Output Factsheet

Output title: T4.2 Cost-benefit analysis of the EMS

Summary of the output (max. 2500 characters)

The 3Smart platform developed within the project as a software tool has been applied to 5 pilots in 5 different countries of the Danube region. The platform enables to perform energy management of buildings and electricity distribution grids in an integrated way, but requires investments to be done on the sides of buildings and grids to enable the platform functioning. Within the cost-benefit analysis output a systematic procedure is agreed and followed for all the pilots to assess the cost and benefits related to the 3Smart system application on sites.

The costs are assessed by documenting all the costs of the investment, but also those costs that would incur when there would be no EU funding, like personnel costs for modules adaptation and installation, for which highly skilled experts are needed.

The benefits are assessed in comparison of the 3Smart platform performance on the pilot with the performance of classical state-of-the-art automation systems with usually a very simple operational logic. The 3Smart platform performance was assessed by applying the 3Smart tool on the data collected from sites, meaning that typical responses of non-controllable processes were used as well as models of building elements derived from on-line collected data from the pilots. Benefits are assessed separately for the cooling and separately for the heating season on each pilot by focussing on characteristic days of operation.

On the grid side the costs and benefits for the distribution system operators when using flexibility potential of its customers were analyzed and assessed. Benefits were derived by following the techno-economical procedure developed within the long-term grid-side 3Smart module.

Also environmental benefits were assessed.

In the output this procedure is documented and performed for each of the 5 pilot sites.

Contribution to EUSDR actions and/or targets

The project in general contributes to Priority Area 2 "To encourage more sustainable energy" of the EUSDR within which the following actions are required: „To explore the possibility to have an increased energy production originating from local renewable energy sources to increase the energy autonomy", „To promote energy efficiency and use of renewable energy in buildings and heating systems", „To facilitate networking and cooperation between national authorities in order to promote awareness and increase the use of renewable energies".

The developed output exposes the procedure for assessment of cost and benefit regarding installation of energy management systems in building and grids which are the key enablers of demand-side flexibility that opens space for increasing the share of renewable energy and for greening the energy system while keeping the security of supply intact. Energy management systems seem to be a clear necessity in the future and this output details how to make an economically informed decision on their installation in buildings and grids.

Performed testing, if applicable

The cost-benefit analysis output documents the testing of the developed procedure on 5 pilots in 5 different countries, in versatile configurations of buildings and grids. Extensions of the developed 3Smart procedures for benefits assessment are further used in Interreg Central Europe project Store4HUC (Integration and energy management of energy storages at historical urban sites), with application to PV system and battery investment structuring on a historical heritage site.

Integration and use of the output by the target group

The output will be very valuable for energy regulators with the development of measures to support demand response abilities within the energy networks.

For DSOs the const-benefit output will be useful to assess the company potential for using demand response alternatives to grid reinforcements.

Local public authorities will have a sample of five pilots assessments regarding cost and benefit which will help them in deciding and planning the return on investments for own buildings stock improvement.

Software companies will have at the disposal a procedure that can be used to inform their customers – potential investors in energy management systems about the expected costs and benefits.

Geographical coverage and transferability

The output is applicable in any of the regulatory and technical environments of the Danube region countries and beyond.

Durability (max. 1500 characters)

It s expected that the output will be used more and more as the interest of regulators and enterprises focuses on enabling flexibility in end-consumption (for ones it is a path to energy system decarbonization while ensuring safety of supply, for the others this is of course a business opportunity). It has no particular validity period as it resides on the technical algorithms and technical performance of the 3Smart platform. Even if the demand response scheme changes significantly from what was presumed in 3Smart, the tool will be adaptable so that it can be also used without considering demand response flexibility provision.

Synergies with other projects/ initiatives and / or alignment with current EU policies/ directives/ regulations, if applicable (max. 1500 characters)

The cost-benefit analysis procedure for measures of energy management including demand response is very important for the coming decades of the energy system full decarbonizaton in the Danube region and the EU, so it s in line with the European Green Deal of the new European Commission as well as with numerous directives and national plans that will stem out of it.

There is a clear synergy of this developed tool with the Interreg Central Europe project Store4HUC which inherits the developed procedure for economical assessment of various

combinations of PV and battery system to decide which configuration is economically optimal.
Output integration in the current political/ economic/ social/ technological/ environmental/ legal/ regulatory framework
The output results will be very valuable for energy regulators to have feedback on what benefit they can expect from different demand response schemes and how to support local replication of the IT systems that advance end-customers to prosumers with controllable and flexible consumption.

Project Deliverable Report

Smart Building – Smart Grid – Smart City

http://www.interreg-danube.eu/3smart

DELIVERABLE D6.4.1

Cost benefit analysis on the pilot level – Croatian pilot

Project Acronym	3Smart
Grant Agreement No.	DTP1-502-3.2-3Smart
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Code name	**Version:** 1.1 Final ☒ Final draft ☐ Draft ☐
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Deliverable participants	UNIZGFER, HEP, UNIBGFME, SVEMOFSR, UNIDEBTTK
Authors (Partners)	Mario Vašak, Tomislav Capuder, Anita Martinčević, Nikola Hure, Danko Marušić, Hrvoje Novak, Paula Perović (UNIZGFER), Leon Lepoša, Tomislav Stašić, Martin Bolfek (HEP)
Contact person	Mario Vašak (UNIZGFER)
Abstract (for dissemination)	The deliverable provides cost-benefit analysis for the installed modular energy management platform on the two buildings and on the electricity distribution grid of the Croatian pilot. The costs have been assessed based on actual investments on sites performed and based on estimated personnel effort needed for further replications of the designed modular 3Smart system. The building-side benefits are determined based on 3Smart modules performance in characteristic days in comparison with state-of-the-art conventional control, with included interaction with the grid. Grid-side benefits are determined based on economic calculations of the long-term grid-side 3Smart modules.
Keyword List	Cost-benefit analysis, public buildings, distribution grid, energy management system, energy efficiency, sustainability, environmental effects

Revision history

Revision	Date	Description	Author (Organization)
0.1	08 February 2018	Template	Andrea Moser (EEE)
0.2	20 May 2018	Inserted costs for the UNIZGFER building	Mario Vašak (UNIZGFER)
0.3	21 May 2018	Inserted costs for HEP Building	Tomislav Stašić, Leon Lepoša (HEP)
0.4	15 November 2018	Renewed costs for UNIZGFER building	Mario Vašak (UNIZGFER)
0.5	15 December 2018	Renewed costs for HEP building	Leon Lepoša (HEP)
0.6	20 December 2018	Inserted cost for grid	Tomislav Capuder (UNIZGFER)
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0.8	30 June 2019	Update of costs and benefits based on so far pilot results	Mario Vašak (UNIZGFER)
0.9	15 December 2019	Finalization of grid-side benefits	Paula Perović, Tomislav Capuder (UNIZGFER)
1.0	23 December 2019	Final draft	Mario Vašak (UNIZGFER)
1.1	25 March 2020	Entered final results from D7.1.3. Performed review.	Mario Vašak (UNIZGFER)

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Executive summary

Cost-benefit analysis is performed for each of the 5 pilots in the 3Smart project, by cumulating the effects of both the building and the grid-side energy management on each pilot location. Also, the broader environmental effects are considered in order to reach the correct ratio of costs and benefits to make a driver for regulatory set-ups change in the Danube region, in favour of the improved energy-efficiency, use of renewable energy, energy security and demand response.

The deliverable provides cost-benefit analysis for the installed modular energy management platform on the two buildings and on the grid side for the Croatian pilot. The pilot consists of UNIZGFER's skyscraper building, HEP's headquarter building and the local electricity distribution grid around the buildings.

1. Introduction

Costs for introducing the 3Smart system are determined based on actual investments performed on the sides of buildings and of the grid. Also personnel cost is estimated for the designed 3Smart system replication on a new site to get an overall cost assessment.

The benefits are estimated based on the 3Smart modules performance. On the side of the buildings calculations were performed based on the optimal building operation, including seizing the demand response opportunities, i.e. reservation and activation payments to the building from a grid-side entity for flexibility provided. Calculations were performed based on models of building HVAC system determined from processing of actual pilot site data. Characteristic days are selected for which computation is done in a way to compute a 24-hour optimal building behaviour and the amount of flexibility that can be offered to the grid by engaging in coordination all the building elements to which the 3Smart system has a reach. It is also important to stress that the initial building state, i.e. state at the beginning of the day, is optimized and it is enforced that the end-state of the building, i.e. state of the building at the end of the day, is the same as the initial state, such that the building is operated in a sustainable way that can be repeated day by day. The total operational cost for the building, including all relevant energy costing terms and degradation cost of equipment, is compared with the operational cost of the state-of-the-art controls performed by conventional well-tuned building automation systems in the same conditions and in this way building-side benefits from the 3Smart system operation are assessed and extrapolated on the whole-year period. Grid-side benefits are estimated based on the long-term grid-side modules economic assessment of the overall amount of money available for end-customers' flexibility engagement. It is accounted that one part comes from not investing the whole available amount in flexibility and the other comes from the time intervals in which at the end flexibility was not activated such that the activation payment is not performed.

2. Methodology

2.1 Costs

The methodology for the cost-benefit analysis of the pilots (buildings and grid) is, to first of all analyze the costs related to the EMS installation. This encompasses the following parts:

- pre-analysis and concept design for the particular building
  - creation of a dynamic building simulation model, if necessary
  - comparing actual and simulated consumption
  - selection of layers to be included in the EMS
  - simulation of building behaviour with the selected layers
  - deciding necessary data flows and possibly additional installations
- mechanical and electrical installations project
- mechanical and electrical installations (equipment and service)
- IT integration and system operation

The hosting partners for the buildings and the grid (UNIZGFER, HEP) in the Croatian pilot analyzed and reported the costs for pre-analysis and concept design, mechanical and electrical installation project, the installations including equipment and service, IT integration as well as running of the building EMS.

Secondly, the costs for setting up of the 3Smart EMS modules are analyzed, followed by adaptations and monitoring costs. Partners in charge for 3Smart EMS installation within the two buildings are pilot leaders and hosts supported by modules developers (pilot leaders: UNIZGFER, HEP; modules developers: UNIZGFER, UNIDEBTTK, UNIBGFME, SVEMOFSR, EON). They commonly reported the related costs for modules installation. These costs were assessed as estimates of the costs for personnel needed to replicate the installation of the 3Smart system.

The DSO partners and R&D partners in charge for setting up the grid-side EMS calculate their costs for the EMS operation maintenance and compare them to the previous (before the EMS installation) mode of the grid operation.

2.2 Benefits

The benefits are assessed based on 3Smart modules performance on the building and on the grid. For buildings, a comparison of building operation with conventional state-of-the-art well-tuned building automation system is performed, in exactly the same conditions. In D7.1.3 Operational logs and seasonal analysis [1] these responses obtained are presented in detail and analysis of them is provided. Here for the CBA only the final operational costs in EUR are extracted and extrapolated for the whole-year period in order to be able to provide the yearly estimate of the benefits. For the grid, the benefits are extracted based on economical assessment which is a part of the long-term grid-side modules operation.

In calculation of the benefits in building operation optimization of building performance on a 24-hour period was performed on all levels engaged within the 3Smart system. On UNIZGFER and HEP building all three levels are being actively optimized: the zone level where rooms heating/cooling profiles are optimized to attain a proper comfort at minimum costs, the central HVAC level where the conditioning of the centrally prepared heating/cooling medium is being optimized in order to attain minimum costs and provide enough energy required by zones, and the microgrid level where the battery system is engaged in order to provide the optimized overall energy exchange profile with the distribution grid. The microgrid level takes into account also the possibilities offered by demand response functionality – the time windows when grid potentially needs flexibility as well as the pricing conditions for reservation and activation of flexibility which are computed by grid-side modules. The microgrid level optimizes the behaviour of the battery system and includes also into account the degradation costs for the battery system operation, but also engages the operation of the HVAC system via localized price signals to shape the behaviour of the whole HVAC system to finally yield optimal operational costs. The microgrid level also provides the optimized flexibility bid of the building that is then offered to the grid. On all three levels also the initial building state is optimized and it is enforced that the end-state of the building equals this optimized initial state which induces that the 3Smart system makes a day-to-day sustainable and repeatable behaviour of the building, i.e. any savings produced cannot be accredited to the difference of the initial and final building state (state after 24 hours) as the building remains in the same conditions.

To get the benefits, the 3Smart system performance on the building side is compared with the performance of conventional state-of-the-art controls practiced in current building automation systems existing on the site. Exactly the same outdoor conditions are used as well as exactly the same building configuration and models of all elements determined by running 3Smart prediction and estimation modules on measurement data obtained on the building and actuation data provided to the building from the 3Smart system. In this way benefits can be assessed that reside only on software side, i.e. on the fact that the 3Smart modules use predictive control and mathematical optimizations while the conventional systems decide on their reaction by taking into account only current state of the building, current outside imposed conditions and current requirements of end-users.

The grid-side benefits are calculated as part of the money which is estimated by the long-term grid-side modules to be available as a consequence of postponing the reinforcement of the grid which is enabled by engagement of flexibility. Different ratios of this money can be selected to be used for flexibility engagement by end-customers and to be retained by the company. Of course, higher amount retained reduces the prices for flexibility reservation and activation to be paid to end-consumers which may lead to the fact that the end-consumers will find the flexibility provision not economically feasible and thus a balance needs to be found. Another source of benefit stemming form the amount of money planned to be invested in flexibility engagement comes from the non-activated flexibilities at the end.

The effects and broader benefits for the environment based on the application of the 3Smart EMS system in the pilot is also assessed. This is performed by determining the saved energy induced via the 3Smart system operation and transforming this to the evaded CO_2 emissions equivalent.

3. Cost-benefit analysis on building side

3.1 Analysis of installation and operation of the EMS

This section provides a detailed overview about the conducted installations at the pilot buildings, that were necessary to create a basis for the 3Smart EMS system. All parts regarding pre-analysis and concept design, mechanical and electrical installation projects, mechanical and electrical installations (equipment and service) and IT integration and operation are listed in this section and the related costs are reported. In addition, the costs for the operation of the EMS system are provided.

UNIZGFER building

The initial state of the UNIZGFER skyscraper building is given in the deliverables of activity 6.2, see e.g. [2], and here it is shortly revised.

The skyscraper building of UNIZGFER (building C of UNIZGFER's buildings complex), at address Unska 3, 10000 Zagreb has a heating and cooling system in place which uses fan coils FCC04 and FCC06 of the vendor Trane in all its laboratory and office spaces, as well as radiators in smaller service rooms and in stairways. The heating energy for the system is supplied from the central city heat distribution system via a heat exchanger in the heating substation of the building of type Kompakt 1000. The cooling energy for the building is supplied from UNIZGFER's own chiller station RTAC 200 HE produced by the Trane manufacturer.

In the existing system fan coils control for maintaining the room temperature was already implemented on the level of every room by using Siemens control devices RXC21.1 or RXC21.5 and accompanying display units QAX34.1 or QAX34.3 which enable the user to control the mode of fan coils local operation and to set the required temperature for the room. All devices are networked with a central monitoring system (SCADA system) based on Siemens DESIGO platform, except for the temporarily extracted control devices on the 9th and 10th floor which used a separate monitoring and control system that already followed the centralized control ideas of 3Smart, and with the planned intervention they needed to be integrated back in the central system that then as a whole follows the idea of 3Smart building energy management.

With the installations in question the existing system of building indoor climate control is improved and the installation of the battery storage system is added. In such a way algorithms for coordination of the entire building operation are planned through the 3Smart EMS developed within the project.

All prices of services provided in Table 1 include also the VAT (25% in Croatia) where applicable. The table lists also what is suggested to be done as preparation steps for the 3Smart system installation to go step-by-step in final decision-making is the 3Smart system appropriate to be installed on a certain building, by weighing benefits versus costs on a particular time scale.

Table 1: Breakdown of installations and costs – UNIZGFER building

Definition of the cost position	Costs [€]
Pre-analysis and concept design	
Deduction of approximate models of rooms, heating elements and central HVAC units based on existing data. Deduction of non-controllable behaviours of the building. Comparing actual and simulated consumption – getting consumption data for a period 1-2 years and corresponding historical weather data	2.500
Selection of layers to be included in the EMS. Simulation of building behaviour with the selected layers, running simulations with included grid interaction (if possible flexibility prices and scenarios from the grid are available)	5.000
Deciding necessary data flows and possibly additional installations. Yielding the project task for installations.	500
Interim sum	**8.000**
Mechanical and electrical installation project	
Subcontract of certified electrical and mechanical engineers	10.000
Local support during the installation project creation	1.000
Interim sum	**11.000**
Electrical, mechanical and IT installations (equipment and services)	
Upgrade of the control application on room controllers RXC21.1 and RXC21.5 to enable monitoring and control of room climate from the 3Smart server in accordance with the 3Smart EMS	10.000
Monitoring and control of fan coils: temperature sensors for fan coil heating/cooling medium on the return pipe for 370 fan coils – sensors, mounting, data communication via the existing available cables on floors, floor concentrators and the central concentrator	19.000
Installation of floor calorimeters (24 pieces) and two large calorimeters,	45.000

calorimeters data connection and integration in the DESIGO SCADA system, emptying/filling the system, balancing mechanical installations	
Central electricity smart meter installation and data communication from it	3.000
Upgrade of the central HVAC system: enabling integration of data from the heating substation and the chiller in the 3Smart database, enabling heating substation control and heating circuit circulation pump measurement and control	10.000
Upgrade of the SCADA system to make available switch for easy transfer from the existing control mode to control from the 3Smart EMS and back, including necessary licences	5.000
Battery system with Li-ion LiFePO4 batteries of 32 kWh capacity with bidirectional power converter of 10 kW power in both directions, with a battery management system for monitoring battery cells voltages and temperatures and active balancing, cells overvoltage and overtemperature protection, alarming via e-mail and sms; power converter AC and DC filters and control/communication logic placed in a cabinet	45.000
Construction materials and work for increasing the level of fire protection in the room with the batteries, fire alarming installations, lighting and ventilation for the battery room, fire alarm system certification and training of the building personnel to work with the fire alarming system	7.000
Documentation and drawings of the executed installations	6.000
Server for the 3Smart EMS	4.000
Server installation and configuration and performing of necessary cabling towards the server for the 3Smart EMS	1.000
Creation of data transfer application and build-up of the 3Smart database	6.000
Installation of the correct logic for the timing of read and write operations of the data communication part in the database, installation of the safety revert to classical control mode via overwatching commands timestamps	2.000
Broadening of the database to create input and output tables for each of the EMS modules	2.000
Optimization software for solving the required mathematical programs during modules operation (during research phase research license used; later on either commercial license needs to be purchased or free software used, here is given the estimated price for a commercial license)	10.000
Weather forecast support (during the project provided for free by Croatian Meteorological and Hydrological Service, here provided estimate for yearly support learned from other pilots)	200 yearly
Supervision of the performed installations by certified electrical and mechanical engineers	5.000
Interim sum	**180.000 + 200 yearly**
Difference in operational costs after/before installation that is directly assigned to installations (costs after minus costs before; + -- costs more than before; - -- costs less than before)	
Building heating/cooling system maintenance costs after EMS installation compared to before	**faster detection of anomalies, improved comfort, not quantified**
TOTAL	**199.000 + 200 yearly**

HEP Building

The initial state of the HEP building is given in the deliverables of activity 6.2 [2], and here it is shortly revised.

