Output Factsheet

Output title: T5.1 Pilot-deployed modular energy management platform

Summary of the output

The output shows how the developed 3Smart tool is applied to 5 diverse pilot sites in 5 countries of the Danube region (HR, SI, AT, BA, HU). It is completed with showing performance of the 3Smart modules on different pilots. Also in this revised output are added now operational logs and seasonal analyses from all pilots.

The Croatian pilot consists of two buildings in Zagreb, one of UNIZGFER and another of HEP, and of the pilot electricity distribution grid of HEP around these two buildings.

The Slovenian pilot consists of a Primary school building and Sports centre of IDRIJA, with the electricity grid of ElektroP around it.

The Austrian pilot consists of two buildings of the municipality Strem, which are the primary school and the retirement and care centre. In addition, the electricity distribution grid of EnergyG is also part of the pilot.

Bosnia and Herzegovina pilot consists of a business building in property of EPHZHB in Tomislavgrad and of the pilot electricity distribution grid of EPHZHB around the building.

The Hungarian pilot consists of a buildings complex of EON in Debrecen and of the pilot electricity distribution grid of EON around the building.

The five individual reports for different pilots show how the 3Smart tool is organized on pilots, how it operates the buildings and the grids, and show also the seasonal analyses of pilots operation for characteristic days with assessed economical benefits. They are used in Output T4.2 for performing cost-benefit analyses of pilots installations exactly regarding the part of adding-up the 3Smart platform to the automation systems.

Contribution to EUSDR actions and/or targets

The output 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 performed pilots show that it is viable to unlock demand response capacities of buildings as largest consumers of energy. It is very important for enabling higher renewable energy integration since the energy system regulation needs to be brought at least in part on the side of consumers within the process of energy system decarbonization.

Performed testing, if applicable
The piloting of the 3Smart tool is performed on 5 3Smart pilots and elaborated in this output – both organization of the modules of the tool and their individual and cumulative performance is shown, including financial benefits.
Integration and use of the output by the target group
Main target groups for the usage of the platform outputs are building owners or managers, infrastructure companies, and national regulators. Building owners can learn how to better use the infrastructure they manage to reduce their operating costs and also help the proliferation of demand response services locally which then also streams secondary benefits of renewable energy capacities increase. A similar position is for infrastructure operators – it shows how the infrastructure operation costs can be lowered via demand response and optimization.
Geographical coverage and transferability
The 3smart EMS platform piloting was conducted in 5 countries in the Danube region, with results showing that it can bring benefits in all these configurations. This proves that its concept and results are transnationally relevant and transferrable to different local contexts and different infrastructure setups.
Durability
The platform validity is not constrained with time and should become more and more relevant as the energy efficiency and demand response regulations get mature over time to trace the path of energy systems decarbonization in Europe and across the globe. The output will evidence how the tool can be organized for different setups and which benefits it can bring.
Synergies with other projects/ initiatives and / or alignment with current EU policies/ directives/ regulations, if applicable (max. 1500 characters)
The platform has a synergy effect with Clean Energy for all Europeans package – it shows how buildings and grids can be smartly managed and how they can interact through demand response. Its testing is also very important for the coming decades of the energy system full decarbonizaton in the Danube region and the EU, so it is in line with the European Green Deal of the 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 (Integration and smart management of energy storages at historical urban sites) which inherits the developed procedures for economical assessment of various combinations of PV and battery systems to decide which configuration is economically optimal, plan its optimal operation and run it. Also a synergy can be assessed with H2020 project REWAISE (Resilient water innovation for smart economy), that is about to start, where demand response and coordination in the water cycle will be developed and tested.

Output integration in the current political/ economic/ social/ technological/ environmental/ legal/ regulatory framework
The output evidences the possibilities of buildings energy management and also the possibilities for their participation in demand response service provision. The output should also be considered in environmental context showing that smart energy management can lower energy consumption not necessarily on the cost of users comfort. The output with its seasonal analyses performed for pilots also gives clear figures about possible savings achievable and demand response potentials of buildings to energy regulators, giving them the benefit-side insight for further policies shaping in the area of energy management and demand response.

Project Deliverable Report

Smart Building – Smart Grid – Smart City

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

DELIVERABLE D7.4.3

Operational logs and their seasonal analysis – Bosnia and Herzegovinian pilot

Project Acronym	3Smart
Grant Agreement No.	DTP1-502-3.2-3Smart
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Project Start Date	1 January 2017
Project Duration	36 months
Work Package	7
Task	7.4
Date of delivery	**Contractual:** 31 December 2019 **Actual:** 31 December 2019
Code name	**Version:** 1.0 Final ☒ Final draft ☐ Draft ☐
Type of deliverable	Report
Security	Public
Deliverable participants	UNIZGFER, EPHZHB
Authors (Partners)	Mario Vašak, Anita Martinčević, Nikola Hure, Hrvoje Novak, Danko Marušić, Marko Kovačević, Paula Perović, Tomislav Capuder (UNIZGFER), Mile Međugorac, Marin Bakula (EPHZHB)
Contact person	Mario Vašak (UNIZGFER)
Abstract (for dissemination)	This document provides operational logs of the 3Smart system for characteristic days in seasons of heating and cooling, for the 3Smart pilot in Bosnia and Herzegovina. These logs are compared with the conventional control system operation in the same conditions to be able to quantify achievable benefits through interaction of building-side and grid-side 3Smart modules which implements optimization of building and grid operational costs. The operational logs include also the optimal building bid for flexibility in the given pricing conditions.
Keyword List	building-side energy management system, grid-side management, operational logs, seasonal analysis, benefits, demand response, reservation, activation

