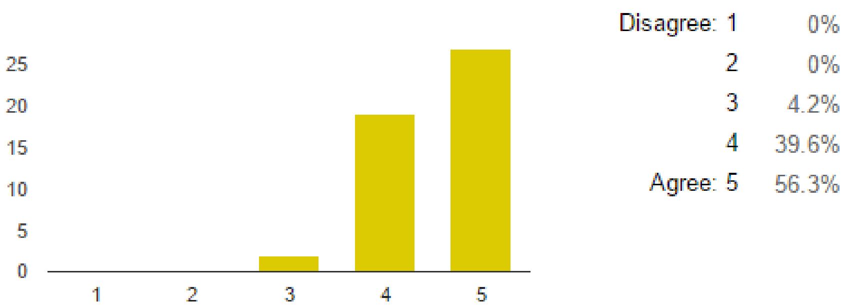


Which are the main disadvantages of the BESOS DSS &BSC application?

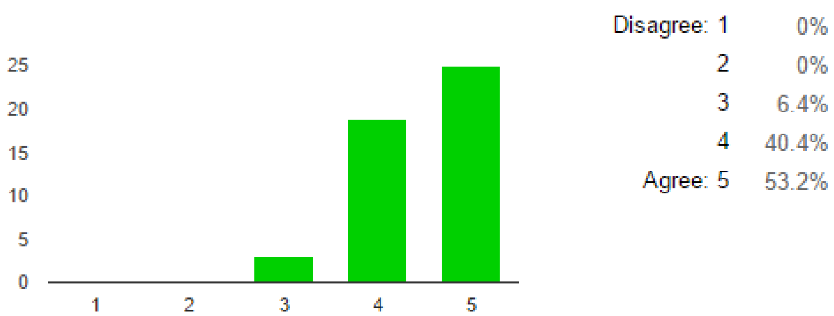


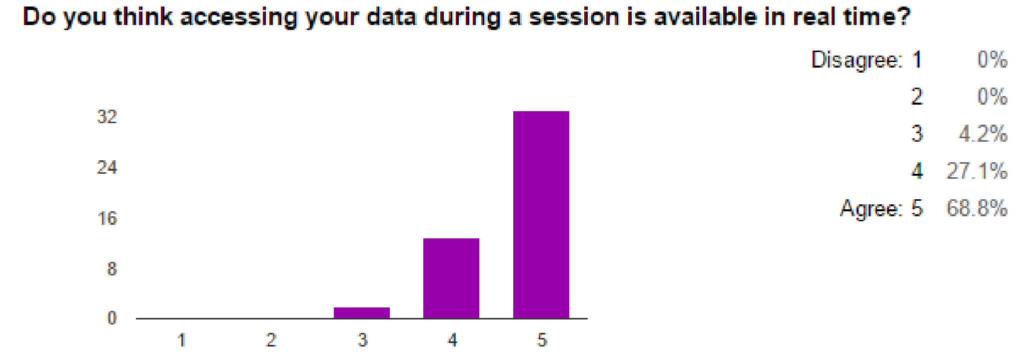
Moving to look and feel evaluation of BESOS DSS, the business stakeholders highlighted the simplicity and the user friendliness of DSS applications. Minimum latency was reported when implementing control actions, not affecting the final impact of control strategies.

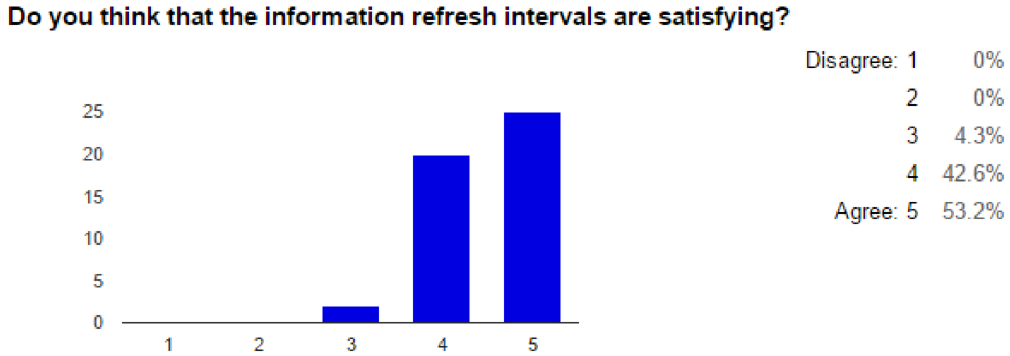
Do you think that the visual interface of the application is appealing



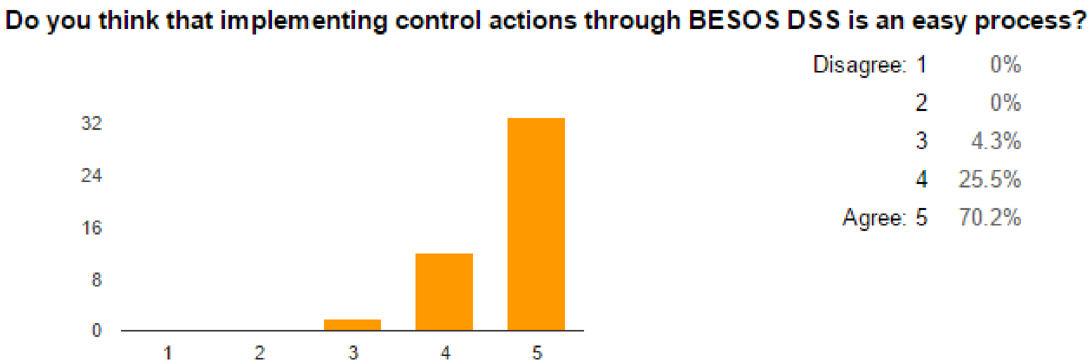
Is it easy to locate the required information on the screen?







The enriched information visualization and flexible controllability offered by the BESOS DSS GUI is remarked by Facility managers and ESCOs through evaluating the tool. Also the development of the platform ensures a high stability level, as no severe breakdowns were reported during the evaluation period.



Overall, the DSSC application is evaluated by the external stakeholders as the flexible tool for the management of asset types, further incorporating in the Decision support process business aspects (SLAs and KPIs). This is one of the main innovations introduced by BESOS DSC as the platform that enables the coordinated management of heterogeneous asset types.

Apart from BESOS BSC & DSS system evaluation, special focus is delivered on the evaluation of BESOS impact to citizens. Within BESOS, we developed a behavioural triggering application in order to engage citizens towards energy efficient behaviour. In addition, EV users are actively involved in project activities by using EVs managed by BESOS platform. Therefore, two extra questionnaires were circulated to the end users (citizens and EV users) of the platform in order to get their valuable feedback.