The building has a total gross area of 10.670 m^2 out of which 8.550 m^2 is in use, with approximately 8.280 m^2 heated space. From the basement to the seventh floor (including the seventh floor) the building is used as an office space with additional facilities, and central corridor. The offices are located on both sides of the corridor (one across another), oriented North-South. Staircases, toilettes and utility rooms are oriented to the North.

The building's west wing basement is entirely heated and used as storage and archives. Additionally, the heating station with associated equipment is located here. The major part of the building's east wing basement is designed as dual-purpose shelter, sub-station, elevators, staircases and toilets. The entire basement is heated.

Having in mind the purpose and its day-to-day function, the building is heated up to 17 hrs daily (05:00 – 22:00), up to 119 hrs weekly. During the heating season the temperatures in the offices are rather high with no option of automatic control of the heating station or management of heating based on weather conditions.

Technical systems in the building are: heating, air conditioning and ventilation, cooling, hot water heating for sanitary facilities, and lighting.

Being located in the basement of the building, the heating station is indirectly connected to the Centralised heating system (CHS Zagreb) through district-heating network. The building has radiators for heating and a separate piping network for fan coils for cooling.

For the purpose of cooling and ventilation two water chillers connected in parallel are installed. Water chillers and header of the cooling system are fitted on the roof of the building. The main cooling medium distribution has been conducted through a vertical channel in the western and eastern part of the building. On each floor balancing valves are installed to ensure the projected flow. Also, there are balancing valves at the major verticals.

The air conditioning of the Hall Meeting Room (7th floor) is done via air handling unit (AHU) and fan coil.

The fan coils are controlled with room thermostats, without any central connection, while the air handling unit is managed locally. Heating medium for the AHU is provided from heating substation KOMPAKT 120, and the cooling medium from the water chillers installed on the roof of the building.

All prices of services provided in Table 2 do not include VAT (note that this is different for UNIZGFER and HEP building). The table lists also what is suggested to be done as preparation steps for the 3Smart system installation to go step-by-step in final decision-making is the 3Smart system appropriate to be installed on a certain building, by weighing benefits versus costs on a particular time scale.

Table 2: Breakdown of installations and costs – HEP building

Definition of the cost position	Costs [€]
Pre-analysis and concept design	
Deduction of approximate models of rooms, heating elements and central HVAC units based on existing data. Deduction of non-controllable behaviours of the building. Comparing actual and simulated consumption – getting consumption data for a period 1-2 years and corresponding historical weather data	2.500
Selection of layers to be included in the EMS. Simulation of building behaviour with the selected layers, running simulations with included grid interaction (if possible flexibility prices and scenarios from the grid are available)	5.000
Deciding necessary data flows and possibly additional installations. Yielding the project task for installations.	500
Interim sum	**8.000**
Mechanical and electrical installation project	
Subcontract of certified electrical and mechanical engineer	13.000
Local support during the installation project creation	1.000
Interim sum	**14.000**
Electrical, Mechanical and IT installations (equipment and services)	
Dismantling works	2.000
Cables and channels	44.000
Electrical distribution cabinets	500
Additional equipment of chillers	2.000
Equipment in the field	73.000
DDC equipment	23.000
Distribution cabinets	16.000
Engineering services	30.000
Central control-adjustment system	23.000
Testing and certificates issuing	5.000
Other works	500
Works related to mechanical installations	9.000
Construction works	6.000
Supervision of the performed installations by certified electrical, mechanical and civil engineers	8.000
Other works (plenum, automatic deaerators, etc.)	2.000
Battery pack	33.000
Interim sum	**277.000**
Difference in operational costs after/before installation that is directly assigned to installations (costs after minus costs before; + -- costs more than before; - -- costs less than before)	
Building heating/cooling system maintenance costs after EMS installation compared to before	**faster detection of anomalies, improved comfort**
Estimated yearly savings due to the introduced building automation system	-10.000 yearly
Interim sum	**-10.000 yearly**
TOTAL	**299.000 - 10.000 yearly**

3.2 Analysis of EMS module integration, adaptation and monitoring

This section shall provide a detailed overview about the costs for setting up of the 3Smart EMS modules, as well as costs that could arise due to different adaptations and costs for monitoring.

Table 3: Breakdown of modules installation and monitoring costs – UNIZGFER building

Description	Costs for module setting up [€]
Adaptation and installation of 3Smart EMS modules, with automated alerting feature if something goes wrong with the module or the needed data stops arriving, documenting and education of personnel (cca. 0.5 person month per module; overall 20 modules) – so 10 person months approximately The person month cost is assessed as the cost of highly skilled experts capable of installing the modules, with deep knowledge on buildings energy management, estimation and control – estimated person month price for such an expert in Croatia is set to 4.000 EUR	40.000
Monitoring and maintenance costs	2.000 yearly
TOTAL	40.000 + 2.000 yearly

Table 4: Breakdown of modules installation and monitoring costs – HEP building

Description	Costs for module setting up [€]
Adaptation and installation of 3Smart EMS modules, with automated alerting feature if something goes wrong with the module or the needed data stops arriving, documenting and education of personnel (cca. 0.5 person month per module; overall 20 modules) – so 10 person months approximately The person month cost is assessed as the cost of highly skilled experts capable of installing the modules, with deep knowledge on buildings energy management, estimation and control – estimated person month price for such an expert in Croatia is set to 4.000 EUR	40.000
Monitoring and maintenance costs	2.000 yearly
TOTAL	40.000 + 2.000 yearly

3.3 Analysis of the benefit of the EMS operation at building side

This section assesses the benefit achievable by the 3Smart EMS system operation on-site. The benefits are assessed by performing computations of optimal daily operation of the 3Smart system including also the benefits incurred through participation in demand response service, as explained in more detail in the Section Methodology. For the benefits assessment the operation of the building in a conventional way is considered, and the operation of the building with the 3Smart system when flexibility provision to the grid is contracted, but not activated and when the flexibility is activated by the grid.

The scenarios of operation analyzed here are provided in more detail within Deliverable 7.1.3 and Output 7.1 [1]. It is important that daily operation with 3Smart is always considered with repeatability constraint imposed, meaning that no gains are incurred from accumulated energy from the previous days.

Estimation of the yearly benefit from the 3Smart system operation is based on yearly extrapolation of benefits achieved in typical days for which analyses were performed.

UNIZGFER building

Table 5: Assessment of benefits from 3Smart operation – UNIZGFER building [1]

	Daily operation cost [€]		
Scenario	Conventional / current	3Smart without activation of flexibility from the grid	3Smart with activation of flexibility from the grid
Sunny workday in January	192	175	179
Sunny workday in July	105	65	58
Estimation of total yearly benefits [€]			
Total benefits in the cooling season	43 € x 90 days of cooling season = 3.870 €		
Total benefits in the heating season	15 € x 120 days of heating season = 1.800 €		
Overall total yearly benefit	5.670 €		

HEP building

Table 6: Assessment of benefits from 3Smart operation – HEP building [1]

	Daily operation cost [€]		
Scenario	Conventional / current	3Smart without activation of flexibility from the grid	3Smart with activation of flexibility from the grid
Sunny workday in January	528	510	510
Sunny workday in July	165	139	139
Estimation of total yearly benefits [€]			
Total benefits in the cooling season	26 € x 90 days of cooling season = 2.340 €		
Total benefits in the heating season	18 € x 120 days of heating season = 2.160 €		
Overall total yearly benefit	4.500 €		

4. Cost-benefit analysis on grid side

4.1 Analysis of costs for grid-side EMS implementation

This section provides a detailed overview about the costs that were necessary to prepare the grid-side for the 3Smart modules integration and the costs for setting up of the 3Smart grid-side EMS modules, as well as costs that arise due to different adaptations and costs for monitoring.

The overview of the grid side module costs is shown in Table 7. Not all the costs had to be paid for the installations performed on the Croatian pilot as some equipment or software was already present; however all of them are listed to be representative for considering further replication options.

Table 7 Overview of installation costs for the grid-side modules

Definition of the cost position	
Personnel expense	**Costs [€]**
IT preparation – database setup	2.000
IT preparation – installation of the needed software	1.000
IT preparation – enabling grid-side communication with building-side	6.000
Documenting	2.000
TOTAL	**11.000**
Capital investment	**Costs [€]**
Server	1.400
Monitor	600
Substation equipment for measuring and remote control - Vrbik	10.500
Substation equipment for measuring and remote control - Savica	10.500
TOTAL	**23.000**
Intangible assets	**Costs [€]**
Optimization and network simulation software	30.000
TOTAL	**30.000**
Operational and maintenance	**Costs [€]**
Optimization and network simulation software maintenance	5.000 yearly
TOTAL	**5.000 yearly**
TOTAL	**64.000 + 5.000 yearly**

4.2 Analysis of EMS module integration, adaptation and monitoring

This section provides an overview of the costs estimates for setting up of the 3Smart grid-side EMS modules, as well as costs that arise due to different adaptations and costs for monitoring and yearly maintenance.

These costs are provided in Table 8. As in tables 5 and 6 for the estimate of building-side modules installation and maintenance costs, it is presumed that a highly skilled expert is required for this work.

Table 8. Overview of adaptation and installation costs for grid-side modules

Definition of the cost position		
Personnel expense	**Estimated effort**	**Costs [€]**
Testing long-term module	0.5 person months	2.000
Testing short-term day-ahead module	0.5 person months	2.000
Testing short-term intra-day module	0.5 person months	2.000
Testing grid-building communication	0.5 person months	2.000
Short-term day-ahead model adaptation	1 person months	4.000
Short-term intra-day model adaptation	0.5 person months	2.000
Long-term model adaptation	0.25 person months	1.000
Communication model adaptation	1 person month	4.000
Short-term module implementation	0.25 person months	1.000
Long-term module implementation	0.25 person months	1.000
Documenting	0.25 person months	1.000
Education	0.5 person months	2.000
TOTAL	**6 person months**	**24.000**

Table 9. Overview of monitoring and maintenance costs for the grid-side modules

Definition of the cost position		UNIZGFER COSTS
YEARLY MAINTENANCE		
Personnel expense	**Person months**	**Costs [€]**
Software updates	0.25	1.000
Documentation	0.25	1.000
TOTAL	**0.5 person months**	**2.000 yearly**

4.3 Analysis of the benefit of the EMS operation at grid side

In 3Smart DSO's approach was that because of cable line overloading (when load exceeds the operational limit of the 10-kV cable line) the company could use flexibility service from buildings alongside the cable line.

In order to be understood better the underlying concept of the use of flexibility service it is worth repeating the business logic of the calculated benefit realised by the DSO based on deferring the necessary investment. For more details see Output 4.1 [3], in part of the long-term grid-side modules explanation.

In the considered case a real investment deferral value is calculated, i.e. a monetary benefit if the investment is deferred (it is just like putting the money in the bank).

The maximum price on flexibility products for the DSOs stems from the DSOs' alternative costs in reinforcement. This forms a sort of price-cap on flexibility products for the DSO. The final price depends on what price the aggregator offers its flexibility products at. If it is sufficiently low, the DSOs are likely to use the offered flexibility product.

If the DSO's only alternative to buying this flexibility product is to upgrade its grid components (cables, transformers, etc.), the price setting is done based on the 1st year value of these upgrades.

For example (Table 10), if the upgrade of a 10-kV feeder costs 60.000 EUR/km, the life expectancy of this upgrade is 40 years, the inflation is 2.5% and an interest rate (in our case the recognised WACC by the regulator) of 4.00% is considered, the value of the grid upgrade deferral will be the following, of which some will be spent on the necessary flexibility product unlocking the possibility of the deferral.

Table 10. Calculation of maximum price

WACC	4.00%
Inflation	2.5%
Useful lifetime	40 years
Cost of 1 km 10-kV cable upgrade	60.000 EUR
Cable length for Savica	2 km
Cable length for Vrbik	1 km
Real interest rate for Savica	$\frac{1+\text{WACC}}{1+\text{Inflation}}-1=6.5\%$
Real interest rate for Vrbik	$\frac{1+\text{WACC}}{1+\text{Inflation}}-1=6.5\%$

The logic of the calculation is depicted in Figure 1.

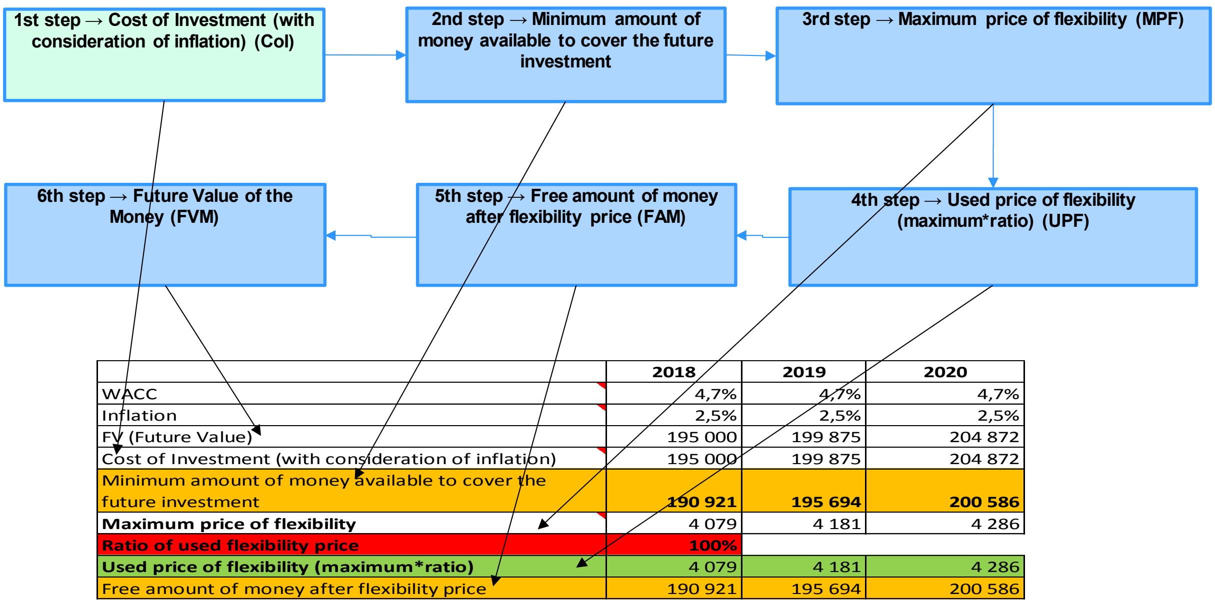

Figure 1. Logic of the price calculation.

1st step → Cost of Investment (with consideration of inflation) (CoI):

This value represents the needed amount of money for the investment that one would like to avoid. It is crucial to mention that the valorisation is necessary each year, since in the next year one has to spend more money on the investment because of the inflation.

2nd step → Minimum amount of money available to cover the future investment (MAM):

This value represents the amount of money which should be put into the bank to cover the next year investment cost. It results from a reverse calculation from the „Cost of Investment" (which is valorised in each year with the inflation). In the reverse calculation we use the WACC as a „bank interest rate" because of the energy industry. Nevertheless, WACC can differ industry by industry and country by country. MAM= next year CoI/1+WACC.

3rd step → Maximum price of flexibility (MPF):

It is calculated from the Future Value of the Money (FVM) and Minimum amount of money available to cover the future investment (MAM). MPF=FVM - MAM. The DSO can spend this amount of money for the flexibility. Only the first year should be considered, the subsequent years calculation can inform us only about what happens if we planned long-term and DSO would require the flexibility only e.g. in the 3rd year. Based on the time series calculation the DSO can consider what should be put into the medium-term plan.

4th step → Used price of flexibility (maximum*ratio) (UPF):

This flexibility price is derived from the Maximum price of Flexibility (MPF), if the DSO does not intend to use the whole amount of the MPF then it can use a ratio (%) by which this MPF will be multiplied, and only a given portion of the Maximum price of Flexibility will be used. If we set the Ratio of Used Flexibility price (RUF) e.g. 80%, then DSO will use only the 80% of the MPF. The remaining part of money will increase the Free amount of Money after flexibility price. In this way DSO will have more money which will increase the Future Value of the Money in the next year.

5th step → Free amount of money after flexibility price (FAM):

This amount of money in the first year is the difference of the Future value of the money (which equals Cost of investment in the first year) and Used price of flexibility. This money theoretically can be put into the Bank and is the basis of the next year Future Value of the Money.

6th step → Future Value of the Money (FVM):

This amount of money in the first year will be the Cost of Investment. In the subsequent years it will be calculated from the previous year Free amount of money after flexibility price (FAM)*(1+WACC), since this amount of money will be in DSO's hand and it can be put in Bank theoretically.

Based on above theoretical background the Long Term Multiannual module price calculator has been developed within 3Smart. The below calculation was the input for the Building side to be able to consider the offered unit price by the DSO. The basis of the calculation – as it is above mentioned – are not only the needed investment costs in terms of the Croatian pilot site (3 km 10-kV cable line investment due to overloading) but the needed flexibility calculation (both in kW and kWh) and the used ratio for the available money for flexibility services.

Tables 11 and 12 describe the assumption of the DSO for the case of the Croatian pilot.

Table 11. Calculation of available money for flexibility services for Savica.

Caclulation of flexibility resource										
WACC	4.00%									
Inflation	2.50%									
The cost of investment	120,360	EUR								
Ratio of used flexibility price	80%									
Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
WACC	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
Inflation	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
FV (Future Value)	120,360	123,730	126,898	130,087	133,342	136,676	140,093	143,596	147,185	150,865
Cost of Investment (with consideration of inflation)	120,360	123,369	126,453	129,615	132,855	136,176	139,581	143,070	146,647	150,313
Minimum amount of money available to cover the future investment	118,624	121,590	124,629	127,745	130,939	134,212	137,568	141,007	144,532	148,145
Maximum price of flexibility	1,736	2,140	2,269	2,341	2,403	2,464	2,526	2,589	2,654	2,720
Used price of flexibility (maximum*ratio)	1,389	1,712	1,815	1,873	1,923	1,971	2,021	2,071	2,123	2,176
Free amount of money after flexibility price	118,971	122,018	125,083	128,213	131,419	134,705	138,073	141,524	145,063	148,689
Unused source	347	428	454	468	481	493	505	518	531	544
Calculation of unit prices										
Reservation ratio	50.0%									
Penalty price multiplicator	2									
Reservation part of Flexibility unit price	0.022	EUR/kW/(15min)								
Activation part of Flexibility unit price	0.088	EUR/kWh								
Penalty	0.175	EUR/kWh								
Quality threshold (max. devviation in size of service without penalty)	-10	%								

Table 12. Calculation of available money for flexibility services for Vrbik.

Caclulation of flexibility resource										
WACC	4.00%									
Inflation	2.50%									
The cost of investment	60,000	EUR								
Ratio of used flexibility price	80%									
Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
WACC	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
Inflation	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
FV (Future Value)	60,000	61,680	63,259	64,849	66,472	68,134	69,837	71,583	73,373	75,207
Cost of Investment (with consideration of inflation)	60,000	61,500	63,038	64,613	66,229	67,884	69,582	71,321	73,104	74,932
Minimum amount of money available to cover the future investment	59,135	60,613	62,128	63,682	65,274	66,905	68,578	70,292	72,050	73,851
Maximum price of flexibility	865	1,067	1,131	1,167	1,198	1,228	1,259	1,291	1,323	1,356
Used price of flexibility (maximum*ratio)	692	854	905	934	958	983	1,007	1,032	1,058	1,085
Free amount of money after flexibility price	59,308	60,826	62,355	63,915	65,513	67,151	68,830	70,551	72,314	74,122
Unused source	173	213	226	233	240	246	252	258	265	271
Calculation of unit prices										
Reservation ratio	50.0%									
Penalty price multiplicator	2									
Reservation part of Flexibility unit price	0.011	EUR/kW/(15min)								
Activation part of Flexibility unit price	0.044	EUR/kWh								
Penalty	0.087	EUR/kWh								
Quality threshold (max. devviation in size of service without penalty)	-10	%								

The calculation shows that maximum prices available for flexibility are 1.736 EUR for Savica and 865 EUR for Vrbik. It should be noticed that in cases when the DSO makes the entire amount of flexibility fund available to the service providers (Building, Aggregator), the DSO does not gain any benefit as compared to business as usual (making the investment). For sake of the simulation we use 80% ratio. In this way the DSO will pay 0.8 * 1.736 EUR for Savica and 0.8 * 865 EUR for Vrbik for the flexibility service of the buildings, i.e. 1.389 EUR for Savica and 692 EUR for Vrbik. The remaining part of the available money (20%) is the benefit of the DSO, i.e. **520 EUR** (347 EUR for Savica and 173 EUR for Vrbik) yearly.

If we assume that only 70% of reservation capacity will be activated, the DSO benefits become more attractive. That means that the DSO benefits are higher for used_price_for_flexibility*(1-reservation_ratio)*0.3, i.e. 208 EUR for Savica and 104 EUR for Vrbik. In this case total benefits for the DSO amount to **832 EUR** yearly.

5. Environmental benefits

In this section effects and environmental benefits based on the application of the 3Smart EMS system in the Croatian pilot are demonstrated. The environmental benefits come from the reduced primary energy use by the building and from the increased grid capability to integrate carbon-neutral energy from photovoltaics enabled by demand response services.

The energy savings from 3Smart operation for the analyzed day in summer for UNIZGFER building amount to roughly 130 kWh of electricity per day and for HEP building 26 kWh. In heating season there are no significant savings in electricity consumption on either of the buildings. For Croatia, the CO2 equivalent for electricity can be roughly assessed as 300 g/kWh (e.g. see https://www.electricitymap.org/), leading thus to daily reduction of CO2 emissions by 0,05 t CO2 daily. For a carbon price of 20 EUR/ton this roughly gives 1 EUR daily benefit, or 90 EUR for the whole cooling season (presumed to last 90 days), i.e. yearly.

The savings in heating energy amount daily in average (activation of flexibility 50% of times, no activation of flexibility 50% of times) to 155 kWh on UNIZGFER building and to 45 kWh on HEP building. If also for the heat factor of 300 gCO2/kWh is used, the daily saving of CO2 emissions is for both buildings roughly 0,06 t CO2 or 1,2 EUR daily benefit in CO2 emissions reduction. Extrapolated on the whole year (heating season presumed to last 120 days), this leads to 144 EUR equivalent environmental benefit for CO2 emissions reduction.

6. Conclusion

The above analyses give an assessment of costs and benefits for installation of the 3Smart system on the Croatian pilot. Investments in pilot buildings preparations for adoption of 3Smart modules amount to roughly 200.000 EUR for UNIZGFER building and 300.000 EUR for HEP building, with estimated basic yearly savings of roughly 10.000 EUR for the case of HEP building (since the building did not possess a building automation system installed beforehand). Additionally, costs of the 3Smart system on each of the buildings are estimated at 40.000 EUR for modules adaptation and installation and 2.000 EUR yearly for the 3Smart system maintenance.

The overall yearly benefit for the UNIZGFER building operated with the 3Smart system is assessed at 5.670 EUR. Since the yearly maintenance for 3Smart modules operation amounts 2.000 EUR, this gives 3.670 EUR yearly for paying off the investment in modules installation of 40.000 EUR, so roughly 11 years for return on investment. Hardware investments and IT preparation, if only introduced for the reason of 3Smart system, would result in too high return on investment. Of course, the installations in commercial replications could be done in a more modest way as the intention of the pilots in 3Smart was also to investigate different options of control when more systems and measurements are available. E.g., for the case of the UNIZGFER building the battery system and calorimeters measurements on the floor level represent a significant investment that might not be used in a commercial replication on some other building – which could reduce the hardware investment by half, with still maintained a significant potential of the HVAC system for savings and demand response. Also the unavailability of experts to perform sophisticated modules adaptations and installations on a massive scale is a problem that significantly increases the costs.

HEP building shows the 3Smart induced savings of 4.500 EUR per year and thus a pay-off period of about 16 years: with costs of 2.000 EUR per year for system maintenance the investment of 40.000 EUR would pay off in 40/2.5=16 years.

On the grid side the benefit compared to the costs shows similar problems for commercial replication, where the investment amounts 64.000 EUR and 5.000 EUR yearly maintenance, and 24.000 EUR for modules adaptation and installation with 2.000 EUR for yearly maintenance of the grid-side 3Smart system. Compared to the estimated benefit of 830 EUR yearly for the DSO, it is obvious that the grid-side modules must be employed more broadly along the distribution network (currently just two feeders were used in the pilot) with approximately similar central platform and modules costs to make the installation economically feasible for replication.

Considering that the demand response on massive scale, including buildings, will be necessary for the European energy system decarbonization and considering that introduction of demand response without predictive controls and planning cannot provide the wanted effect of maintaining comfort and achieving power flexibility, it seems that also national, regional and European energy transition plans will have to consider the presented economical gaps via subsidies.

Bibliography

[1] D7.1.3 Operational logs and their seasonal analysis – Croatian pilot. 3Smart deliverable, December 2019

[2] D6.2.1 Pilots conceptual projects with detailed analysis of pilots current technical state and requirements and preliminary cost-benefit analysis of the planned investments (Croatian pilot). 3Smart deliverable, November 2017.

[3] Output 4.1 Modular cross-spanning energy management tool. 3Smart deliverable, June 2019.

Project Deliverable Report

Smart Building – Smart Grid – Smart City

http://www.interreg-danube.eu/3smart

DELIVERABLE D6.4.1

Cost-benefit analysis on the pilot level – Slovenian pilot

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Security	Public
Deliverable participants	Municipality of Idrija (Idrija), E3, Elektro primorska (EP)
Authors (Partners)	Nina Carli (ElektroP), Marko Baša (E3), Tadej Rupnik (Idrija), Mario Vašak (UNIZGFER)
Contact person	Tadej Rupnik (Idrija)
Abstract (for dissemination)	This deliverable provides cost-benefit analysis for the installed modular energy management platform on the building and on the grid side for the Slovenian pilot. This deliverable contains all the investment and operational cost of the system.
Keyword List	Cost-benefit analysis, public buildings, distribution grid, energy management system, energy efficiency, sustainability, environmental effects

Revision history

Revision	Date	Description	Author (Organization)
0.1	8 February 2018	Template	Andrea Moser (EEE)
0.2	6 December 2018	First Draft Version	Tadej Rupnik (IDRIJA), Nina Carli (ElektroP), Marko Baša (E3)
1.0	15 March 2020	Entry of the remaining data for the SI pilot	Tadej Rupnik (UNIZGFER)
1.1	20 March 2020	Final check and corrections	Mario Vašak (UNIZGFER)

Table of contents

Executive summary

This deliverable provides cost-benefit analysis for applying the EMS system to the pilot in Idrija.

The costs are separated in several parts:

1. Research, mechanical and electrical installations projects, public procurements, supervisions, permits and other documents;
2. Mechanical and electrical installations divided to three public procurements;
3. Additional costs not included in procurement documents;
4. EMS module integration, adaptation and monitoring costs;
5. Grid side EMS implementation costs;
6. Operational costs on the level of the Idrija pilot.

Benefits are estimated based on the 3Smart platform performance on the pilot.

1. Introduction

Costs for introducing the 3Smart system are determined based on actual investments performed on the sides of buildings and of the grid. Also, personnel cost is estimated for the designed 3Smart system replication on a new site to get an overall cost assessment.

The benefits are estimated based on the 3Smart modules performance. On the side of the buildings calculations were performed based on the optimal building operation, including seizing the demand response opportunities, i.e. reservation and activation payments to the building from a grid-side entity for flexibility provided. Calculations were performed based on models of building HVAC system determined from processing of actual pilot site data. Characteristic days are selected for which computation is done in a way to compute a 24-hour optimal building behaviour and the amount of flexibility that can be offered to the grid by engaging in coordination all the building elements to which the 3Smart system has a reach. It is also important to stress that the initial building state, i.e. state at the beginning of the day, is optimized and it is enforced that the end-state of the building, i.e. state of the building at the end of the day, is the same as the initial state, such that the building is operated in a sustainable way that can be repeated day by day. The total operational cost for the building, including all relevant energy costing terms and degradation cost of equipment, is compared with the operational cost of the state-of-the-art controls performed by conventional well-tuned building automation systems in the same conditions and in this way building-side benefits from the 3Smart system operation are assessed and extrapolated on the whole-year period. Grid-side benefits are estimated based on the long-term grid-side modules economic assessment of the overall amount of money available for end-customers' flexibility engagement. It is accounted that one part comes from not investing the whole available amount in flexibility and the other comes from the time intervals in which at the end flexibility was not activated such that the activation payment is not performed.

2. Methodology

2.1 Costs

The methodology for the cost-benefit analysis of the pilots (buildings and grid) is, to first of all analyze the costs related to the EMS installation. This encompasses the following parts:

- pre-analysis and concept design for the particular building:
    - creation of a dynamic building simulation model, if necessary;
    - comparing actual and simulated consumption;
    - selection of layers to be included in the EMS;
    - simulation of building behaviour with the selected layers;

    - deciding necessary data flows and possibly additional installations;
- mechanical and electrical installations project;
- mechanical and electrical installations (equipment and service);
- IT integration and system operation.

The project host for the Slovenian pilot analyzed and reported the costs of mechanical and electrical installation project, the installations including equipment and service, IT integration as well as running of the building EMS.

Secondly, the costs for setting up of the 3Smart EMS modules are analyzed, followed by adaptations and monitoring costs. Partners in charge for 3Smart EMS installation within the building are pilot leaders and hosts supported by modules developers (pilot leaders: E3, modules developers: UNIZGFER, UNIDEBTTK, UNIBGFME, SVEMOFSR, EON, ElektroP, E3). They commonly reported the related costs for modules installation. These costs were assessed as estimates of the costs for personnel needed to replicate the installation of the 3Smart system.

The DSO partners and R&D partners in charge for setting up the grid-side EMS calculated their costs for the EMS operation maintenance and compare them to the previous (before the EMS installation) mode of the grid operation.

2.2 Benefits

The benefits are assessed based on 3Smart modules performance on the building and on the grid. For buildings, a comparison of building operation with conventional state-of-the-art well-tuned building automation system is performed, in exactly the same conditions. In D7.2.3 Operational logs and seasonal analysis [1] these responses obtained are presented in detail and analysis of them is provided. Here for the CBA only the final operational costs in EUR are extracted and extrapolated for the whole-year period in order to be able to provide the yearly estimate of the benefits. For the grid, the benefits are extracted based on economical assessment which is a part of the long-term grid-side modules operation.

In calculation of the benefits in building operation optimization of building performance on a 24-hour period was performed on all levels engaged within the 3Smart system. On Primary school building all three levels are being actively optimized: the zone level where rooms heating profiles are optimized to attain a proper comfort at minimum costs, the central HVAC level where the conditioning of the centrally prepared heating medium is being optimized in order to attain minimum costs and provide enough energy required by zones. The microgrid level takes into account also the possibilities offered by demand response functionality – the time windows when grid potentially needs flexibility as well as the pricing conditions for reservation and activation of flexibility which are computed by grid-side modules. The microgrid level also provides the optimized flexibility bid of the building that is then offered to the grid. On all three levels also the initial building state is optimized and it is enforced that the end-state of the building equals this optimized initial state which induces that the 3Smart system makes a day-to-day sustainable and repeatable behaviour of the building, i.e. any savings produced cannot be accredited to the difference of the initial and final building state (state after 24 hours) as the building remains in the same conditions.

To get the benefits, the 3Smart system performance on the building side is compared with the performance of conventional state-of-the-art controls practiced in current building automation systems existing on the site. Exactly the same outdoor conditions are used as well as exactly the same building configuration and models of all elements determined by running 3Smart prediction and estimation modules on measurement data obtained on the building and actuation data provided to the building from the 3Smart system. In this way benefits can be assessed that reside only on software side, i.e. on the fact that the 3Smart modules use predictive control and mathematical optimizations while the conventional systems decide on their reaction by taking into account only current state of the building, current outside imposed conditions and current requirements of end-users.

The grid-side benefits are calculated as part of the money which is estimated by the long-term grid-side modules to be available as a consequence of postponing the reinforcement of the grid which is enabled by engagement of flexibility. Different ratios of this money can be selected to be used for flexibility engagement by end-customers and to be retained by the company. Of course, higher amount retained reduces the prices for flexibility reservation and activation to be paid to end-consumers which may lead to the fact that the end-consumers will find the flexibility provision not economically feasible and thus a balance needs to be found. Another source of benefit stemming from the amount of money planned to be invested in flexibility engagement comes from the non-activated flexibilities at the end.

The effects and broader benefits for the environment based on the application of the 3Smart EMS system in the pilot is also assessed. This is performed by determining the saved energy induced via the 3Smart system operation and transforming this to the evaded CO2 emissions equivalent.

3. Cost-benefit analysis on building side

3.1 Analysis of installation and operation of the EMS

This section provides a detailed overview about the conducted installations at the primary school and sports centre that were necessary to create a basis for the 3Smart EMS system. All parts regarding pre-analysis and concept design, mechanical and electrical installation projects, mechanical and electrical installations (equipment and service) are listed in this section and the related costs are reported. In addition, the costs for the operation of the EMS system are provided.