5.4 EV Users Questionnaire Analysis

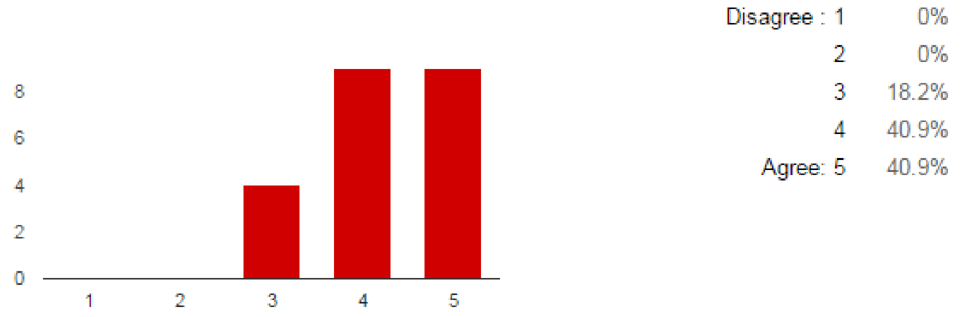
The ex-post questionnaire for EV Users is available in Annex B. More than 20 EV Users participated at the evaluation process, with the specific goal to evaluate the control strategies implemented for EV management scenario. The focus of the evaluation process is on the functionalities implemented during the evaluation period, as no specific user interface is provided to the EV Users, informing them for the status of strategy implementation. The usefulness and user satisfaction rating are presented:

	1	2	3	4	5
Useful	0%	0%	0%	17.40%	**82.60%**
Pleasant	0%	0%	8.70%	30.40%	**60.90%**
Bad	**60.90%**	39.10%	0%	0%	0%
Nice	0%	0%	8.70%	**56.50%**	34.80%
Effective	0%	0%	17.40%	**65.20%**	17.40%
Likeable	0%	0%	26.10%	34.80%	39.10%
Assisting	0%	0%	13%	**52.20%**	34.80%
Undesirable	**87%**	13%	0%	0%	0%

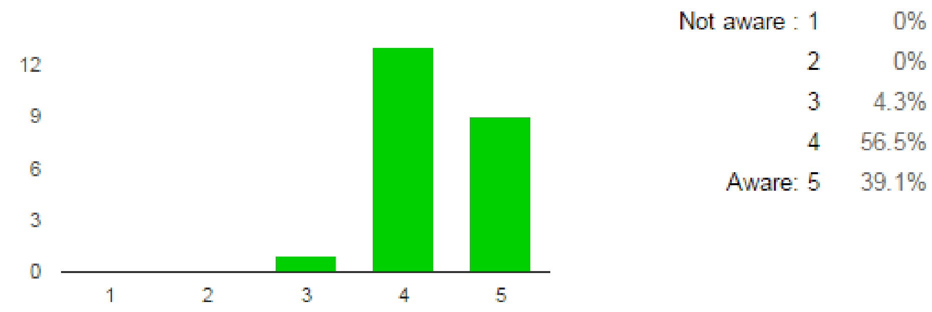
The TAM analysis shows the acceptance of the EV application from the EV users. The EV application is not characterized as bad or undesirable but also is not likeable or favourable for the end user. The EV application is perfectly characterized as useful and assisting that facilitates the charging process for the electric vehicles.

The EV users participating in BESOS activities by evaluating EV platform, show high interest for this functionality offered by the system. The end users were aware about the potential of the different control strategies and are willing to actively participate in a sophisticated management framework.

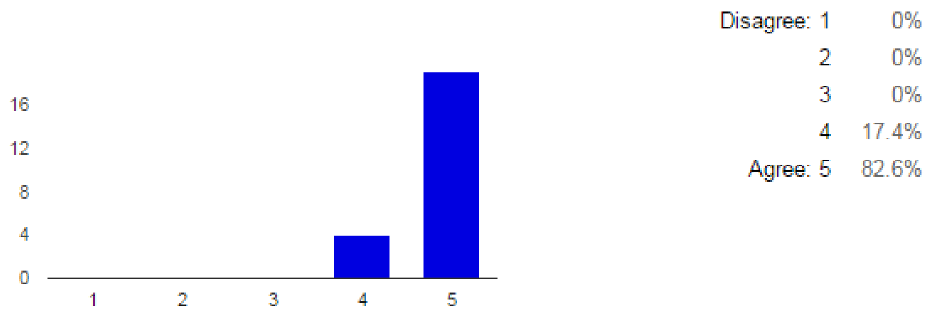
Has your energy behaviour changed as a result of your participation in the BESOS?



The energy consumption information has affected your overall performance?

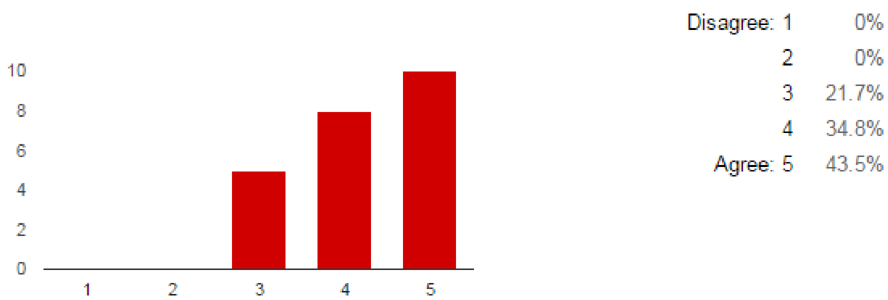


Was it easy to understand the different control strategies implemented?