Table 1: Breakdown of installations and costs

Definition of the cost position	Costs [€]
Research, mechanical and electrical installations projects, public procurements, supervisions, permits and other documents	
Dynamic building model	6.000
Procurements	4.000
Supervision	5.000
Feasibility studies and pre-analysis (CHP, PV, zones)	13.000
Installations projects (PV, CHP, zone control)	22.000
Permits	1.500
Interim sum	**51.500**
Zone level installations	
Hydraulic balancing and changing works	9.000
Radiator valves	13.000
Radiator wireless controlled heads Afriso AVD 10	16.000
Radiator thermo heads	10.000
Sensors of return water temperature EO bridge	10.000
Room temperature sensors Afriso FTM TF	12.000
Presence detectors Eltako FBH55SB	5.000
Gateways and communications	4.000
3smart control center GUI	2.000
Computer	3.000
Installation and test of control center	9.000
Interim sum	**93.000**
PV Plant and connections to low voltage grid	
PV modules Luxor LX-270P	
ac/dc SolarEdge SE27,6k	
optimizer Solare Edge, double, P600	

Weather station (irradiance SE1000-SEN-IRR-S1, temp. SE1000-SEN-TAMB-S1)	
Connections of the PV and CHP to electrical grid (all materials and works)	
Interim sum	**82.000**
CHP and DHW tank heaters	
CHP Indop INDOS 50M	
DHW tank heaters 7+15+15 kW	
Water, gas and electrical installations (works and material)	
Interim sum	**105.000**
SUM	**331.500**

3.2 Analysis of EMS module integration, adaptation and monitoring

This section shall provide a detailed overview about the costs for setting up of the 3Smart EMS modules, as well as costs that could arise due to different adaptations and costs for monitoring.

Table 2: Breakdown of module installations costs

Description	Costs for module setting up [€]
Adaptation and installation of 3Smart EMS modules (16 modules, 0.5 person-month each, 4.000 EUR per person-month for the skilled personnel required)	32.000
IT services (database installations, development of services, server installation and set-up …)	15.000
Monitoring and maintenance costs (estimated needed maintenance is 4hrs/month. Skilled technician, able to do such work charges around 50€/h)	2.500 yearly
	47.000 + 2.500 yearly

3.3 Analysis of the benefit of the EMS operation at building side

This section assesses the benefit achievable by the 3Smart EMS system operation on-site. The benefits are assessed by performing computations of optimal daily operation of the 3Smart system including also the benefits incurred through participation in demand response service, as explained in more detail in the Section Methodology. For the benefits assessment the operation of the building in a conventional way is considered, and the operation of the building with the 3Smart system when flexibility provision to the grid is contracted, but not activated and when the flexibility is activated by the grid.

The scenarios of operation analyzed here are provided in more detail within Deliverable 7.2.3 and Output 7.1. It is important that daily operation with 3Smart is always considered with repeatability constraint imposed, meaning that no gains are incurred from accumulated energy from the previous days.

Estimation of the yearly benefit from the 3Smart system operation is based on yearly extrapolation of benefits achieved in typical days for which analyses were performed.

Table 3: Assessment of benefits from 3Smart operation

	Daily operation cost [€]		
Scenario	Conventional / current	3Smart without activation of flexibility from the grid	3Smart with activation of flexibility from the grid
Sunny workday in November	86	75	63
Sunny workday in June	13	9	8
Estimation of total yearly benefits [€]			
Total benefits in the summer season	4 € x 90 days of summer season = 360 €		
Total benefits in the heating season	16 € x 120 days of heating season = 1.920 €		
Overall total yearly benefit	2.280 €		

4. Cost-benefit analysis on grid side

4.1 Analysis of costs for grid-side EMS implementation

This section provides a detailed overview about the costs that were necessary to prepare the grid-side for the 3Smart modules integration and the costs for setting up of the 3Smart grid-side EMS modules, as well as costs that arise due to different adaptations and costs for monitoring. The overview of the grid side module costs is shown in Table 4

Table 4: Overview of installation costs for the grid-side modules

Definition of the cost position	
Personnel expense	Costs [€]
IT preparation – database setup	**2.000**
IT preparation – installation of the needed software	**1.000**
IT preparation – enabling grid-side communication with building-side	**6.000**
Documenting	**2.000**
TOTAL	**11.000**
Intangible assets	Costs [€]
Optimization and network simulation software	**30.000**
TOTAL	**30.000**

Operation and maintenance	Costs [€]
Optimization and network simulation software maintenance	**5.000 yearly**
TOTAL	**5.000 yearly**
TOTAL	**52.000 + 5.000 yearly**

4.2 Analysis of EMS module integration, adaptation and monitoring

This section provides an overview of the costs estimates for setting up of the 3Smart grid-side EMS modules, as well as costs that arise due to different adaptations and costs for monitoring and yearly maintenance.

These costs are provided in Table 5. As in the table for the estimate of building-side modules installation and maintenance costs, it is presumed that a highly skilled expert is required for this work.

Table 5: Overview of adaptation and installation costs for grid-side modules

Definition of the cost position		
Personnel expense	Estimated effort	Costs [€]
Testing long-term module	0.5 person months	2.000
Testing short-term day-ahead module	0.5 person months	2.000
Testing grid-building communication	0.5 person months	2.000
Short-term day-ahead model adaptation	1 person months	4.000
Long-term model adaptation	0.25 person months	1.000
Communication model adaptation	1 person month	4.000
Short-term module implementation	0.25 person months	1.000
Long-term module implementation	0.25 person months	1.000
Documenting	0.25 person months	1.000
Education	0.5 person months	2.000
TOTAL	5 person months	20.000

Table 6. Overview of monitoring and maintenance costs for the grid-side modules

Definition of the cost position		
YEARLY MAINTENANCE		
Personnel expense	Person months	Costs [€]
Software updates	0.25	1.000
Documentation	0.25	1.000
TOTAL	0.5 person months	2.000 yearly

4.3 Analysis of the benefit of the EMS operation at grid side

As provided in D7.2.2, the money available for flexibility payments by the DSO to end-customers, on the name of postponed grid reinforcement investment is 5,063.00 EUR.

It should be noticed that in cases when the DSO make the entire amount of flexibility fund available to the service providers (Building, Aggregator), the DSO does not gain any benefit if all flexibilities get activated. If 80% is invested in flexibility payments and 20% retained, then the benefit of the DSO amounts at this 20% (0,2*5,063.00 EUR) plus all evaded payments for when the flexibility was not activated. Since the ratio between reservation and activation payments is 50%, for a presumed 50% chance of activation, the benefit from the non-activated flexibility would be 0,8*0,5*0,5*5,063.00 EUR. In this way the DSO yearly benefit is (0,2+0,8*0,5*0,5)*5,063.00 EUR = 0,4*5,063.00 EUR = 2.025,20 EUR.

5. Environmental benefits

In this section effects and environmental benefits based on the application of the 3Smart EMS system in the Slovenian pilot are demonstrated. The environmental benefits come from the reduced primary energy use by the building and from the increased grid capability to integrate carbon-neutral energy from photovoltaics enabled by demand response services.

The energy savings in terms of heat from 3Smart operation are in D7.2.3 on a daily level assessed as 43 kWh (Table 2.1 in D7.2.3). Extrapolating on yearly level through 120 days of heating season brings overall savings of 5.16 MWh on yearly basis of heat. Regarding electricity, in pricing conditions where the returned energy to the grid is not paid, the 3Smart system shows its full benefit in maximally exploiting the produced electricity from PVs for own consumption, and also well exploits the possibilities of CHP for demand response provision. It thus enables a better integration of renewable energy, with smaller grid integration problems. Usage of CHP and gas-electricity-heat coupling is again optimally exploited with 3Smart which again enabled significant flexibility provision and thus further enhanced possibilities for renewable energy integration.

In this analysis the focus is put only on the benefit achievable with 3Smart compared to the conventional ways of operation in buildings and grids, thus no gains from photovoltaic production and installed equipment for enabled good conventional control are accounted, only the benefits on top of them which differentiate the 3Smart operation from the conventional algorithms.

6. Conclusion

The above analyses give an assessment of costs and benefits for installation of the 3Smart system on the Slovenian pilot. Investments in pilot buildings preparations for adoption of 3Smart modules amount to roughly 300.000 EUR. The hardware costs and costs for enabling basic automation functions are presumed to be well balanced with achievable gains with state-of-the-art system running. The surplus costs for 3Smart system installation amount to roughly the costs for the return medium sensors installation (10.000 EUR), all advanced IT features (15.000 EUR) and costs for 3Smart modules adaptation (32.000 EUR) and yearly maintenance (2.500 EUR yearly). The benefits are assessed at 2.280 EUR which barely equals the yearly maintenance costs.

From this analysis it turns out that the benefits are not sufficiently high to cover for the additional investment in putting the 3Smart system into operation. Problematic currently is the unavailability of experts to perform sophisticated modules adaptations and installations on a massive scale and this significantly increases the costs.

On the grid side the benefit compared to the costs shows similar problems for commercial replication, where the investment amounts 52.000 EUR and 5.000 EUR yearly maintenance, and then additionally 20.000 EUR for modules adaptation and installation with 2.000 EUR for yearly maintenance of the grid-side 3Smart system. Compared to the estimated benefit of 2.000 EUR yearly for the DSO, it is obvious that the grid-side modules must be employed more broadly along the distribution network (currently just one feeder was used in the pilot) with approximately similar central platform and modules costs to make the installation economically feasible for replication.

Considering that the demand response on massive scale, including buildings, will be necessary for the European energy system decarbonization and considering that introduction of demand response without predictive controls and planning cannot provide the wanted effect of maintaining comfort and achieving power flexibility, it seems that also national, regional and European energy transition plans will have to consider the presented economical gaps via subsidies. The emphasized environmental benefits achieved with 3Smart should represent a clear push for that.

7. Bibliography

[1] D7.1.3 Operational logs and their seasonal analysis – Croatian pilot. 3Smart deliverable, December 2019

[2] D6.2.1 Pilots conceptual projects with detailed analysis of pilots current technical state and requirements and preliminary cost-benefit analysis of the planned investments (Croatian pilot). 3Smart deliverable, November 2017.

[3] Output 4.1 Modular cross-spanning energy management tool. 3Smart deliverable, June 2019.

Project Deliverable Report

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DELIVERABLE D6.4.1

Cost benefit analysis on the pilot level – Austrian pilot

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Security	Public
Deliverable participants	EEE, Strem, EnergyG, UNIZGFER
Authors (Partners)	Andrea Moser (EEE), Joachim Hacker (EEE); Bernhard Deutsch (Strem), Mario Vašak (UNIZGFER)
Contact person	Andrea Moser (EEE)
Abstract (for dissemination)	The deliverable provides cost-benefit analysis for the installed modular energy management platform on the two buildings for the Austrian pilot. It consists of the primary school and the retirement and care centre building.
Keyword List	Cost-benefit analysis, public buildings, distribution grid, energy management system, energy efficiency, sustainability, environmental effects

Revision history

Revision	Date	Description	Author (Organization)
0.1	08 February 2018	Template	Andrea Moser (EEE)
0.2	11 June 2018	Inserting costs for the primary school and the retirement and care building	Andrea Moser (EEE), Bernhard Deutsch (Strem)
0.3	30 June 2018	Inserting additional costs for the two pilot buildings	Andrea Moser (EEE), Bernhard Deutsch (Strem)
0.4	20 September 2019	Integrating new cost positions and related description	Andrea Moser (EEE), Bernhard Deutsch (Strem)
1.0	17 January 2020	Integration of new benefit analysis and finalization of descriptions	Andrea Moser (EEE), Mario Vašak (UNIZGFER)
1.1	22 January 2020	Finalization of descriptions	Mario Vašak (UNIZGFER)

Table of Contents

Executive summary

This deliverable provides a cost-benefit analysis for the installed modular energy management system within the 3Smart project at the two involved pilot buildings in the municipality Strem. Those buildings are the primary school building and the retirement and care centre building and the cost-benefit analysis describes the experiences with installing the EMS system at the sites.

1. Introduction

Cost-benefit analyses have been performed for each of the 5 pilots in the 3Smart project, by cumulating the effects of both the building and the grid-side energy management on each pilot location. Also, the broader environmental effects will be considered in order to reach the correct ratio of costs and benefits to make a driver for regulatory set-ups change in the Danube region, in favour of the improved energy-efficiency, use of renewable energy and energy security in the Danube region.

2. Methodology

2.1 Costs

The methodology for the cost-benefit analysis of the pilots (buildings and grid) is, to first of all analyse the costs related to the EMS installation. This encompasses the following parts:

- pre-analysis and concept design for the particular building;
    - creation of a dynamic building simulation model, if necessary;
    - comparing actual and simulated consumption;
    - selection of layers to be included in the EMS;
    - simulation of building behaviour with the selected layers;
    - deciding necessary data flows and possibly additional installations;
- mechanical and electrical installations project;
- mechanical and electrical installations (equipment and service);
- IT integration and system operation.

The hosting partners for the buildings and the grid (EEE, Strem, EnG) in the Austrian pilot analysed and reported the costs for pre-analysis and concept design, mechanical and electrical installation project, the installations including equipment and service, IT integration as well as running of the building EMS.

Secondly, the costs for setting up of the 3Smart EMS modules are analysed, followed by adaptations and monitoring costs. Partners in charge for 3Smart EMS installation within the two buildings are pilot leaders and hosts supported by modules developers (pilot leader: EEE; modules developers: UNIZGFER, UNIDEBTTK, UNIBGFME, SVEMOFSR, EON). They commonly reported the related costs for modules installation. These costs were assessed as estimates of the costs for personnel needed to replicate the installation of the 3Smart system.

2.2 Benefits

The benefits are assessed based on 3Smart modules performance on the building and on the grid. For buildings, a comparison of building operation with conventional state-of-the-art well-tuned building automation system is performed, in exactly the same conditions. For the CBA only the final operational costs in EUR are extracted and extrapolated for the whole-year period in order to be able to provide the yearly estimate of the benefits. For the grid, the benefits are extracted based on economical assessment which is a part of the long-term grid-side modules operation.

In calculation of the benefits in building operation optimization of building performance on a 24-hour period was performed on all levels engaged within the 3Smart system. On the pilot buildings overall all three levels could be optimized: the zone level where rooms heating/cooling profiles are optimized to attain a proper comfort at minimum costs, the central HVAC level where the conditioning of the centrally prepared heating/cooling medium is being optimized in order to attain minimum costs and provide enough energy required by zones, and the microgrid level where the battery system is engaged in order to provide the optimized overall energy exchange profile with the distribution grid. The microgrid level takes into account also the possibilities offered by demand response functionality – the time windows when grid potentially needs flexibility as well as the pricing conditions for reservation and activation of flexibility which are computed by grid-side modules. The microgrid level optimizes the behaviour of the battery system and includes also into account the degradation costs for the battery system operation, but also engages the operation of the HVAC system via localized price signals to shape the behaviour of the whole HVAC system to finally yield optimal operational costs. The microgrid level also provides the optimized flexibility bid of the building that is then offered to the grid. On all three levels also the initial building state is optimized and it is enforced that the end-state of the building equals this optimized initial state which induces that the 3Smart system makes a day-to-day sustainable and repeatable behaviour of the building, i.e. any savings produced cannot be accredited to the difference of the initial and final building state (state after 24 hours) as the building remains in the same conditions.

To get the benefits, the 3Smart system performance on the building side is compared with the performance of conventional state-of-the-art controls practiced in current building automation systems existing on the site. Exactly the same outdoor conditions are used as well as exactly the same building configuration and models of all elements determined by running 3Smart prediction and estimation modules on measurement data obtained on the building and actuation data provided to the building from the 3Smart system. In this way benefits can be assessed that reside only on software side, i.e. on the fact that the 3Smart modules use predictive control and mathematical optimizations while the conventional systems decide on their reaction by taking into account only current state of the building, current outside imposed conditions and current requirements of end-users.

The grid-side benefits are calculated as part of the money which is estimated by the long-term grid-side modules to be available as a consequence of postponing the reinforcement of the grid which is enabled by engagement of flexibility. Different ratios of this money can be selected to be used for flexibility engagement by end-customers and to be retained by the company. Of course, higher amount retained reduces the prices for flexibility reservation and activation to be paid to end-consumers which may lead to the fact that the end-consumers will find the flexibility provision not economically feasible and thus a balance needs to be found. Another source of benefit stemming from the amount of money planned to be invested in flexibility engagement comes from the non-activated flexibilities at the end.

The effects and broader benefits for the environment based on the application of the 3Smart EMS system in the pilot is also assessed. This is performed by determining the saved energy induced via the 3Smart system operation and transforming this to the evaded CO_2 emissions equivalent.

3. Cost-benefit analysis on building side

3.1 Analysis of installation and operation of the EMS

This section provides an overview about the installations that were executed at the two Austrian pilot buildings to enable the operation of the 3Smart EMS system.

In a first step, all cost positions that arose in the primary school building (including external expertise, mechanical and electrical installations, IT support, etc.) are shown.

Breaking down the installations at zone, central HVAC system and microgrid level the following list gives an overview about what was done at those levels:

- *ZONE LEVEL – installations:*
- at zone level costs for mechanical and electrical installations occurred
- in addition, installations on measurement equipment and establishment of a new controller were done
- *HVAC LEVEL*
- on HVAC level costs for the installations on the district heating substation occurred, as a new district heating controller had to be installed
- integration in the controller
- *Microgrid LEVEL*
- two existing meters were combined to one smart meter– allowance to the access to the meter data is unclear and still has to be resolved
- *Database*
- installation costs for IT services occurred, as a master computer had to be installed as well as all necessary software tools, solver, etc.
- integration of the relevant parts of the database
- *Weather data*
- solution for online data of direct & diffuse irradiation is found

Table 1: Breakdown of installations and costs at pilot building 1 – the primary school

Definition of the cost position	Costs [€]
Pre-analysis and concept design	
External expertise for the pre-analysis of the existing system in the primary school, selection of layers to be included in the EMS, deciding necessary data flows and possible additional installations and yielding the project task for installations.	€ 3.000,-
Mechanical installations (equipment and services)	
Subcontract of certified mechanical engineers for the execution of adaptations on the	€ 4.000,00

heat distribution system in the building	
Costs for adjustments at the district heating transfer station on the building side	€ 950,00
Subcontracting of mechanical engineers for installation work on the central heating distributor	€ 3.300,00
Costs for certified mechanical engineers for installations and adjustments on the overall heating system in order to secure a controllable system, secure a right positioning of sensors and actors, etc.	€ 1.450,00
Electrical installations (equipment and services)	
Subcontract of electrical installation engineers (service and equipment)	€10.000,-
Measurement and control (equipment and services)	
Subcontract of measurement and control experts and installation of the central heating control equipment	€ 12.000,00
Subcontracting of certified experts for programming the new adjustable heating system, for programming the central controller	€ 8.400,00
Works for improvements of the measurement and control system and coordination with the IT experts	€ 700,00
IT installations	
IT Installations on the master computer	€ 200,00
IT installations on regarding the integration of needed software, creation of different connections and access points for external experts, module developers etc., server installation and configuration	€ 2.400,00
Subcontracting of IT experts for solving the requirements of the 3Smart modules running, database development, coordination with external experts and experts that developed the central controlling system	€ 2.100,00
Update of the measurement computer and the server	€ 400,00
Integration of weather data	€ 700,00
TOTAL	€ 59.600,00 ,-

In a next step, all cost positions that arose in the retirement and care building (including external expertise, mechanical and electrical installations, IT support, etc.) are shown.

Breaking down the installations at zone, central HVAC system and microgrid level the following list gives an overview about what was done at those levels:

- *ZONE LEVEL*
- mechanical installations
- electrical installations

- *HVAC LEVEL*
- HVAC level for cooling and heating
- integration of meters on cooling side
- *Microgrid LEVEL*
- battery storage system purchased
- *Database*
- master computer is prepared (as in the school building with all necessary software tools, solver, etc.)
- integrating the relevant parts of the database
- *Weather data*
- solution for online data of direct & diffuse irradiation is found

Table 2: Breakdown of installations and costs at pilot building 2 – the retirement and care building

Definition of the cost position	Costs [€]
Pre-analysis and concept design **Mechanical and electrical installation project**	
External expertise for the pre-analysis of the existing system in the retirement and care centre building, selection of layers to be included in the EMS, deciding necessary data flows and possible additional installations and yielding the project task for installations.	€7.600,-
Mechanical installations (equipment and services)	
Battery storage and equipment – BlueSky Energy	€ 21.600 ,-
Subcontract of certified mechanical engineers for the execution of adaptations on the energy system of the building	€ 6.300,00
External expertise for coordination and supervision of the mechanical installations, control of the sensors, devices and the mechanical equipment and coordination of the appropriate installation and positioning to be suitable for the 3Smart system	€ 13.600,00 ,-
Electrical installations (equipment and services)	
Subcontracting of electrical installation company (service and equipment)	€ 8.400 ,-
Subcontracting of electrical experts for electric installations for the measurement and control system	€ 4.800 ,-
Additional electrical adjustments	€ 550 ,-
Measurement and control (equipment and services)	
Subcontracting of installation works at the measurement and control devices of the existing and integrated Honeywell devices and controllers	€ 2.500 ,-
Subcontracting of external experts for programming work at the KNX controlling system	€ 15.500 ,-
Switching and control work – Ing. Gerald Fischer Elektrotechnik	€ 15.400 ,-
Subcontracting of experts for the Modbus configuration at the new established central 3Smart controller	€ 750,00 ,-
External expertise for coordination and supervision of the installations at the measurement and control devices	€ 5.400,00 ,-
IT installations	
IT Installations – server, database, computing of controlling advices and communication protocols	€ 3.500,-
TOTAL	**€ 105.900,00 ,-**

3.2 Analysis of the benefit of the EMS operation at building side

This section provides assesses the benefit achieved by the 3Smart EMS system operation on-site. The benefits are assessed by performing computations of optimal daily operation of the 3Smart system including also the benefits incurred through participation in demand response service, as explained in more detail in the Section Methodology. For the benefits assessment the operation of the building in a conventional way is considered, and the operation of the building with the 3Smart system when flexibility provision to the grid is contracted, but not activated and when the flexibility is activated by the grid.

The scenarios of operation analysed here are provided in more detail within Deliverable 7.1.3 and Output 7.1. It is important that daily operation with 3Smart is always considered with repeatability constraint imposed, meaning that no gains are incurred from accumulated energy from the previous days. Estimation of the yearly benefit from the 3Smart system operation is based on yearly extrapolation of benefits achieved in typical days for which analyses were performed.

Primary School Building

Table 5: Assessment of benefits from 3Smart operation – Primary School building

Scenario	Daily operation cost [€]		
	Conventional / current	3Smart without activation of flexibility from the grid	3Smart with activation of flexibility from the grid
Sunny workday in November	60,70	42,51	42,13
Estimation of total yearly benefits [€]			
Total benefits in the heating season	18 € x 120 days of heating season = 2.160 €		
Overall total yearly benefit	2.160 €		

Retirement and Care Centre Building

Table 6: Assessment of benefits from 3Smart operation – Retirement and care centre building

Scenario	Daily operation cost [€]		
	Conventional / current	3Smart without activation of flexibility from the grid	3Smart with activation of flexibility from the grid
Sunny workday in November	136,05	131,76	128,33
Sunny workday in July	119,83	110,91	110,99
Estimation of total yearly benefits [€]			
Total benefits in the cooling season	9 € x 90 days of cooling season = 810 €		
Total benefits in the heating season	7 € x 120 days of heating season = 840 €		
Overall total yearly benefit	1.650 €		

4. Cost-benefit analysis on grid side

4.1 Analysis of costs for grid-side EMS implementation

This section provides an overview about the costs, that were necessary to prepare the grid-side for the 3Smart module integration.

Table 3: Breakdown of installations and costs on grid side

Definition of the cost position	Costs [€]
Costs of server installation	
Subcontracting of experts for the Hard- and Software installations of the server infrastructure on grid side	€5.600,-
External Expertise	
Subcontracting of external experts for the support in the grid data collection and grid simulations	€ 7.800 ,-
Database installation	
Installation of database and modules	€ 3.000 ,-
TOTAL	**€ 16.400 ,-**

4.2 Analysis of EMS module integration, adaptation and monitoring

This section shall provide an overview about the costs for setting up of the 3Smart grid-side EMS modules, as well as costs that could arise due to different adaptations and costs for monitoring.

Table 4: Breakdown of modules installation and monitoring costs – primary school building

Description	Costs for module setting up [€]
Adaptation and installation of 3Smart EMS modules, with automated alerting feature if something goes wrong with the module or the needed data stops arriving, documenting and education of personnel (cca. 0.5 person month per module; overall 14 modules) – so 7 person months approximately The person month cost is assessed as the cost of highly skilled experts capable of installing the modules, with deep knowledge on buildings energy management, estimation and control – estimated person month price for such an expert in Austria is set to 5.000 EUR	35.000
Monitoring and maintenance costs	2.000 yearly
TOTAL	35.000 + 2.000 yearly

Table 5: Breakdown of modules installation and monitoring costs – retirement and care centre building

Description	Costs for module setting up [€]
Adaptation and installation of 3Smart EMS modules, with automated alerting feature if something goes wrong with the module or the needed data stops arriving, documenting and education of personnel (cca. 0.5 person month per module; overall 18 modules) – so 9 person months approximately The person month cost is assessed as the cost of highly skilled experts capable of installing the modules, with deep knowledge on buildings energy management, estimation and control – estimated person month price for such an expert in Croatia is set to 5.000 EUR	45.000
Monitoring and maintenance costs	2.000 yearly
TOTAL	45.000 + 2.000 yearly

The DSO partners that are in charge for setting up of the grid-side EMS shall additionally calculate the costs, showing the comparison of the actual and previous (before EMS installation) mode of operation.

Table 6. Overview of adaptation and installation costs for grid-side modules

Definition of the cost position		
Personnel expense	**Estimated effort**	**Costs [€]**
Testing long-term module	0.5 person months	2.500
Testing short-term day-ahead module	0.5 person months	2.500
Testing grid-building communication	0.5 person months	2.500
Short-term day-ahead model adaptation	1 person months	5.000
Long-term model adaptation	0.25 person months	1.250
Communication model adaptation	1 person month	5.000
Short-term module implementation	0.25 person months	1.250
Long-term module implementation	0.25 person months	1.250
Documenting	0.25 person months	1.250
Education	0.5 person months	2.500
TOTAL	**6 person months**	**25.000**

Table 7. Overview of monitoring and maintenance costs for the grid-side modules

Definition of the cost position		
YEARLY MAINTENANCE		
Personnel expense	**Man months**	**Costs [€]**
Software updates	0.25	1.250
Documentation	0.25	1.250
TOTAL	**0.5 person months**	**2.500 yearly**

4.3 Analysis of the benefit of the EMS operation at grid side

In 3Smart DSO's approach was that because of cable line overloading (when load exceeds the operational limit of the 10-kV cable line) the company could use flexibility service from buildings alongside the cable line.

In order to understand better the underlying concept of the use of flexibility service it is worth repeating the business logic of the calculated benefit realised by the DSO based on deferring the necessary investment. For more details see Output 4.1 [3], in part of the long-term grid-side modules explanation.

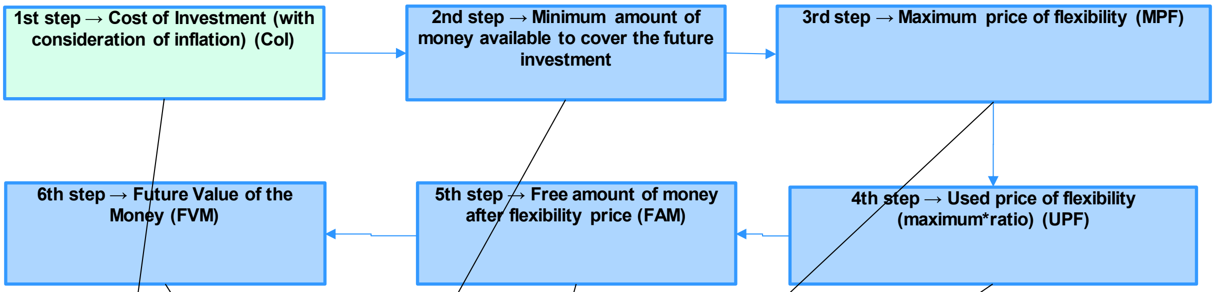
In the considered case a real investment deferral value is calculated, i.e. a monetary benefit if the investment is deferred (it is just like putting the money in the bank).

The maximum price on flexibility products for the DSOs stems from the DSOs' alternative costs in reinforcement. This forms a sort of price-cap on flexibility products for the DSO. The final price depends on what price the aggregator offers its flexibility products at. If it is sufficiently low, the DSOs are likely to use the offered flexibility product.

If the DSO's only alternative to buying this flexibility product is to upgrade its grid components (cables, transformers, etc.), the price setting is done based on the 1st year value of these upgrades.

For example, if the upgrade of a 10-kV feeder costs 60.000 EUR/km, the life expectancy of this upgrade is 40 years, the inflation is e.g. 2.5% and an interest rate of 4.00% is considered, the value of the grid upgrade deferral will be the following, of which some will be spent on the necessary flexibility product unlocking the possibility of the deferral.

The logic of the calculation is depicted in Figure 1.



	2018	2019	2020
WACC	4,7%	4,7%	4,7%
Inflation	2,5%	2,5%	2,5%
FV (Future Value)	195 000	199 875	204 872
Cost of Investment (with consideration of inflation)	195 000	199 875	204 872
Minimum amount of money available to cover the future investment	**190 921**	**195 694**	**200 586**
Maximum price of flexibility	4 079	4 181	4 286
Ratio of used flexibility price	**100%**		
Used price of flexibility (maximum*ratio)	4 079	4 181	4 286
Free amount of money after flexibility price	190 921	195 694	200 586

Figure 1 – Logic of the price calculation

1st step → Cost of Investment (with consideration of inflation) (CoI):

This value represents the needed amount of money for the investment that one would like to avoid. It is crucial to mention that the valorisation is necessary each year, since in the next year one has to spend more money on the investment because of the inflation.

2nd step → Minimum amount of money available to cover the future investment (MAM):

This value represents the amount of money which should be put into the bank to cover the next year investment cost. It results from a reverse calculation from the „Cost of Investment" (which is valorised in each year with the inflation). In the reverse calculation we use the WACC as a „bank interest rate" because of the energy industry. Nevertheless, WACC can differ industry by industry and country by country. MAM= next year CoI/1+WACC.

3rd step → Maximum price of flexibility (MPF):

It is calculated form the Future Value of the Money (FVM) and Minimum amount of money available to cover the future investment (MAM). MPF=FVM - MAM. The DSO can spend this amount of money for the flexibility. Only the first year should be considered, the subsequent years calculation can inform us only about what happens if we planned long-term and DSO would require the flexibility only e.g. in the 3rd year. Based on the time series calculation the DSO can consider what should be put into the medium-term plan.

4th step → Used price of flexibility (maximum*ratio) (UPF):

This flexibility price is derived from the Maximum price of Flexibility (MPF), if the DSO does not intend to use the whole amount of the MPF then it can use a ratio (%) by which this MPF will be multiplied, and only a given portion of the Maximum price of Flexibility will be used. If we set the Ratio of Used Flexibility price (RUF) e.g. 80%, then DSO will use only the 80% of the MPF. The remaining part of money will increase the Free amount of Money after flexibility price. In this way DSO will have more money which will increase the Future Value of the Money in the next year. For the Austrian pilot UPF amounts roughly at 1.000 EUR.

5th step → Free amount of money after flexibility price (FAM):

This amount of money in the first year is the difference of the Future value of the money (which equals Cost of investment in the first year) and Used price of flexibility. This money theoretically can be put into the Bank and is the basis of the next year Future Value of the Money.

6th step → Future Value of the Money (FVM):

This amount of money in the first year will be the Cost of Investment. In the subsequent years it will be calculated from the previous year Free amount of money after flexibility price (FAM)*(1+WACC), since this amount of money will be in DSO's hand and it can be put in Bank theoretically.

The benefit on the grid side can be assessed as 20% percentage of UPF (meaning that the DSO leaves) + 50% of the activation part of the 80% of UPF used to activate the flexibility, accounting for the flexibility windows in which activation will not be made. Thus the benefit is (0,2+0,5*0,5*0,8)*UPF=0,4*UPF=400 EUR.

5. Environmental benefits

In this section effects and environmental benefits based on the application of the 3Smart EMS system in the Austrian pilot are demonstrated. The environmental benefits come from the reduced primary energy use by the building and from the increased grid capability to integrate carbon-neutral energy from photovoltaics enabled by demand response services.

The energy savings from 3Smart operation in the primary school building of heating energy is 190 kWh daily and in the retirement and care building it is 22 kWh of heating energy savings daily. In the cooling season savings in primary energy are negligible. If the heating season lasts for 120 days, this means yearly saving of 25,44 MWh of heating energy from the district heating network. The heating is biomass-based, and thus CO_2-neutral.

6. Conclusion

The above analyses give an assessment of costs and benefits for installation of the 3Smart system on the Austrian pilot. Investments in pilot buildings preparations for adoption of 3Smart modules amount to roughly 60.000 EUR for primary school building and 106.000 EUR for retirement and care building and estimated costs of the 3Smart system on buildings estimated in average at 40.000 EUR per building (35.000 for school and 45.000 for the retirement and care centre) for modules adaptation and installation and 2.000 EUR yearly per building for the 3Smart system maintenance, with estimated basic yearly savings of 2.160 EUR for the case of the primary school building and 1.650 EUR for the retirement and care building. The yearly benefits are roughly equal to the cost of modules yearly maintenance, but cannot recover the investment cost. The situation may change positively with the need to also introduce peak pricing and load shifting in the heating grid. Then the 3Smart system could secure significant benefits especially for the case of floor heating/cooling elements where flexibility in consumption due to large inertia is highly emphasized.

On the grid side the investment amounts have been 16.400 EUR with 25.000 EUR cost for modules installation and 2.500 EUR yearly for their maintenance, and compared to yearly benefit by the operation of the 3Smart system with 400 EUR the CBA for the grid is not positive.

Considering that the demand response on massive scale, including buildings, will be necessary for the European energy system decarbonization and considering that introduction of demand response without predictive controls and planning cannot provide the wanted effect of maintaining comfort and achieving power flexibility, it seems that also national, regional and European energy transition plans will have to consider the presented economical gaps via subsidies.

Bibliography

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Project Deliverable Report

Smart Building – Smart Grid – Smart City

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DELIVERABLE D6.4.1

Cost benefit analysis on the pilot level – Bosnia and Herzegovinian pilot

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Abstract (for dissemination)	This document describes cost-benefit analysis for EPHZHB pilot. Costs are based on the performed installation on the site and benefits from the operational logs and seasonal analyses performed.
Keyword List	Cost-benefit analysis, public buildings, distribution grid, energy management system, energy efficiency, sustainability, environmental effects

Revision history

Revision	Date	Description	Author (Organization)
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0.3	15 June 2018	Draft version	Igor Bošnjak (SVEMOFSRE)
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1.0	20 March 2020	Inserted costs from the operational logs and seasonal analysis, document review	Mario Vašak (UNIZGFER)

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Executive summary

Cost-benefit analysis is performed for each of the 5 pilots in the 3Smart project, by cumulating the effects of both the building and the grid-side energy management on each pilot location. Also, the broader environmental effects are considered in order to reach the correct ratio of costs and benefits to make a driver for regulatory set-ups change in the Danube region, in favour of the improved energy-efficiency, use of renewable energy, energy security and demand response.