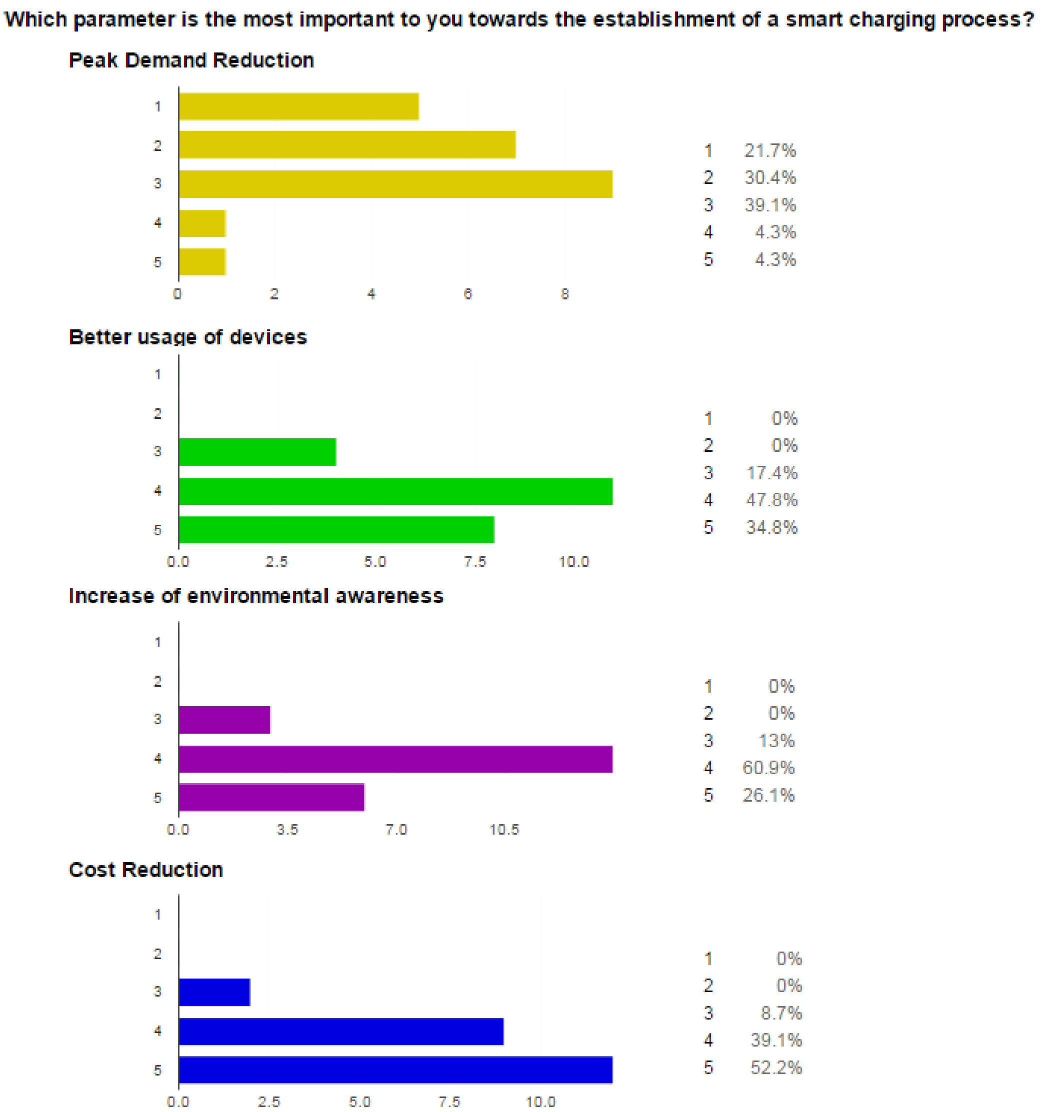


The questionnaire participants are willing to accept a charging mechanism (during night hours) if this does not affects their daily patterns and leads to a significant reduction on energy process (peak demand and energy cost reduction).

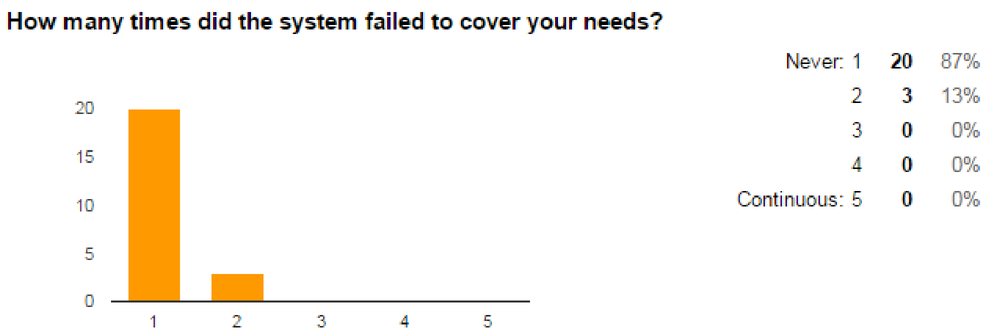
Are you willing to accept a night changing process if this does not affect your daily patterns?



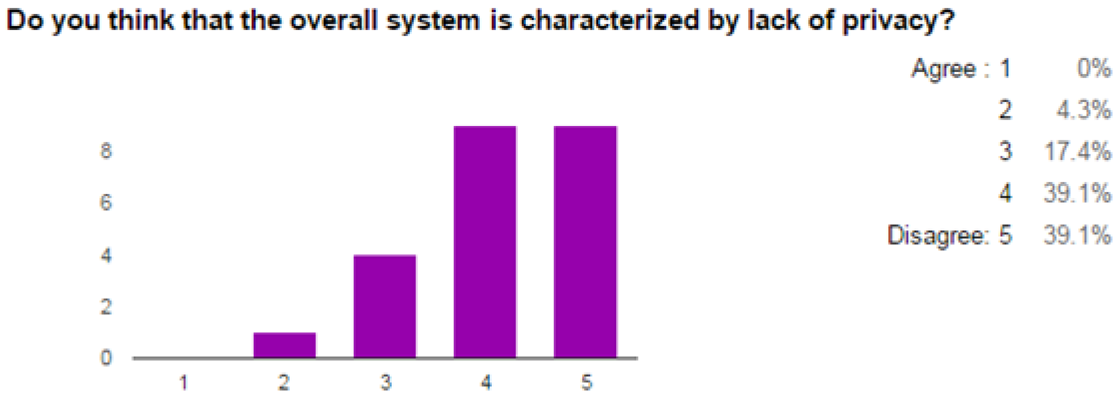
As about the criteria that affect end users' enrolment in EV charging models, as these examined in BESOS project these are:



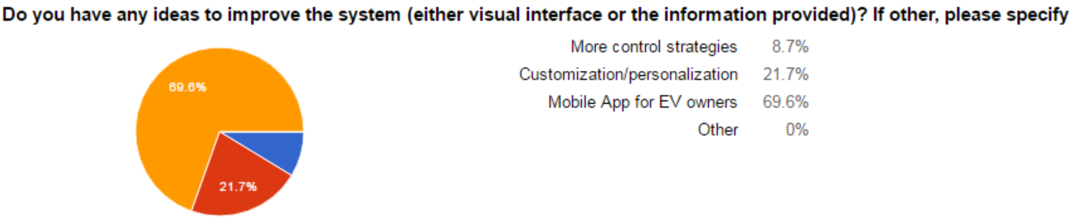
The application was characterized by high levels of reliability during the reporting period and thus no complaints were reported for possible breakdowns of the application



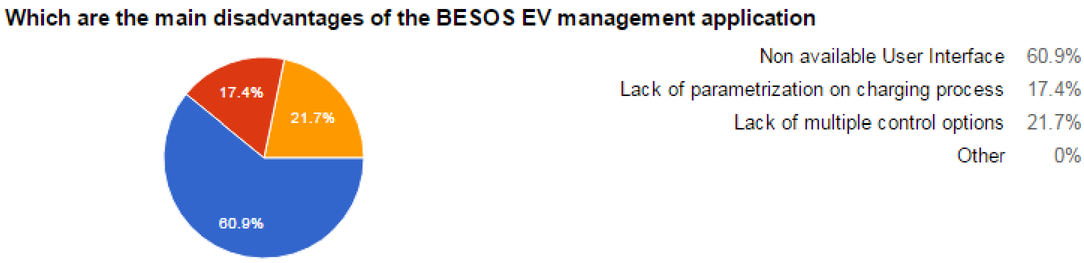
Privacy and security concerns are extensively examined in BESOS project. The EV Users participating in the evaluation process didn't raise any special request about the management delivered in EVs, as BESOS platform fully preserves end users privacy concerns.



EV owners highlighted the added value from receiving information about the charging process. Information about the status of charging process along with additional parameters related to electric vehicle operation should be available through a mobile/web app to the end users of the system (EV Owners).



The need for a UI towards the optimal management of EV process is also highlighted in the list of disadvantages of BESOS EV management application, considering also the requirement for a flexible customization of charging process.



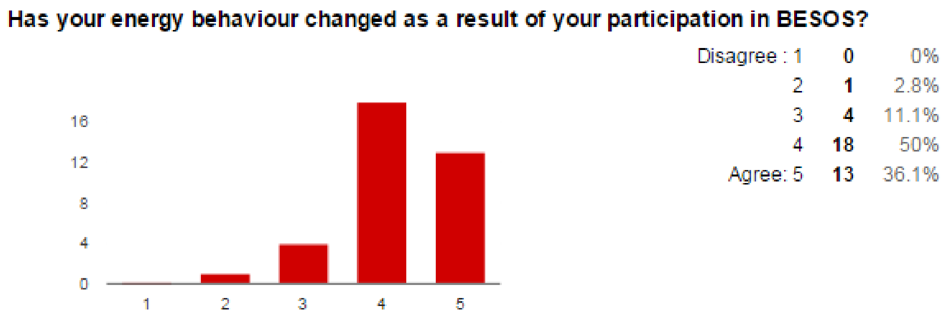
One of the main innovations of BESOS project is the integration of electric vehicles in BESOS platform. During the project period, we examined different control functionalities, directly affecting the charging process for EVs. Thus, it was important to evaluate the impact of BESOS EV management service, getting direct feedback from the actual users of the platform, the EV users.

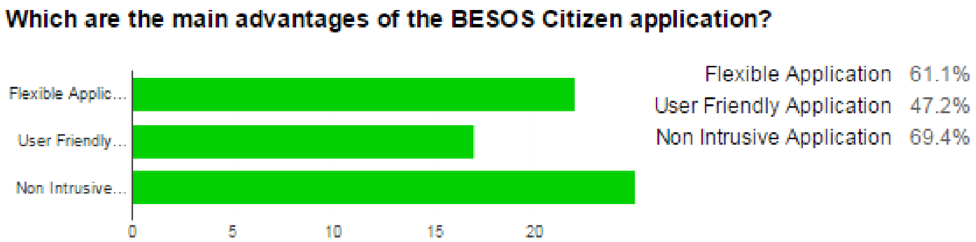
5.5 Citizens Questionnaire Analysis

The ex-post questionnaire for Citizens is available in Annex B. More than 35 citizens participated in the evaluation process, with the main focus to evaluate BMA application and the behavioural triggering framework examined in the project. Not only the pilot site users were involved in this evaluation process but also technical partners from both pilot sites in order to evaluate the easiness and friendliness of the BMA application. The usefulness and user satisfaction rating as defined through TAM mythology are presented:

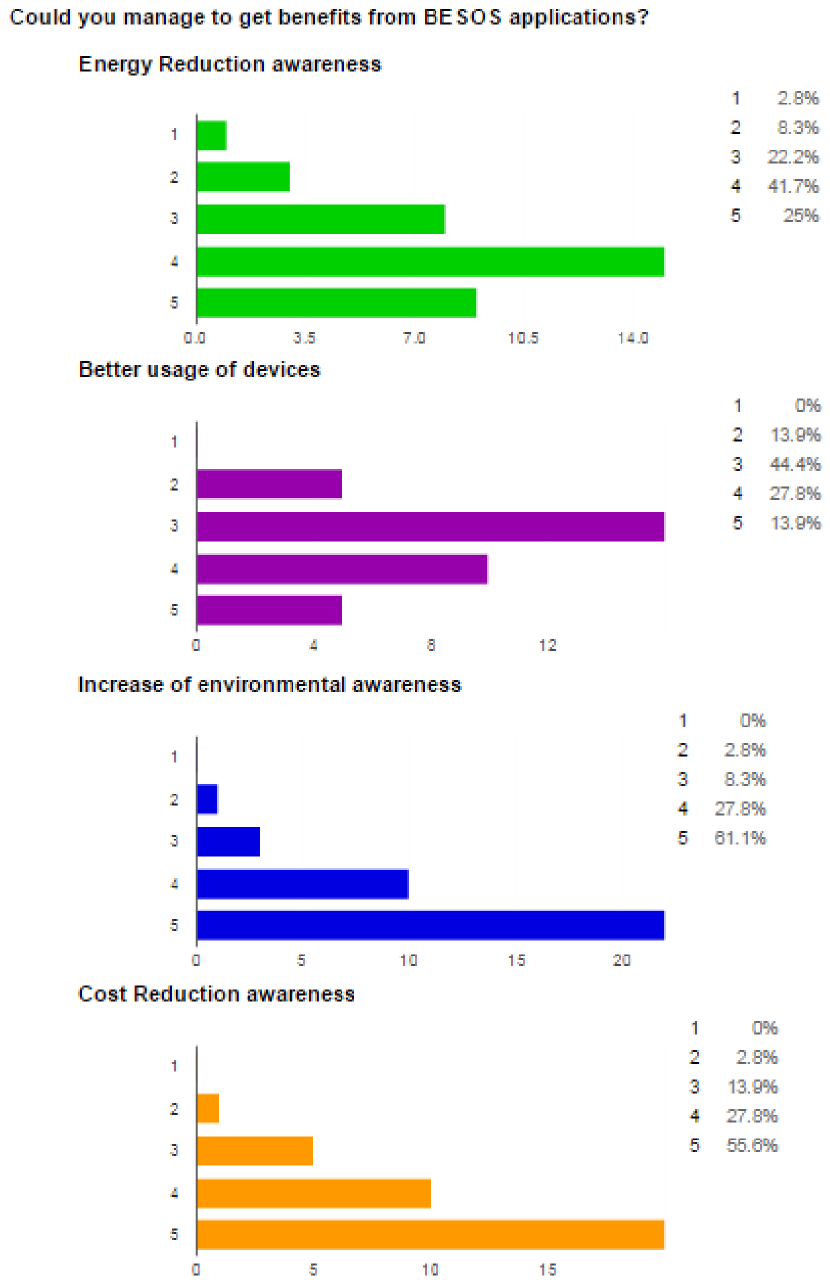
	1	2	3	4	5
Useful	0%	0%	8%	**50%**	**42%**
Pleasant	0%	0%	6%	14%	**81%**
Bad	**58%**	36%	6%	0%	0%
Nice	0%	0%	8%	**42%**	**50%**
Effective	0%	0%	28%	**47%**	25%
Likeable	0%	0%	6%	33%	**61%**
Assisting	0%	0%	14%	22%	**64%**
Undesirable	**89%**	11%	0%	0%	0%

The end users participating in questionnaire analysis specifically highlighted the importance of the different functionalities offered by the BMA application, directly impacting the behaviour of end users about energy consumption.