The deliverable provides cost-benefit analysis for the installed modular energy management platform on building and on the grid side for the pilot in Bosnia and Herzegovina. The pilot consists of EPHZHB’s business building in Tomislavgrad and the local electricity distribution grid around the building.

1. Introduction

Costs for introducing the 3Smart system are determined based on actual investments performed on the sides of buildings and of the grid. Also, personnel cost is estimated for the designed 3Smart system replication on a new site to get an overall cost assessment.

The benefits are estimated based on the 3Smart modules performance [1]. On the side of the building calculations were performed based on the optimal building operation, including seizing the demand response opportunities, i.e. reservation and activation payments to the building from a grid-side entity for flexibility provided. Calculations were performed based on models of building HVAC system determined from processing of actual pilot site data. Characteristic days are selected for which computation is done in a way to compute a 24-hour optimal building behaviour and the amount of flexibility that can be offered to the grid by engaging in coordination all the building elements to which the 3Smart system has a reach. It is also important to stress that the initial building state, i.e. state at the beginning of the day, is optimized and it is enforced that the end-state of the building, i.e. state of the building at the end of the day, is the same as the initial state, such that the building is operated in a sustainable way that can be repeated day by day. The total operational cost for the building, including all relevant energy costing terms and degradation cost of equipment, is compared with the operational cost of the state-of-the-art controls performed by conventional well-tuned building automation systems in the same conditions and in this way building-side benefits from the 3Smart system operation are assessed and extrapolated on the whole-year period. Grid-side benefits are estimated based on the long-term grid-side modules economic assessment of the overall amount of money available for end-customers' flexibility engagement. It is accounted that one part comes from not investing the whole available amount in flexibility and the other comes from the time intervals in which at the end flexibility was not activated such that the activation payment is not performed.

2. Methodology

2.1 Costs

The methodology for the cost-benefit analysis of the pilots (buildings and grid) is to first of all analyse the costs related to the EMS installation. This encompasses the following parts:

- pre-analysis and concept design for the particular building;
  - creation of a dynamic building simulation model, if necessary;
  - comparing actual and simulated consumption;
  - selection of layers to be included in the EMS;
  - simulation of building behaviour with the selected layers;
  - deciding necessary data flows and possibly additional installations;
- mechanical and electrical installations project;
- mechanical and electrical installations (equipment and service);
- IT integration and system operation .

The hosting partner for the building and the grid (both EPHZHB) in the pilot in Bosnia and Herzegovina analysed and reported the costs for pre-analysis and concept design, mechanical and electrical installation project, the installations including equipment and service, IT integration as well as running of the building EMS.

Secondly, the costs for setting up of the 3Smart EMS modules are analysed, followed by adaptations and monitoring costs. Partners in charge for 3Smart EMS installation in the building are pilot leaders and host supported by modules developers (pilot leaders: EPHZHB, SVEMOFSR; pilot host: EPHZHB; modules developers: UNIZGFER, UNIDEBTTK, UNIBGFME, SVEMOFSR, EON). They commonly reported the related costs for modules installation. These costs were assessed as estimates of the costs for personnel needed to replicate the installation of the 3Smart system.

The DSO partners and R&D partners in charge for setting up the grid-side EMS calculated their costs for the EMS operation and maintenance and compared them to the previous (before the EMS installation) mode of the grid operation.

2.2 Benefits

The benefits are assessed based on 3Smart modules performance on the building and on the grid. For buildings, a comparison of building operation with conventional state-of-the-art well-tuned building automation system is performed, in exactly the same conditions. In D7.4.3 Operational logs and seasonal analysis – Bosnia and Herzegovinian pilot [1] these responses obtained are presented in detail and analysis of them is provided. Here for the CBA only the final operational costs in EUR are extracted and extrapolated for the whole-year period in order to be able to provide the yearly estimate of the benefits. For the grid, the benefits are extracted based on economical assessment which is a part of the long-term grid-side modules operation.

In calculation of the benefits in building operation optimization of building performance on a 24-hour period was performed on all levels engaged within the 3Smart system. On EPHZHB building all three levels are being actively optimized: the zone level where rooms heating/cooling profiles are optimized to attain a proper comfort at minimum costs, the central HVAC level where the conditioning of the centrally prepared heating/cooling medium is being optimized in order to attain minimum costs and provide enough energy required by zones, and the microgrid level where the battery system is engaged in order to provide the optimized overall energy exchange profile with the distribution grid. The microgrid level takes into account also the possibilities offered by demand response functionality – the time windows when grid potentially needs flexibility as well as the pricing conditions for reservation and activation of flexibility which are computed by grid-side modules. The microgrid level optimizes the behaviour of the battery system and includes also into account the degradation costs for the battery system operation, but also engages the operation of the HVAC system via localized price signals to shape the behaviour of the whole HVAC system to finally yield optimal operational costs. The microgrid level also provides the optimized flexibility bid of the building that is then offered to the grid. On all three levels also the initial building state is optimized and it is enforced that the end-state of the building equals this optimized initial state which induces that the 3Smart system makes a day-to-day sustainable and repeatable behaviour of the building, i.e. any savings produced cannot be accredited to the difference of the initial and final building state (state after 24 hours) as the building remains in the same conditions.

To get the benefits, the 3Smart system performance on the building side is compared with the performance of conventional state-of-the-art controls practiced in current building automation systems existing on the site. Exactly the same outdoor conditions are used as well as exactly the same building configuration and models of all elements determined by running 3Smart prediction and estimation modules on measurement data obtained on the building and actuation data provided to the building from the 3Smart system. In this way benefits can be assessed that reside only on software side, i.e. on the fact that the 3Smart modules use predictive control and mathematical optimizations while the conventional systems decide on their reaction by taking into account only current state of the building, current outside imposed conditions and current requirements of end-users.

The grid-side benefits are calculated as part of the money which is estimated by the long-term grid-side modules to be available as a consequence of postponing the reinforcement of the grid which is enabled by engagement of flexibility. Different ratios of this money can be selected to be used for flexibility engagement by end-customers and to be retained by the company. Of course, higher amount retained reduces the prices for flexibility reservation and activation to be paid to end-consumers which may lead to the fact that the end-consumers will find the flexibility provision not economically feasible and thus a balance needs to be found. Another source of benefit stemming form the amount of money planned to be invested in flexibility engagement comes from the non-activated flexibilities at the end.

The effects and broader benefits for the environment based on the application of the 3Smart EMS system in the pilot is also assessed. This is performed by determining the saved energy induced via the 3Smart system operation and transforming this to the evaded CO_2 emissions equivalent.

3. Cost-benefit analysis on building side

3.1 Analysis of installation and operation of the EMS

This section shall provide a detailed overview about the conducted installations at the pilot buildings that were necessary to create a basis for the 3Smart EMS system. All parts regarding pre-analysis and concept design, mechanical and electrical installation projects, mechanical and electrical installations (equipment and service) and IT integration and operation are listed in this section and the related costs are reported. In addition, the costs for the operation of the EMS system shall be demonstrated.

The initial state of the EPHZHB building is given in the deliverables of activity 6.2, see e.g. [2], and here it is shortly revised.

The building of EPHZHB at address Vučiji brig bb, 80240 Tomislavgrad has a heating and cooling system in place which uses fan coils type YFCN and YHK of the manufacturer YORK. The heating energy for the system is supplied from the system which uses heat pump type YLHA (YORK), electrical thermo block type Termo extra (Termostroj) and buffer tank. The cooling energy for the building is supplied from the system which uses the same heat pump and same buffer tank.

Within the 3Smart project, fan coils control system for maintaining the room temperature was implemented on the level of every room by using Siemens control devices type DXR and accompanying display units QMX which enable the user to control the mode of fan coils local operation and to set the required temperature for the room. The devices are networked with a central monitoring system (SCADA system) based on Siemens DESIGO platform.

With the installations in question the existing system of building indoor climate control is improved and the installation of the battery storage system is added. In such a way algorithms for coordination of the entire building operation are planned through the 3Smart EMS developed within the project.

All prices of services provided in Table 1 exclude VAT (17% in Bosnia and Herzegovina) as well as prices in the other tables. The table lists also what is suggested to be done as preparation steps for the 3Smart system installation to go step-by-step in final decision-making is the 3Smart system appropriate to be installed on a certain building, by weighing benefits versus costs on a particular time scale.

Table 1 shows breakdown of installations and costs.

Table 1: Breakdown of installations and costs

Definition of the cost position	Costs [€]
Pre-analysis and concept design	
Development of dynamic building model	5.225,00
Development of simplified mathematical model	2.470,00
Mechanical and electrical installation project	
Design of mechanical, electrical and IT systems for the project 3Smart	9.718,67
Mechanical installations (equipment and services)	
Fan coil unit and AHU controllers (28 pcs), temperature sensors (58 pcs)	12.107,59
Heat meters (9 pcs)	8.082,69
Heat pump works	11.249,49
Electrical installations (equipment and services)	
Photovoltaic power plant 49,8 kWp	51.915,76
Battery storage system 32 kWh, 10 kW (up to 40 kW)	49.911,35
Electrical meters (7 pcs)	4.441,86
Pyranometers (2 pcs)	5.842,72
IT installations (equipment and services)	
Direct Digital control system	19.622,04
SCADA platform, hardware and software	22.015,35
Mechanical, Electrical and IT installations documentation	
Declarations, records, test, as-built documentation	2.455,24
Supervision	
Supervision costs	4.936,06
EMS operation costs	
IT services (database installations, development of services)	1.500,00
TOTAL	**211.493,82**

3.2 Analysis of EMS module integration, adaptation and monitoring

This section shall provide a detailed overview about the costs for setting up of the 3Smart EMS modules, as well as costs that could arise due to different adaptations and costs for monitoring. Table 2 shows breakdown of modules installation costs for building-side.

Table 2: Breakdown of modules installation costs for building-side

Description	Costs for module setting up [€]
Adaptation and installation of 3Smart EMS modules, with automated alerting feature if something goes wrong with the module or the needed data stops arriving, documenting and education of personnel (cca. 0,5 person month per module; overall 17 modules) – so 8,5 person months approximately The person month cost is assessed as the cost of highly skilled experts capable of installing the modules, with deep knowledge on buildings energy management, estimation and control – estimated person month price for such an expert in Bosnia and Herzegovina is set to 3.000 EUR	25.500
Monitoring and maintenance costs	1.500 yearly
TOTAL	**25.500 + 1.500 yearly**

3.3 Analysis of the benefit of the EMS operation at building side

This section assesses the benefit achievable by the 3Smart EMS system operation on-site. The benefits are assessed by performing computations of optimal daily operation of the 3Smart system including also the benefits incurred through participation in demand response service, as explained in more detail in the Section Methodology. For the benefits assessment the operation of the building in a conventional way is considered, and the operation of the building with the 3Smart system when flexibility provision to the grid is contracted, but not activated and when the flexibility is activated by the grid.

The scenarios of operation analyzed here are provided in more detail within Deliverable 7.4.3 and Output 7.1 [1]. It is important that daily operation with 3Smart is always considered with repeatability constraint imposed, meaning that no gains are incurred from accumulated energy from the previous days.

Estimation of the yearly benefit from the 3Smart system operation is based on yearly extrapolation of benefits achieved in typical days for which analyses were performed. Table 3 shows Assessment of benefits from the 3Smart operation.

Table 3: Assessment of benefits from the 3Smart operation

Scenario	Daily operation cost [€]		
	Conventional / current	3Smart without activation of flexibility from the grid	3Smart with activation of flexibility from the grid
Sunny workday in November	22.57	8.19	8.19
Sunny workday in July	1.14	-11.61	-11.57
Estimation of total yearly benefits [€]			
Total benefits in the cooling season	12 € x 90 = 1.080 €		
Total benefits in the heating season	14 € x 150 = 2.100 €		
Overall total yearly benefit	3.180 €		

4. Cost-benefit analysis on grid side

4.1 Analysis of costs for grid-side EMS implementation

This section provides a detailed overview about the costs that were necessary to prepare the grid-side for the 3Smart modules integration and the costs for setting up of the 3Smart grid-side EMS modules, as well as costs that arise due to different adaptations and costs for monitoring.

The overview of the grid side module costs is shown in Table 4. Not all the costs had to be paid for the installations performed on the pilot in Bosnia and Herzegovina as some equipment or software was already present; however, all of them are listed to be representative for considering further replication options.

Table 4: Overview of installation costs for grid-side modules operation

Definition of the cost position	
Personnel expense	Costs [€]
IT preparation – database setup	1.000
IT preparation – installation of the needed software	500
IT preparation – enabling grid-side communication with building-side	3.000
Documenting	1.500
Personnel expense total	**6.000**
Capital investment	Costs [€]
Server	1.400
Monitor	600
Substation equipment for measuring and remote control	7.000
Capital investment total	**9.000**
Intangible assets	Costs [€]
Optimization and network simulation software	25.000
Intangible assets total	**25.000**
TOTAL	**40.000**

4.2 Analysis of EMS module integration, adaptation and monitoring

This section provides an overview of the costs estimates for setting up of the 3Smart grid-side EMS modules, as well as costs that arise due to different adaptations and costs for monitoring and yearly maintenance.

These costs are provided in Table 5 and Table 6. As in the table for the estimate of building-side modules installation and maintenance costs, it is presumed that a highly skilled expert is required for this work.

Table 5: Modules installation costs for grid-side

Definition of the cost position		
Personnel expense	Estimated effort	Costs [€]
Testing long-term module	0.5 person months	1.500
Testing short-term day-ahead module	0.5 person months	1.500
Testing grid-building communication	0.5 person months	1.500
Short-term day-ahead module adaptation	1 person months	3.000
Long-term module adaptation	0.25 person months	750
Communication module adaptation	1 person month	3.000
Short-term module implementation	0.25 person months	750
Long-term module implementation	0.25 person months	750
Documenting	0.25 person months	750
Education	0.5 person months	1.500
TOTAL	**5 person months**	**15.000**

Table 6: Modules installation costs for grid-side – monitoring and maintenance

Description	Price [EUR]
Monitoring and maintenance costs	1.500 yearly

4.3 Analysis of the benefit of the EMS operation at grid side

In 3Smart DSO's approach was that because of cable line overloading (when load exceeds the operational limit of the 10-kV cable line) the company could use flexibility service from buildings alongside the cable line.

In order to be understood better the underlying concept of the use of flexibility service it is worth repeating the business logic of the calculated benefit realised by the DSO based on deferring the necessary investment. For more details see Output 4.1 [3], in part of the long-term grid-side modules explanation.

In the considered case a real investment deferral value is calculated, i.e. a monetary benefit if the investment is deferred (it is just like putting the money in the bank).

The maximum price on flexibility products for the DSOs stems from the DSOs' alternative costs in reinforcement. This forms a sort of price-cap on flexibility products for the DSO. The final price depends on the price the aggregator offers its flexibility products at. If it is sufficiently low, the DSOs are likely to use the offered flexibility product.

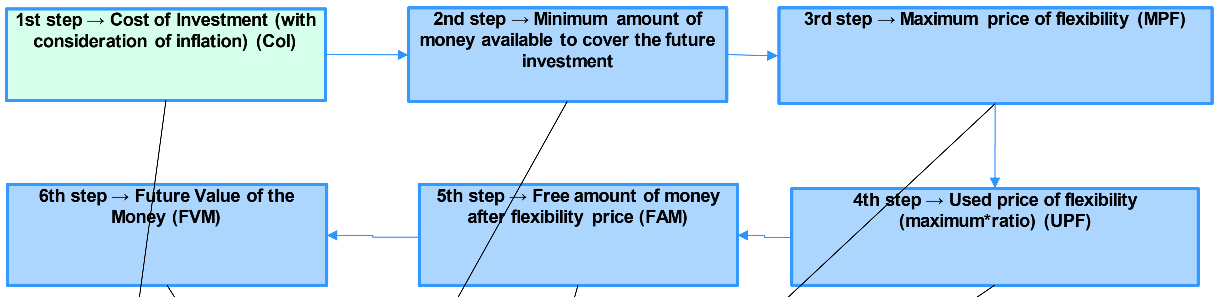
If the DSO's only alternative to buying this flexibility product is to upgrade its grid components (cables, transformers, etc.), the price setting is done based on the 1st year value of these upgrades.

For example (Table 7), if the upgrade of a 10-kV feeder costs 30.000 EUR/km, the life expectancy of this upgrade is 40 years, the inflation is 2.5% and an interest rate of 5% is considered, the value of the grid upgrade deferral will be the following, of which some will be spent on the necessary flexibility product unlocking the possibility of the deferral.

Table 7: Calculation of maximum price

WACC	5%
Inflation	2.5 %
Useful lifetime	40 years
Cost of 1 km 10-kV cable upgrade	30.000 EUR
Cable length	6 km

The logic of the calculation is depicted in Figure 1.



	2018	2019	2020
WACC	4,7%	4,7%	4,7%
Inflation	2,5%	2,5%	2,5%
FV (Future Value)	195 000	199 875	204 872
Cost of Investment (with consideration of inflation)	195 000	199 875	204 872
Minimum amount of money available to cover the future investment	**190 921**	**195 694**	**200 586**
Maximum price of flexibility	4 079	4 181	4 286
Ratio of used flexibility price	**100%**		
Used price of flexibility (maximum*ratio)	4 079	4 181	4 286
Free amount of money after flexibility price	190 921	195 694	200 586

Figure 1. Logic of the price calculation.

1st step → Cost of Investment (with consideration of inflation) (CoI):

This value represents the needed amount of money for the investment that one would like to avoid. It is crucial to mention that the valorisation is necessary each year, since in the next year one has to spend more money on the investment because of the inflation.