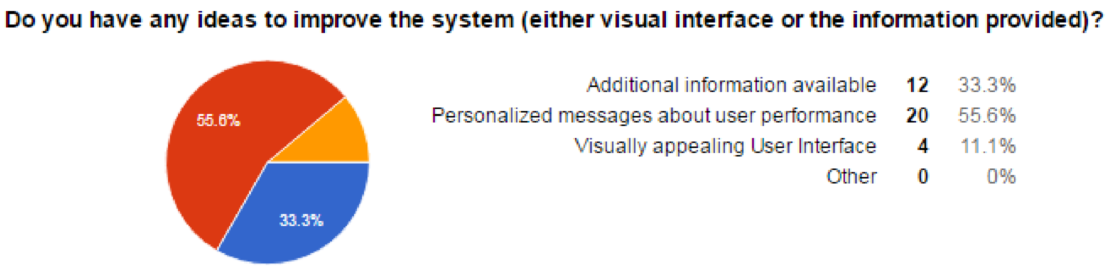




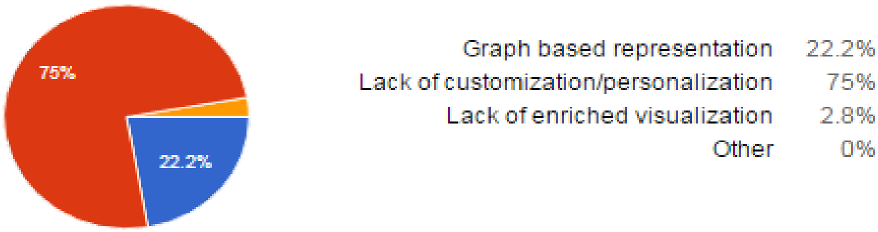
By periodically providing information to the citizens about energy consumption and environmental impact, we manage to increase end users awareness. In addition, notifications received by BMA application and associated with specific contextual conditions provide added value to the BMA platform.



The main disadvantage of the BMA App as highlighted by the citizens is the lack of customization and personalization about energy efficiency information, along with a more visually appealing user interface.

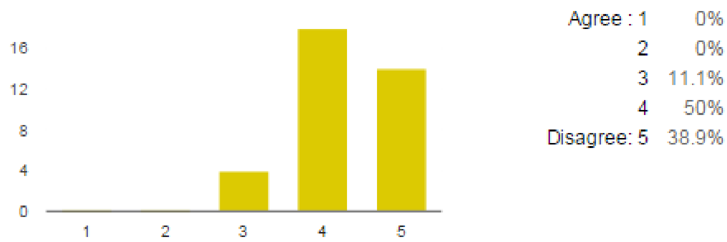


Which are the main disadvantages of the BESOS residential Users application?



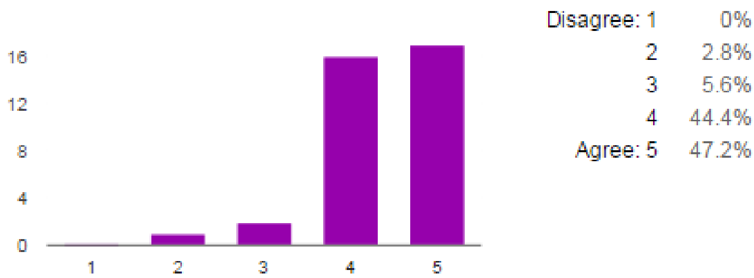
Privacy and security concerns are of high interest within BESOS project. The citizens participating at the evaluation process didn't raise any concerns about these aspects. The login process supported by the app ensures a trusted and secure access on personalized information.

Do you think that the overall system is characterized by lack of privacy?

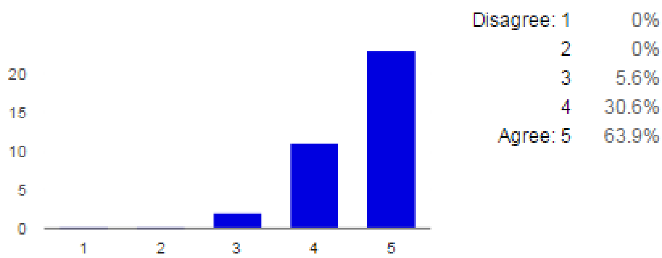


In addition to operational characteristics, end users also evaluated the look and feel of BMA application. Based on users feedback, the BMA App is simple to navigate and visually appealing. The notifications are considered as a feature, useful for citizens, while the updates of application information are adequate enough to ensure the interaction of users with the platform.

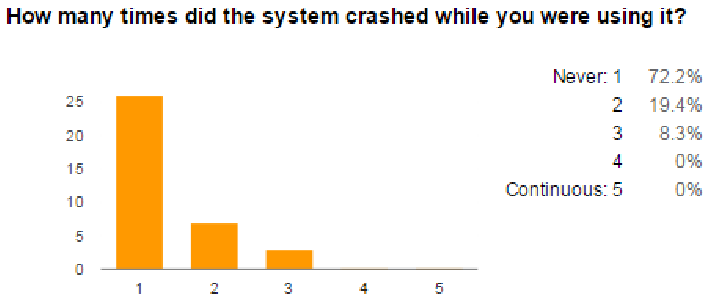
Do you think that the visual interface of the application is appealing



Is it easy to locate the required information on the screen?



Towards the evaluation of stability, minor issues related to BMA app reliable operation where easily handled by rebooting the BMA Application.



5.6 Summary and main outcomes

The feedback received from partners involved in project activities was very useful for the evaluation of BESOS platform. The different applications were evaluated with special focus on the innovative features brought by BESOS tools. These characteristics were also highlighted by the end users of the platform as the main findings of questionnaire surveys:

- Management of SLAs by monitoring KPIs values at different spatiotemporal granularity is an important feature for public authorities and ESCOs
- In addition, the functionality of dynamically renegotiating SLAs and KPIs is an important feature for the optimal placement of portfolio assets in energy management strategies.
- The definition of clusters with similar characteristics could be considered as an interesting feature for mass scale applications towards the selection of assets that fit to specific business models and contractual agreements
- The DSS tool is integrating different types of heterogeneous devices, handling that way a critical limitation in smart cities era; the lack of interoperability from the different hardware vendors. The business stakeholders of BESOS tools highlighted also the adaptation of IEC CIM in BESOS framework, as IEC CIM is a commonly adopted standard in smart grids applications.
- A fully automated framework, as provided by the DSS tool, is an interesting feature for asset managers. The end user of the tool may set the high level objectives which are further transformed to asset level control strategies.
- Special interest was delivered on the integration of BESOS forecasting engine as a feature of BESOS DSS.
- As an extra feature of DSS, we highlight the “Alarm Service” engine, triggering alarms in case of abnormal conditions.
- The mobile app, is a simple and intuitive app, providing information needed by citizens. Comparative analysis among different time period and further informative messages are highly evaluated by the citizens evaluating the mobile application
- The EV management process was delivered in a non-obtrusive way and thus we didn’t face any complaints from EV users.

We have to highlight also some comments received by the pilot stakeholders that are useful for further extending the existing BESOS tools

- An EV management application (UI) should be considered as an extra feature to further complement the EV management process (not part of BESOS project)
- The BBSC and DSS tools should be further integrated to commercial asset management tools already in place.
- The different applications should be customizable in order to fit the different case scenarios examined in the different pilot sites.

Overall, the end users' experience evaluation was performed during the 2nd evaluation period of the project, along with the full scale evaluation process. The evaluation was performed from ~150 end users directly interfacing with the tools developed in BESOS project, enabling that way the concrete evaluation of the different applications. ESCOs, Authorities and citizens participated in the evaluation process in order to retrieve their useful feedback. The end users' evaluation was positive for project outcomes with some remarks to be considered for further exploitation of BESOS outcomes.

6 Conclusions

The results from BESOS evaluation analysis show that the proposed platform can reach the goals set by the project. Particularly, as shown in impact assessment analysis, higher energy efficiency has been achieved with optimization techniques able to act on different subsystems. Furthermore, CO2 emissions have been decreased significantly and the interaction with third party services has been proved successful. To highlight also the RES exploitation as one of the main objectives examined in the project. By aggregating different types of assets, we are able to support the different functional scenarios examined in the project.

Following impact assessment analysis, we need to address the impact of BESOS platform for the different end users of the system. The BESOS platform is considered as a user oriented framework and therefore, as part of the evaluation, a set of questionnaires were circulated to the business stakeholders in order to receive their feedback about BESOS platform. The different stakeholders (municipalities, facility managers, facility owners, ESCOs, asset managers) highlighted the main innovations brought by the platform, characterizing BESOS as a modular framework that enables the optimal management of heterogeneous asset types.

This deliverable is documenting part of the evaluation analysis as defined in the evaluation plan. While this document is focusing on impact assessment analysis and end users experience evaluation, D7.3 provides the technical assessment and business evaluation of the project. We have to point out that this document, and more specifically the impact assessment analysis, provides the big picture of BESOS platform to further enable the business exploitation of project outcomes. Therefore, this deliverable and more specifically the results extracted from the evaluation analysis, will further contribute to the definition of the main exploitable outcomes in D7.3.

ANNEX A: References and Acronyms

6.1 References

[1] D1.1 Requirements and Use Case Specification
[2] D1.2 BESOS Business Models
[3] D1.3 Key Performance Indicators
[4] D7.1 Ex-Ante Analysis and Baseline Definition
[5] D7.3 Technical Dissemination and Exploitation
[6] Jinke D. Van Der Laan, Adriaan Heino, Dick De Waard, 1997, A simple procedure for the assessment of acceptance of advanced transport telematics, Transportation Research Part C: Emerging Technologies

6.2 Acronyms

Acronyms List	
BaU	Baseline scenario
PV	Photovoltaics
EMS	Energy Management Systems
PLS	Public Lighting Systems
TLS	Traffic Lighting Systems
EV	Electric Vehicles
RES	Renewable Energy Sources
MAPE	Mean Absolute Percentage Error
MAPD	Mean Absolute Percentage Deviation
PF	Power Factor
DSS	Decision Support System
BSC	Balanced ScoreCard
SDX	Sodexo
BCN	Barcelona
KPIs	Key Performance Indicators
TAM	Technology Acceptance Model
IT	Information Technology
UA	user acceptance
SLA	Service Level Agreements
BMA	Behavioural Mobile Application

ANNEX B: Ex-post Questionnaires Analysis

This Annex is reporting the different types of questionnaires circulated to BESOS stakeholders for ex-post evaluation. Four types of questionnaires are presented to support the end users evaluation of BESOS project.

BESOS Citizens Questionnaire_ BMA Application

Ex post evaluation -The following template is aimed at gathering information to enrich the BESOS evaluation framework, thereby allowing a more concrete development of the BESOS platform, for a mass application. The scope of this questionnaire is to examine the potential impact of BESOS project to residential users.

What is your overall judgment for the BESOS application you tried?

1: minimum, 5: maximum

	1	2	3	4	5
useful					
pleasant					
bad					
nice					
effective					
likeable					
assisting					
undesirable					

Has your energy behaviour changed as a result of your participation in the BESOS?

Figure 32 BESOS Citizens Questionnaire _ BMA Application

BESOS Citizens Questionnaire_ EV Application

Ex post evaluation -The following template is aimed at gathering information to enrich the BESOS evaluation framework, thereby allowing a more concrete development of the BESOS platform, for a mass application. The scope of this questionnaire is to examine the potential impact of BESOS project to residential users.