2nd step → Minimum amount of money available to cover the future investment (MAM):

This value represents the amount of money which should be put into the bank to cover the next year investment cost. It results from a reverse calculation from the „Cost of Investment" (which is valorised in each year with the inflation). In the reverse calculation we use the WACC as a „bank interest rate" because of the energy industry. Nevertheless, WACC can differ industry by industry and country by country. MAM= next year CoI/1+WACC.

3rd step → Maximum price of flexibility (MPF):

It is calculated form the Future Value of the Money (FVM) and Minimum amount of money available to cover the future investment (MAM). MPF=FVM - MAM. The DSO can spend this amount of money for the flexibility. Only the first year should be considered, the subsequent years calculation can inform us only about what happens if we planned long-term and DSO would require the flexibility only e.g. in the 3rd year. Based on the time series calculation the DSO can consider what should be put into the medium-term plan.

4th step → Used price of flexibility (maximum*ratio) (UPF):

This flexibility price is derived from the Maximum price of Flexibility (MPF), if the DSO does not intend to use the whole amount of the MPF then it can use a ratio (%) by which this MPF will be multiplied, and only a given portion of the Maximum price of Flexibility will be used. If we set the Ratio of Used Flexibility price (RUF) e.g. 80%, then DSO will use only the 80% of the MPF. The remaining part of money will increase the Free amount of Money after flexibility price. In this way DSO will have more money which will increase the Future Value of the Money in the next year.

5th step → Free amount of money after flexibility price (FAM):

This amount of money in the first year is the difference of the Future value of the money (which equals Cost of investment in the first year) and Used price of flexibility. This money theoretically can be put into the Bank and is the basis of the next year Future Value of the Money.

6th step → Future Value of the Money (FVM):

This amount of money in the first year will be the Cost of Investment. In the subsequent years it will be calculated from the previous year Free amount of money after flexibility price (FAM)*(1+WACC), since this amount of money will be in DSO's hand and it can be put in Bank theoretically.

Based on above theoretical background the Long-Term Multiannual module price calculator has been developed within 3Smart. The below calculation was the input for the Building side to be able to consider the offered unit price by the DSO. The basis of the calculation – as it is above mentioned – are not only the needed investment costs in terms of the pilot in Bosnia and Herzegovina but the needed flexibility calculation (both in kW and kWh) and the used ratio for the available money for flexibility services.

Figure 2 describes the assumption of the DSO for the case of the pilot in Bosnia and Herzegovina.

	A	B	C	D	E	F	G	H	I	J	K
1	**Caclulation of flexibility resource**										
2	WACC	5,00%									
3	Inflation	2,50%									
4	The cost of investment	180.000	EUR								
5	Ratio of used flexibility price	80%									
6	Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
7	WACC	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%	5,0%
8	Inflation	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%
9	FV (Future Value)	180.000	185.400	190.224	195.019	199.903	204.902	210.025	215.276	220.658	226.174
10	Cost of Investment (with consideration of inflation)	180.000	184.500	189.113	193.840	198.686	203.653	208.745	213.963	219.313	224.795
11	Minimum amount of money available to cover the future investment	175.714	180.107	184.610	189.225	193.956	198.805	203.775	208.869	214.091	219.443
12	Maximum price of flexibility	4.286	5.293	5.614	5.794	5.947	6.098	6.251	6.407	6.567	6.731
13	**Used price of flexibility (maximum*ratio)**	3.429	4.234	4.491	4.635	4.758	4.878	5.001	5.126	5.254	5.385
14	Free amount of money after flexibility price	176.571	181.166	185.733	190.384	195.145	200.024	205.025	210.150	215.404	220.789
15	Unused source	857	1.059	1.123	1.159	1.189	1.220	1.250	1.281	1.313	1.346
16	**Calculation of unit prices**										
17	Reservation ratio	50,0%									
18	Penalty price multiplicator	2									
19	**Reservation part of Flexibility unit price**	0,263	EUR/kW/(15min)								
20	**Activation part of Flexibility unit price**	1,052	EUR/kWh								
21	**Penalty**	2,104	EUR/kWh								
22	**Quality threshold (max. devviation in size of service without**	-10	%								

Figure 2. Calculation of available money for flexibility services for pilot in Bosnia and Herzegovina

The calculation shows that maximum price available for flexibility is 4.286 EUR. It should be noticed that in cases when the DSO make the entire amount of flexibility fund available to the service providers (Building, Aggregator), the DSO does not gain any benefit as compared to business as usual (making the investment). For sake of the simulation we used 80% ratio. In this way the DSO will pay 0.8 * 4.286 EUR for the flexibility service of the buildings which is 3.429 EUR. The remaining part of the available money (20%) is the benefit of the DSO which is 857 EUR yearly.

If we assume that only 70% of reservation capacity will be activated, the DSO benefits become even more attractive. That means that the DSO benefits are higher for used_price_for_flexibility*(1-reservation_ratio)*0.3 which is 515 EUR. In this case total benefits for the DSO amount to 1.372 EUR yearly.

5. Environmental benefits

In this section effects and environmental benefits based on the application of the 3Smart EMS system in the pilot in Bosnia and Herzegovina are demonstrated. The environmental benefits come from the reduced primary energy use by the building and from the increased grid capability to integrate carbon-neutral energy from photovoltaics enabled by demand response services.

The energy savings from 3Smart operation for the analyzed day in summer amount to roughly 25 kWh per day [1] and during the heating season electricity consumption is similar – in one year period this is extrapolated by 90 cooling days at 2250 kWh. For Bosnia and Herzegovina, the CO2 equivalent for electricity can be roughly assessed as 700 g/kWh (e.g. see https://www.electricitymap.org/), leading thus to yearly reduction of CO2 emissions by 1,6 t CO2 yearly. For a carbon price of 20 EUR/ton this roughly gives additional 32 EUR monetized yearly benefit for the environment from the 3Smart system operation.

6. Conclusion

The above analyses give an assessment of costs and benefits for installation of the 3Smart system on the pilot in Bosnia and Herzegovina. Investment in pilot buildings preparations for adoption of 3Smart modules amount to roughly 212.000 EUR. Additionally, cost of the 3Smart system on the building are estimated at 25.500 EUR for modules adaptation and installation and 1.500 EUR yearly for the 3Smart system maintenance.

The overall yearly benefit for the EPHZHB building operated with the 3Smart system is assessed at 3.180 EUR. The installation of the 3Smart system gives thus a long return time of investment when only the modules installation and maintenance cost would be considered: 25.5/1.68=15,2 years. Hardware investments and IT preparation, if only introduced for the reason of 3Smart system, would result in too high return on investment. Of course, the installations in commercial replications could be done in a more modest way as the intention of the pilots in 3Smart was also to investigate different options of control when more systems and measurements are available. E.g., for the case of the EPHZHB building the battery system and some electrical and heat measurements represent a significant investment that might not be used in a commercial replication on some other building – which could reduce the hardware investment, with still maintained a significant potential of the HVAC system for savings and demand response. Also, the unavailability of experts to perform sophisticated modules adaptations and installations on a massive scale is a problem that significantly increases the costs.

On the grid side the benefit compared to the costs shows similar problems for commercial replication, where the investment amounts 40.000 EUR, and 15.000 EUR for modules adaptation and installation with 1.500 EUR for yearly maintenance of the grid-side 3Smart system. Compared to the estimated benefit of 1.372 EUR yearly for the DSO, it is obvious that the grid-side modules must be employed more broadly along the distribution network with approximately similar central platform and modules costs to make the installation economically feasible for replication.

Considering that the demand response on massive scale, including buildings, will be necessary for the European energy system decarbonization and considering that introduction of demand response without predictive controls and planning cannot provide the wanted effect of maintaining comfort and achieving power flexibility on the demand side, it seems that also national, regional and European energy transition plans will have to consider the presented economical gaps via subsidies.

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[3] Output 4.1 Modular cross-spanning energy management tool. 3Smart deliverable, June 2019.

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DELIVERABLE D6.4.1

Cost benefit analysis on the pilot level – Hungarian pilot

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Deliverable participants	EON, UNIDEBTTK, UNIZGFER
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Abstract (for dissemination)	This deliverable provides cost-benefit analysis for the installed modular energy management platform on the building and on the grid side for the Hungarian pilot. This deliverable contains all the investment and operational cost of the system.
Keyword List	Cost-benefit analysis, public buildings, distribution grid, energy management system, energy efficiency, sustainability, environmental effects

Revision history

Revision	Date	Description	Author (Organization)
0.1	08 February 2018	Template	Andrea Moser (EEE)
0.2	15 June 2018	First Draft Version, Costs	Katalin Décseiné Giczi (EON)
0.3	05 December 2018	Draft Version, Costs	Katalin Décseiné Giczi (EON)
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1.0	17 January 2020	Benefits	Gabor Mihaly Peter, Tibor Beni, Katalin Bognar-Benkovits (EON)
1.1	20 March 2020	Final numbers entry for benefits. Review of the deliverable.	Mario Vašak (UNIZGFER)

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Executive summary

This deliverable provides cost-benefit analysis for applying the EMS system on an existing building.

The costs had been separated for two parts:

1. Needed investments, pre-analyses, installation projects, interventions and installation, licenses, operational costs on the level of the Hungarian pilot – this part is relevant in this deliverable.
2. Software module development costs: this is not relevant on pilot level

Building and grid side costs are included in separated chapters, CAPEX and OPEX costs are separated also.

This cost-benefit analysis describes the experiences with installing the EMS system on an existing HVAC system, without installing a new HVAC system in the building.

Costs and benefits need to be assigned with the market players on the grid side, and to be handled with considering the current regulatory framework and existing market participants in Hungary. As a new market participant entity will appear on the market, the costs and benefits could change.

1. Introduction

Cost-benefit analysis will be performed for each of the 5 pilots, by cumulating the effects of both the building and the grid-side energy management on each pilot location. Also, the broader environmental effects will be considered in order to reach the correct ratio of costs and benefits to make a driver for regulatory set-ups change in the Danube region, in favor of the improved energy-efficiency, use of renewable energy and energy security in the Danube region.

2. Methodology

The methodology for the cost-benefit analysis of the pilots (buildings and grid) is, to first of all analyze the costs related to the EMS installation. This encompasses the following parts:

- pre-analysis and concept design for the particular building
    - creation of a dynamic building simulation model
    - comparing actual and simulated consumption
    - selection of layers to be included in the EMS
    - simulation of building behavior with the selected layers
    - deciding necessary data flows and possibly additional installations
- mechanical and electrical installations project
- mechanical and electrical installations (equipment and service)
- IT integration and system operation

The hosting partner for the building and the grid (EON) in the Hungarian pilot analyzed and reported the costs for pre-analysis and concept design, mechanical and electrical installation project, the installations including equipment and service, IT integration as well as running of the building EMS.

Secondly, the costs for setting up of the 3Smart EMS modules, adaptations and monitoring were analyzed. Partners in charge for 3Smart EMS installation (pilot leader and host: UNIDEBTTK and EON, module developers: UNIZGFER, UNIDEBTTK, UNIBGFME, SVEMOFSR) reported the related costs. The partners in charge for EMS setting up on the building side also calculated the corresponding costs and compared them to the previous (before the EMS installation) mode of operation. Similarly, the DSO partners and R&D partners in charge for setting up the grid-side EMS calculated their costs compared to the previous (before the EMS installation) mode of operation.

The effects and broader benefits for the environment based on the application of the 3Smart EMS system in the pilots, that lead to a better structured energy-mix, were demonstrated.

3. Cost-benefit analysis on building side

3.1 Analysis of installation and operation of the EMS

This section shall provide a detailed overview about the conducted installations at the pilot building, that were necessary to create a basis for the 3Smart EMS system. All parts regarding pre-analysis and concept design, mechanical and electrical installation projects, mechanical and electrical installations (equipment and service) and IT integration and operation are listed in this section and the related costs are reported. In addition, the costs for the operation of the EMS system are demonstrated.

The initial state of the building is given in the deliverables of activity 6.2 and here is shortly revised.

The building complex comprises 5 buildings with multiple floors: A building has 3 floors, B building has 7 floors, C building has 4 floors, D building has 5 floors and E building has 5 floors.
The total floor area of the building complex is 7330 m^2, but the offices cover 3920 m^2. On the roof of the building there are installed PV panels. The building complex has a fan coil system which is capable to provide both heating and cooling. The source of the heating service is the district heating network, meanwhile the cooling is provided by electricity.
From the fan coil system point of view there are 4 groups of zones, B and C building are handled together, meanwhile the other buildings are controlled separately. The heating and cooling service can be controlled centrally, but there are analog thermostats in the offices which can be only manually controlled.

The type of heating/cooling system is two-pipe. The cooling system consists of the following items:

- CIAT LGN 900Z (2 pcs),
- CIAT LGN 600Z (1pc),
- CIAT LGN 400Z (1 pc).

The fan coil system consists of 225 pcs CIAT Major2 fan coils (with 125, 144, or 180 W fan). Both the heating and cooling mode can be controlled, so they can be used as controllable loads. The heating system has less room / capacity to provide benefits from the electricity optimization perspective, while cooling system can be used for load / demand control/managements.
Electrical consumption of the building was for 2015 1181 MWh in total, and for 2016 1071 MWh in total.

Heat consumption of the building complex is approximately 3000 GJ/year.

With the installations our aim was to provide a complex building energy monitoring and management system, with control functions, and ensure controllable loads in case of electrical consumption.

Definition of the cost position	Costs [€]
Pre-analysis and concept design	
Concept design (staff cost on side of UNIDEBTTK and EON)	17700,00
Dynamic building model (staff cost on side of UNIDEBTTK)	2700,00
Energy audit based on standards (EON)	2279,21
System consultancy in BEMS systems, external expert	4127,17
Water chiller control external expert	1679,62
Mechanical and electrical installation project	
Installation project for photovoltaic system	1278,98
Installation project for mechanical interventions and equipment installations	4718,55
Installation project for communication network (LAN)	1865,39
Mechanical installations (equipment and services)	
Pilot installation, expert support (UNIDEBTTK)	31775,00
Sensors, measurements installation, mechanical interventions on building side	60978,89
Electrical installations (equipment and services)	
PV installation	23203,35
Additional cabling for sensors and server	290,13
IT installations	
Server + Windows server license	9069,00
Communication (LAN) network installation	30677,38
System integration, software development, GUI	75033,11
Backup	419,76
Module installations and database creation (estimation) (UNIDEBTTK)	10000,00
Qlik licence (visualisation and reporting tool for EMS)	1100,00
TOTAL CAPEX	278895,68
EMS operation costs	EUR/year
Server operational cost/year	6684,99
Internet connection cost/year	2226,91
Special Network firewall between 3Smart network and EON Corporate Network/year	4289,03
BEMS software operational cost/year	17367,09
Communication network operational cost/year	10117,57
TOTAL OPEX	40685,59

1. Table Breakdown of installations and costs

The prices do not include the VAT (27% in Hungary).

*: It is needed to consider these costs, if the host has a strict IT Security Policy and it is not allowed to integrate the system into the Corporate Network. In this case, further costs may arise.

3.2 Analysis of EMS module integration, adaptation and monitoring

This section shall provide a detailed overview about the costs for setting up of the 3Smart EMS modules, as well as costs that could arise due to different adaptations and costs for monitoring.

Description	Costs for module setting up [€]
Installation of 3Smart EMS modules (cca. 0.5 person month per module; overall 17 modules) – so 8.5 person months approximately The person month cost is assessed as the cost of highly skilled experts capable of installing the modules, with deep knowledge on buildings energy management, estimation and control – estimated person month price for such an expert in Hungary is set to 4.000 EUR	34.000
Monitoring	**Costs for monitoring [€]**
Yearly maintenance operations for the 3Smart modules on the building side	2.500
TOTAL	34.000 + 2.500 yearly

2. Table: Breakdown of modules installation costs – E.ON building

3.3 Analysis of the benefit of the EMS operation at building side

This section assesses the benefit achievable by the 3Smart EMS system operation on-site. The benefits are assessed by performing computations of optimal daily operation of the 3Smart system including also the benefits incurred through participation in demand response service, as explained in more detail in the Section Methodology. For the benefits assessment the operation of the building in a conventional way is considered, and the operation of the building with the 3Smart system when flexibility provision to the grid is contracted, but not activated and when the flexibility is activated by the grid.

The scenarios of operation analyzed here are provided in more detail within Deliverable 7.5.3 and Output 7.1. It is important that daily operation with 3Smart is always considered with repeatability constraint imposed, meaning that no gains are incurred from accumulated energy from the previous days.

Estimation of the yearly benefit from the 3Smart system operation is based on yearly extrapolation of benefits achieved in typical days for which analyses were performed.

Scenario	Daily operation cost [€]		
	Conventional / current	3Smart without activation of flexibility from the grid	3Smart with activation of flexibility from the grid
Sunny workday in January	814.93	662.34	742.25
Sunny workday in August	229.58	186.28	174.46
Estimation of total yearly benefits [€]			
Total benefits in the cooling season	49 € x 90 days of cooling season = 4.410 €		
Total benefits in the heating season	114 € x 120 days of heating season = 13.680 €		
Overall total yearly benefit	18.090 €		

3. Table: Assessment of benefits from the 3Smart system operation – EON building

4. Cost-benefit analysis on grid side

4.1 Analysis of costs for grid-side EMS implementation

The overall technical state before the installations was described in the deliverables of activity 6.2, (D6.2.1.) and activity 5.4. (D5.4.1.), and here is shortly revised.

1. Figure Pilot location

The building complex is connected to the low voltage distribution grid via 39474 Kossuth TITÁSZ MV/LV substation. Currently it is the only building supplied by this transformer station. The building is supplied via 3 parallel 4x240 mm^2 cables. There is one 630 kVA transformer in 39474 station.