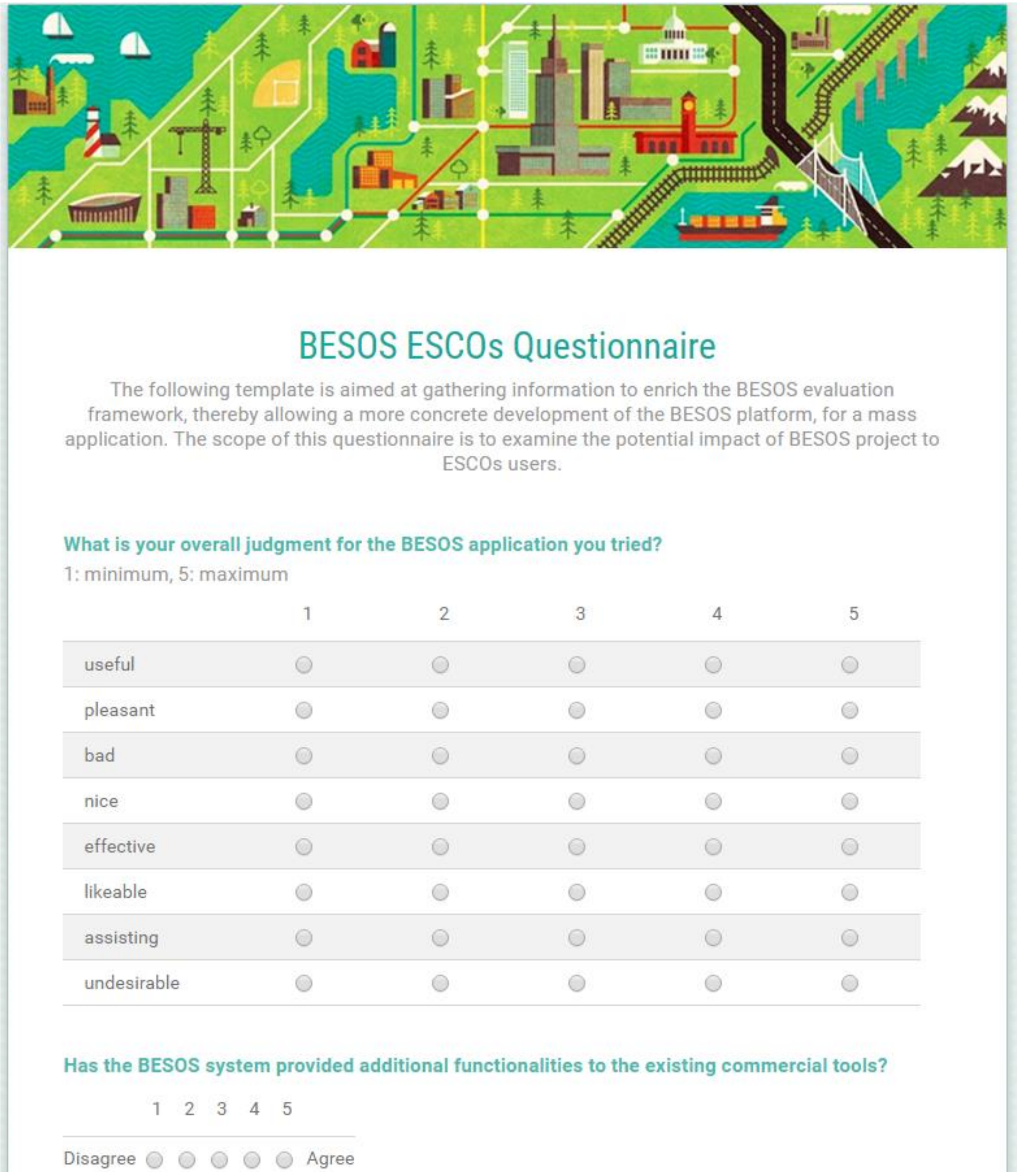
What is your overall judgment for the BESOS application you tried?

1: minimum, 5: maximum

	1	2	3	4	5
useful	○	○	○	○	○
pleasant	○	○	○	○	○
bad	○	○	○	○	○
nice	○	○	○	○	○
effective	○	○	○	○	○
likeable	○	○	○	○	○
assisting	○	○	○	○	○
undesirable	○	○	○	○	○

Has your energy behaviour changed as a result of your participation in the

Figure 33 BESOS Citizens Questionnaire _ EV Application



BESOS ESCOs Questionnaire

The following template is aimed at gathering information to enrich the BESOS evaluation framework, thereby allowing a more concrete development of the BESOS platform, for a mass application. The scope of this questionnaire is to examine the potential impact of BESOS project to ESCOs users.

What is your overall judgment for the BESOS application you tried?

1: minimum, 5: maximum

	1	2	3	4	5
useful	○	○	○	○	○
pleasant	○	○	○	○	○
bad	○	○	○	○	○
nice	○	○	○	○	○
effective	○	○	○	○	○
likeable	○	○	○	○	○
assisting	○	○	○	○	○
undesirable	○	○	○	○	○

Has the BESOS system provided additional functionalities to the existing commercial tools?

	1	2	3	4	5	
Disagree	○	○	○	○	○	Agree

Figure 34 BESOS ESCoS Questionnaire

BESOS Authorities Questionnaire

The following template is aimed at gathering information to enrich the BESOS evaluation framework, thereby allowing a more concrete development of the BESOS platform, for a mass application. The scope of this questionnaire is to examine the potential impact of BESOS project to Public Authorities users.

What is your overall judgment for the BESOS application you tried?

1: minimum, 5: maximum

	1	2	3	4	5
useful	○	○	○	○	○
pleasant	○	○	○	○	○
bad	○	○	○	○	○
nice	○	○	○	○	○
effective	○	○	○	○	○
likeable	○	○	○	○	○
assisting	○	○	○	○	○
undesirable	○	○	○	○	○

Has the BESOS system provided additional functionalities to the existing commercial tools?

	1	2	3	4	5	
Disagree	○	○	○	○	○	Agree

Figure 35 BESOS Authorities Questionnaire

ANNEX C: Lisbon Pilot site Simulation scenarios

Due to the lack of data from PLS and TLS EMSs integrated in Lisbon pilot site, we cannot proceed with the concrete evaluation of the associated use cases. Therefore, and in order to facilitate the evaluation process, we have conducted some simulation scenarios in order to evaluate the impact of different control strategies. The simulation analysis results will be further exploited towards the evaluation of the holistic energy management scenario.

Energy demand optimization of the public lighting based on light environment

As limited data values are retrieved from Lisbon PLS EMS integrated in BESOS platform, we simulate the missing values (e.g. control based on luminance conditions) by replicating BCN Public Lighting EMS. The results from use case evaluation period are presented in the following table:

Evaluation Indicator	KPI Reduction
Energy Consumption	13.34%
CO2 Emissions	17.65%
Energy Cost	13.55%

Table 85 PLS Energy demand optimization

We first define the PLS baseline, taking into account typical PLS operation. Then, the DSS system triggers appropriate control commands to the associated PLSs taking as input parameter the external luminance conditions. The total energy consumption reduction is due to the dimming functionality enabling the optimal management of PLS. The overall reduction is even higher for the cost of energy, as the dimming process is performed during day hours where the total cost of energy is higher. On the other hand, no control strategy is implemented during night hours where the cost of energy is low. In addition, we are evaluating total CO2 emissions for the reporting periods. As a limited number of control actions are implemented, there is no significant impact on CO2 emissions and the total CO2 emissions reduction equals to energy consumption reduction.

A typical load curve for Lisbon PLS simulated scenario is presented.

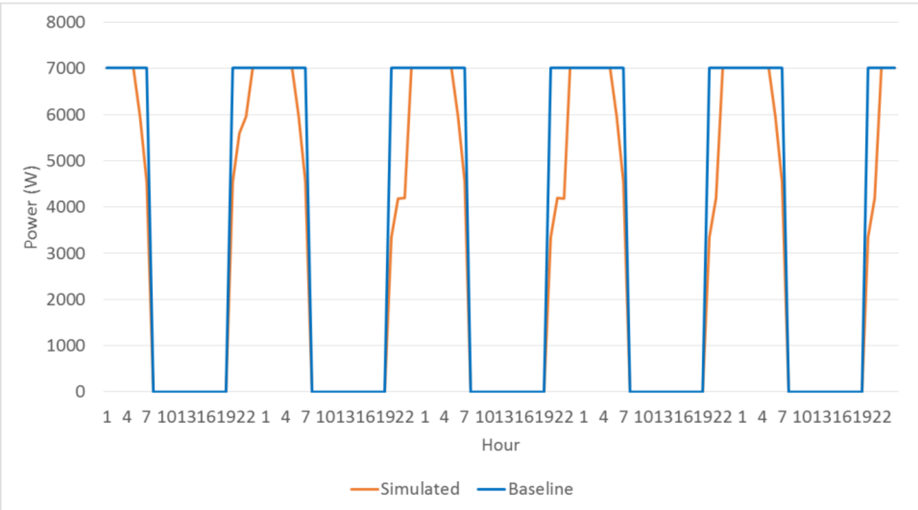


Figure 36 Public lighting based on light environment

The potential of this control functionality is limited and as we are missing data from the full integration of Lisbon PLS, we are not extensively evaluating this use case. The goal for this case is to support the implementation of integrated scenario, considering PLS EMS as part of the holistic management framework. Public lighting optimization process is considered as part of the integrated smart city energy optimization framework and the aforementioned curves set the simulation datasets for the holistic management framework.

Energy demand curve optimization based on traffic conditions

The integration of traffic lighting system combined with mobility/traffic density data, enables the evaluation of this use case. The main objective of this use case is to optimally operate PLS/TLS systems, taking into account traffic density patterns. The level of lighting for a given point of light *p* in a road segment *r* will depend on the following parameters:

- The minimum level of user comfort set by legislation
- The size of road
- The density of the traffic in the considered time slot t

A high level presentation of the algorithm incorporated in BESOS DSS is presented.

Taking the length of each road lane, we are considering a point of light every 30 meters and 100W per point of light. We consider that the scheduled curve of every point of light equals to the baseline data coming from TLS system of Entrecampos control centre integrated in the platform. We further defined three types of road:

- Low speed road, where speed <= 30 km/h
- Moderate speed road, where 30 < speed <= 60 km/h
- High speed road, where speed > 60km/h

All roads at Lisbon pilot site (40 streets in Entrecampos area) are defined following the current traffic conditions:

- Viaduto Duarte Pacheco, Av. República, Av. Fontes Pereira de Melo, Av. António Augusto de Aguiar, Av. das Forças Armadas, Campo Grande → High speed road
- A mixing of moderate and low speed road for the rest of the streets at Entrecampos area.

Based on the type of road and the traffic density, the following table is defined. Values represent the percentage of dimming to be set:

Traffic density	Low speed road	Moderate speed road	High speed road
Very light traffic (1)	0.6	0.5	0.4
Light traffic (2)	0.65	0.6	0.5
Heavy traffic (3)	0.7	0.9	0.9
Very heavy traffic (4)	0.75	0.8	0.9
Traffic jam (5)	0.8	0.5	0.4

Table 86 Traffic Lighting System - BESOS DSS

What we are missing from Lisbon pilot site is traffic density data required for the simulation process. Therefore, data coming from BCN pilot city are considered to further simulate this case scenario and evaluate the TLS management platform in Lisbon pilot site. The results from the demonstration of this use case are presented. First we are presenting the impact for a 4-week operational period of TLS DSS mechanism.

	Week 1	Week 2	Week 3	Week 4
Energy Consumption (KWh)	8806.280	8838.155	8864.545	8874.770
Energy Cost (euro)	1320.033	1325.057	1329.467	1331.432
CO2 Emissions (gr)	2470.509	2479.440	2487.149	2489.946
Actual vs. Baseline Analysis				
Energy Consumption	0.728	0.731	0.732	0.733
Energy Cost	0.749	0.752	0.753	0.754
CO2 Emissions	0.731	0.733	0.735	0.735

Table 87 Traffic Lighting System – Evaluation Analysis

The dimming functionality on TLS leads to a significant decrease of energy consumption (and therefore energy cost and CO2 emissions), directly associated with the traffic density patterns and the dimming capabilities of DSS system as presented in **Table 86.** There is no remarkable differentiation at the output results for the different operational periods, as the same traffic density data are retrieved from TLS EMSs. The next figure presents the DSS simulation results for a weekly period.

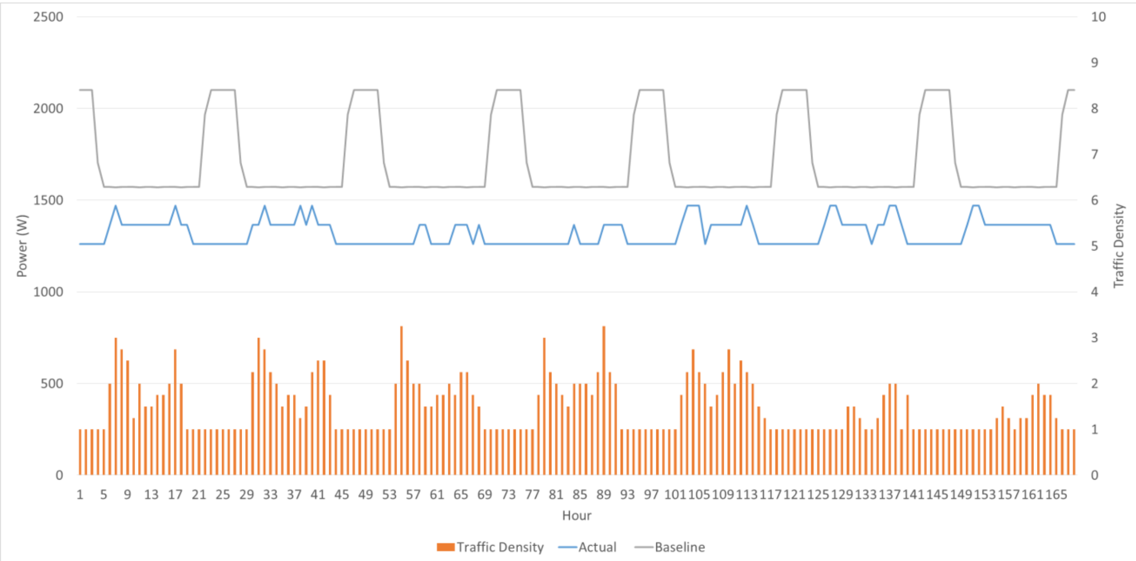


Figure 37 Energy demand curve optimization based on traffic conditions

We first define a baseline scenario taking into account energy consumption data from pilot site. Then, by incorporating DSS tool in BESOS platform, control strategies are implemented at the TLS assets. The average results for the testing period are presenting, showing the impact of control strategy in TLS assets integrated in BESOS platform.

Evaluation Indicator	KPI Reduction
Energy Consumption	-26.90%
CO2 Emissions	-24.79%
Energy Cost	-26.65%

Table 88 TLS Energy demand optimization

It is clear that the final impact in energy consumption, energy cost and CO2 emissions is dependent on the control strategies implemented taking also into account TLS technical characteristics and traffic density data. The next step is to examine the impact of Traffic PLS in conjunction with other BESOS assets in smart city energy demand management scenario.