The medium voltage grid is a 11 kV cable network, it has arc and ring topology and it is operated radially. The same applies to the low voltage 0.4 kV cable network.

The pilot building is supplied from Debrecen Délkeleti 132/11 kV substation, through an 11 kV line. During normal operation, 4 MV/LV substations (39152, 39474, 39068 and 39053) are supplied from this feeder. The 39051 station at the end of this MV feeder is supplied from another HV/MV substation.

Apart from the pilot building, we have detailed measurements for five consumers in this area in the period 2008-2014. Industrial metering devices are located at the consumers' connection point and they communicate via GPRS modems. Active and reactive energy consumption (and generation) is measured in 15-minute intervals and read daily. All other data is read once a month; including instantaneous voltage, peak power, reactive energy registers and event log.

Interventions:

To have the possibility it was needed to collect detailed information and parameters of the grid, and provide the simulation model of the grid.

To reach our targets on the grid side, namely to have the possibility for shifting the loads, it was needed to implement such kind of measurement which is suitable for integration into the 3Smart system, and compatible with the building side measurements from communication and sampling time point of view.

In order to give trigger sign for the load shifting, the new measurement on MV cable and also on LV cable line had been integrated into the 3Smart database.

Development on the Smart Meter Reading Centre was necessary as well, because of the uniformed, 1 minute sampling time.

One of the aims of the project is to have the capability on the building side to optimize the consumption with considering the electricity market prices. It is needed to ensure the information flow between the retailer and the 3Smart database.

In order to run load flow calculations, it was needed to procure a Neplan software license also.

Definition of the cost position	Costs [€]
Pre-analysis and concept design	
LV and MV grid modelling (staff cost, EON)	3500
Concept design (staff cost, EON)	9345
Mechanical and electrical installation project	
Installation projects for smart meters in MV/LV tr. stations (DSO)	1774,07
Mechanical installations (equipment and services)	

Preparation and installation of 3 smart meters in tr. stations (DSO)	6435,92
Electrical installations (equipment and services)	
Cost of 3 smart meters (DSO)	1778,60
modem	514,54
IT installations and integration	
Automated process for providing DA and ID prices for EMS (retailer)	320
Long and short term module installation, database creation	850,00
Converge (smart meter reading centre) development	320
neplan	7931,55
Scenario running, flexibility table preparation, contract preparation (staff cost DSO)	850,00
Long term application development	44444,84
Short term customization	11111,21
Smart metering integration and data transfer	6172,89
TOTAL CAPEX	94194,08,73

3. Table Grid side costs breakdown

The prices do not include the VAT (27% in Hungary).

4.2 Analysis of the benefit of the EMS operation at grid side

This section shall provide an overview about the "benefit" of the 3Smart EMS system on the grid side. An analysis of costs before the EMS installation and after shall be conducted.

In 3Smart DSO's approach was that because of cable line overloading or voltage band deviation (when load exceeds the operational limit of the 10kV cable line or PV penetration causes a voltage band deviation in time of maximum power generation) the company could use flexibility service from buildings alongside the cable line. In our case we considered only the overloading factor because there is no high PV proliferation which could cause voltage band deviation.

In order to be understood better the underlying concept of the use of flexibility service it is worth repeating the business logic of the calculated benefit realised by the DSO based on deferring the necessary investment.

In our case we calculate a real investment deferral value, i.e. a monetary benefit if we defer the investment (it is just like putting the money in the bank).

The maximum price on flexibility products for the DSOs will be set from the DSOs' alternative costs in reinforcement. This will form a sort of price-cap on flexibility products for the DSO. The final price will depend on what price the Aggregator offers its flexibility products at. If it is sufficiently low, the DSOs are likely to use the offered flexibility product.

If the DSO's only alternative to buying this flexibility product is to upgrade its grid components (cables, transformers, etc.), the price setting could be done based on the 1st year value of these upgrades.

For example, if the upgrade of a 10 kV feeder costs 65,000 EUR/km, the life expectancy of this upgrade is 40 years, the inflation is 2,5 % and an interest rate (in our case the recognised WACC by the regulator) of 4,69% is considered, the value of the grid upgrade deferral will be the following, of which some will be spent on the necessary flexibility product un-locking the possibility of the deferral.

WACC	4.69%
Inflation	2.5%
Useful lifetime	40 years
Cost of 1 km 10 kV cable upgrade	65,000 EUR
Cable length	3 km
Real interest rate	$\frac{1+\text{WACC}}{1+\text{Inflation}} - 1 = 3.65\%$

4. Table Calculation of maximum price

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
WACC	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%
Inflation	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%
FV (Future Value)	195 000	199 875	204 872	209 994	215 244	220 625	226 140	231 794	237 589	243 528	249 616
Cost of Investment (with consideration of inflation)	195 000	199 875	204 872	209 994	215 244	220 625	226 140	231 794	237 589	243 528	249 616
Minimum amount of money available to cover the future investment	**190 921**	**195 694**	**200 586**	**205 601**	**210 741**	**216 009**	**221 410**	**226 945**	**232 618**	**238 434**	**244 395**
Maximum price of flexibility	4 079	4 181	4 286	4 393	4 503	4 615	4 731	4 849	4 970	5 094	5 222
Ratio of used flexibility price	**100%**										
Used price of flexibility (maximum*ratio)	4 079	4 181	4 286	4 393	4 503	4 615	4 731	4 849	4 970	5 094	5 222
Free amount of money after flexibility price	190 921	195 694	200 586	205 601	210 741	216 009	221 410	226 945	232 618	238 434	244 395

Based on above theoretical background we have developed the Long Term Multiannual module price calculator. The below calculation was the input for the Building side to be able to consider the offered unit price by the DSO. The basis of the calculation – as we above mentioned – are not only the needed investment cost in terms of HU pilot site (3km 10kv cable line investment due to overloading) but the needed flexibility calculation (both in kW and kWh) and the used ratio for the available money for flexibility services.

The below table describes the assumption of the DSO:

5. Table Calculation of available money for flexibility serives

Caclulation of flexibility resource								
WACC	4,69%							
Inflation	2,50%							
The cost of investment	195 000	EUR						
Ratio of used flexibility price	90%							
Year	2019	2020	2021	2022	2023	2024	2025	2026
WACC	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%
Inflation	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%
FV (Future Value)	195 000	200 302	205 354	210 493	215 756	221 150	226 678	232 345
Cost of Investment (with consideration of inflation)	195 000	199 875	204 872	209 994	215 244	220 625	226 140	231 794
Minimum amount of money available to cover the future investment	190 921	195 694	200 586	205 601	210 741	216 009	221 410	226 945
Maximum price of flexibility	4 079	4 608	4 768	4 892	5 015	5 140	5 269	5 400
Used price of flexibility (maximum*ratio)	3 671	4 147	4 291	4 403	4 513	4 626	4 742	4 860
Free amount of money after flexibility price	191 329	196 155	201 063	206 090	211 242	216 523	221 936	227 485
Unused source	408	461	477	489	501	514	527	540
Calculation of unit prices								
Reservation ratio	50,0%							
Penalty price multiplicator	2							
Reservation part of Flexibility unit price	0,015	EUR/kW/(15min)						
Activation part of Flexibility unit price	0,061	EUR/kWh						
Penalty	0,122	EUR/kWh						
Quality threshold (max. devviation in size of service without penalty)	-10	%						

The calculation shows that the maximum price for flexibility is 4079EUR, but the DSO took the opportunity to set the Ratio of used flexibility price in order to gain benefit from the business. If the DSO adjusted 100% then it results in zero benefit for the DSO because all available money would be paid for the service providers (Buildings, Aggregator), therefore for sake of the simulation we used 90% ratio. In this way the DSO will pay 0,9*4079 EUR for the flexibility service for the buildings, i.e. 3671 EUR. The remaining part of the available money (10%) is the benefit of the DSO, i.e. **408 EUR**.

The above calculation served as an input for the Building benefit calculation as well, the building calculation considered the calculated flexibility unit prices.

Nevertheless if there was a flexibility market the DSO could get more benefit if the unit price of flexibility was lower then the calculated one based on investment deferral. Below an example shows what would have been if DSO could get an attractive price which is the half of the money which was devoted originally to flexibility services.

Caclulation of flexibility resource								
WACC	4,69%							
Inflation	2,50%							
The cost of investment	195 000	EUR						
Ratio of used flexibility price	50%							
Year	2019	2020	2021	2022	2023	2024	2025	2026
WACC	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%	4,7%
Inflation	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%	2,5%
FV (Future Value)	195 000	202 010	208 178	213 968	219 623	225 274	230 990	236 808
Cost of Investment (with consideration of inflation)	195 000	199 875	204 872	209 994	215 244	220 625	226 140	231 794
Minimum amount of money available to cover the future investment	190 921	195 694	200 586	205 601	210 741	216 009	221 410	226 945
Maximum price of flexibility	4 079	6 316	7 592	8 367	8 882	9 265	9 580	9 864
Used price of flexibility (maximum*ratio)	2 040	3 158	3 796	4 183	4 441	4 632	4 790	4 932
Free amount of money after flexibility price	192 960	198 852	204 382	209 784	215 182	220 642	226 200	231 877
Unused source	2 040	3 158	3 796	4 183	4 441	4 632	4 790	4 932
Calculation of unit prices								
Reservation ratio	50,0%							
Penalty price multiplicator	2							
Reservation part of Flexibility unit price	0,008	EUR/kW/(15min)						
Activation part of Flexibility unit price	0,034	EUR/kWh						
Penalty	0,068	EUR/kWh						
Quality threshold (max. devviation in size of service without penalty)	-10	%						

This possibility was modelled by setting 50% of the Ratio of used flexibility price. That is the market could give such a price which allows the DSO to save 2040 EUR/year. So it is significantly higher than 408 EUR. However, it is just a thought experiment that shows the future opportunities and potentials if there was an effective flexibility market.

Another aspect of the future model is the ratio between Reservation and Activation. In the above calculation we assumed a 50-50% ratio. If the DSO could save the half of the money of the available money devoted to flexibility services (as was it described above) then there is remaining further possibility to gain money from the flexibility services, namely if the Activation will be not fully used. So let's calculate again the money transfer if the activation will be used only in 50%.

Money what is sure for the DSO: 50% of available money, i.e. 2040EUR.

The remaining part of the money will be used for Reservation and Activation. In case of Reservation the DSO has no room for maneuver (i.e. 1020 EUR have to be paid), but if the Activation will be used only in 50%, then the DSO could get the half of the money devoted for the Activation, namely 1020/2= 510EUR.

In this way the supposed maximum profit for the DSO is 2040EUR+510EUR= **2550 EUR.**

From the above calculation it can be derived that DSO could get profit between 408 and 2550 EUR. Both assumptions are extreme, so a plausible value somewhere is between the two, namely 1480 EUR.

5. Environmental benefits

In this section effects and environmental benefits based on the application of the 3Smart EMS system in the pilots shall be demonstrated. Indicators for environmental benefits have to be defined.

The environmental benefits come from the reduced primary energy use by the building and from the increased grid capability to integrate carbon-neutral energy from photovoltaics enabled by demand response services.

The energy savings from 3Smart operation for the analyzed day in summer amount to roughly 6,1 MWh of consumption with conventional control to 4,7 MWh which is a saving of 1,4 MWh of electricity per day. For Hungary, the CO_2 equivalent for electricity can be roughly assessed as 300 g/kWh (e.g. see https://www.electricitymap.org/), leading thus to daily reduction of CO_2 emissions by 0,420 t CO_2 daily. For a carbon price of 20 EUR/ton this roughly gives 8 EUR daily benefit.

In heating season the reduction of heating energy consumption is roughly estimated at 3,8 MWh daily. If also for the heat factor of 300 gCO_2/kWh is used, the daily saving of CO_2 emissions is roughly 1,14 t CO_2 or 23 EUR daily benefit in CO_2 emissions reduction.

6. Conclusion

The document provided the assessment of costs and benefits for the 3Smart pilot in Hungary.

The Building side EMS installation costed ~ 280kEUR, meanwhile the operation 40kEUR. During the installation work we have encountered some not planned cost, namely the new communication network installation (there was an assumption that existing old network would be sufficient, but it turned out that some new hardwares are necessary for the project requirement) and a new SCADA system for data gathering (the old system was not able to serve the project requirements). Beside of the installation the integration costed 34kEUR.

The yearly gain of the 3Smart system operation compared to conventional control is determined as 18.090 EUR. If half of this amount would be yearly spent on different maintenance services (3Smart modules maintenance, supporting IT system maintenance), the remaining half can compensate for the capital investment in modules installation (34.000 EUR for modules adaptation and installation, roughly the same amount for the necessary supporting IT – rounded on 70.000 EUR) leading to return on investment in 3Smart within 70/8= 8,8 years.

The Grid side EMS installation and integration costed ~94 kEUR, the significant amount of cost is related to LT and ST installation and integration. The other significant element of cost is related to Smart metering installation and integration to meter reading centre.

The grid side benefit can be derived from the DSO profit, i.e. the prolongation of investment due to overloading. The calculation showed different scenarios which embraced a wide range from profit point of view. The lowest profit was 408 EUR for DSO, meanwhile the assumed maximum profit was 2550 EUR, our assumption is that the reality can be found between these two extremes, namely is 1480 EUR.

Regarding the grid side benefit the conclusion is that without involvement of more buildings into the flexibility service the benefit is not so attractive for DSO. Nevertheless it is worth mentioning that the significant part of the grid side installation can be used for other buildings as well. The main point is the interest rate, the WACC which is used by the Regulator, if the WACC were higher then the available money for flexibility also would be higher, and in this way the basis of the benefit also would be higher.

Bibliography

[1] D7.5.3 Operational logs and their seasonal analysis – Hungarian pilot. 3Smart deliverable, March 2020.

[2] Output 4.1 Modular cross-spanning energy management tool. 3Smart deliverable, June 2019.

Output Quality Report

Output title: T4.2 Cost-benefit analysis of the EMS	
Type of output:	☐ Documented learning interaction ☐ Strategy/ Action Plan ☑ Tool ☐ Pilot action
Contribution to PO indicator:	**P24 No of tools to improve energy security and energy efficiency developed and/or implemented**

Summary of the output (max. 1500 characters)
The 3Smart platform developed within the project as a software tool has been applied to 5 pilots in 5 different countries of the Danube region. The platform enables to perform energy management of buildings and electricity distribution grids in an integrated way, but requires investments to be done on the sides of buildings and grids to enable the platform functioning. Within the cost-benefit analysis output a systematic procedure is agreed and followed for all the pilots to assess the cost and benefits related to the 3Smart system application on sites. The costs are assessed by documenting all the costs of the investment, but also those costs that would incur when there would be no EU funding, like personnel costs for modules adaptation and installation, for which highly skilled experts are needed. The benefits are assessed in comparison of the 3Smart platform performance on the pilot with the performance of classical state-of-the-art automation systems with usually a very simple operational logic. The 3Smart platform performance was assessed by applying the 3Smart tool on the data collected from sites. Benefits are assessed separately for the cooling and separately for the heating season on each pilot by focussing on characteristic days of operation.. Also environmental benefits were assessed. In the output this procedure is documented and performed for each of the 5 pilot sites.

Added value

The added value of the developed cost-benefit analysis lies dominantly on the benefit side which is much harder to tackle. The cost side is also sophisticated in a way that not all investments performed on pilots should be assigned to the 3Smart system and likewise not all the gains achieved. E.g., the costs experienced to introduce a state-of-the-art building automation system on a site, as well as gains stemming out of its application to the building should be excluded from the analysis. On the costs side this was achieved by focussing only on the IT system add-on to the automation systems that is a prerequisite for 3Smart installation. On the benefit side the performance of the 3Smart system is compared exactly with the state-of-the-art automation system to show the benefit achievable over well tuned today's building automation system, when operating in the same conditions.

Finally the application to versatile pilots is shown where numbers that follow the responses achieved for seasonal analysis of different pilots (Output 7.1) together give a full insight on the power of predictive control based energy management, but also its performance limits.

Another added value is that the benefits assessment procedure also includes the demand response functionality meaning that the building can decide whether or not to participate in demand response and with how large flexibility bid.

Applicability and replicability (max. 1500 characters)

The procedure within the cost-benefit analyses document should be followed to replicate the cost-benefit analysis for another site. The investor needs to assess, with a help of an expert that follows the exposed procedure, what would be the costs to introduce the 3Smart system on different levels of the building (zones, central HVAC system, microgrid). It would also need to assess the achievable benefits from employment of the 3Smart system on different levels of the building. Here the 3Smart tool developed would have to be adapted for the simplified model of the building and its components and then applied for daily operations planning to gain insight what behaviours are exhibited, how much flexibility the building could provide to the grid etc. After the assessment of expected building behaviour in different configurations of the tool, an informed investment decision could be made.

It will be especially important and valuable with time to collect different models of building components, like those that were for now created for 3Smart and its different pilots, to make the adaptations of the tool for a particular building faster and cheaper. In any case the expert will be required to perform the assessment of financial feasibility by adhering to the developed 3Smart tool and procedure for the cost-benefit analysis.

Suggestions for improvement, if applicable

A gradual improvement that should be developed with time is the library of common components in buildings for which typical simple models should be generated for further replications. Within 3Smart project the simplified models of 5 pilots were created and hopefully this 'library' will further grow with new applications and replications on different sites.

This will make with time the application of the developed tools in average easier for new sites.

Output Quality Level	☐ Low ☐ Average ☐ Good ☑ Excellent

Name of the Quality Manager

Prof. dr. Hrvoje Pandžić

Signature of the Quality Manager