Revision history

Revision	Date	Description	Author (Organization)
1.0	31 December 2019	Collected and explained operational logs from the Bosnia and Herzegovina pilot	Mario Vašak, Anita Martinčević, Nikola Hure, Danko Marušić, Hrvoje Novak, Marko Kovačević (UNIZGFER)

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Executive summary

The 3Smart project deals with real-time integrated grid-building energy management including demand response. It considers this key topic for the forthcoming process of decarbonization of the energy system from regulatory, technology and economical aspects.

From the technology side, the project has yielded a modular software tool that is adaptable for application to various buildings and grids configurations. Within the project five pilots are performed where these tools are tested. Each of the pilots encompasses the grid and the buildings perspective. These five pilots are situated in five different countries: Croatia, Slovenia, Austria, Bosnia and Herzegovina and Hungary.

This deliverable provides operational logs of the 3Smart system operation on the Bosnia and Herzegovinian pilot, focussed on particular characteristic days in the heating and cooling season. It provides a comparison with the conventional control performed under the same conditions. In this way it is possible to quantify the benefits achievable exactly due to the 3Smart system operation on the site. Moreover we are able to compute the optimal flexibility bid for the building in given pricing conditions from the grid. The benefits with and without flexibility activation from the grid side are assessed.

1. Introduction

The Bosnia and Herzegovinian pilot consists of a pilot building of EPHZHB in Tomislavgrad and of the pilot electricity distribution grid of EPHZHB around it.

The pilot setup on the side of the building and the grid, including the 3Smart system structure on the pilot, is provided in the deliverable D7.4.2 [1].

This deliverable concerns the operational logs obtained by operation of the 3Smart modules on the setup of the Bosnia and Herzegovinian pilot. The focus here is on the analysis of the essential modules that enable predictive and coordinated behaviour of the entire building connected to the grid operated also with the 3Smart modules. The building is analyzed in conditions specific for different seasons – heating and cooling, on the level of characteristic days.

With these operational logs we are giving answers to the following questions posed for building operation during a certain day which are not easy to be answered without the 3Smart tool adapted for a particular building:

- What is the optimal way of daily building operation in terms of the overall building operational costs:
    - When and how much to heat/cool a specific of several tenths of zones?
    - When and how much to heat/cool the centrally prepared medium for heating/cooling of zones?
    - When and how much to charge/discharge the battery system?
    - From which initial condition should building start at the beginning of the day?
    - What should be the amount of offered flexibility from the building to the grid?
- How much is the optimal way of operation better than usual, conventional one?

In this analysis the 3Smart tool is used to enforce a repeatable day-to-day behaviour in a way that starting building condition (at the day start, at midnight) is enforced to be the same as the ending day condition (at the following midnight). In this way the evaluation of the 3Smart system operation is fair meaning that the 3Smart system does not exploit any initial condition in the building for inducing savings, but leaves the building in the same condition as it was at the beginning of the day – i.e. no energy cumulated in initial conditions is exploited. The computations performed within 3Smart predictive control modules also select the optimal starting building condition for minimum operational costs.

In Chapter **Pogreška! Nepoznat argument skretnice.** the operational logs and seasonal analysis for the EPHZHB building are presented. In it the necessary inputs from the grid side (pricing and flexibility conditions) are provided to be able to generate the operational logs and perform the seasonal analysis.

2. EPHZHB building operational logs and seasonal analysis

The operational logs and seasonal analysis are performed for two selected typical days of building operation – sunny workday in July as a representative for the cooling season operation of the building and sunny workday in November as a representative of the heating season operation of the building.

2.1 Grid-side and boundary conditions for the building operation – cooling season

The explanation of the operational logs is started by presenting the conditions provided by the grid for a sunny workday in July.

The needed flexibility time windows for the grid within the analysed day are as follows:

- 12:30-12:45;
- 13:00-13:30;
- 13:45-16:00.

The pricing conditions computed by performing the calculations by long-term grid-side modules are as follows:

- reservation price: 0.0021 EUR/kW/15 min;
- activation price: 0.0084 EUR/kW;
- penalty price: 0.0168 EUR/kWh.

The expected day-ahead electricity pricing is shown in Figure 2.1.

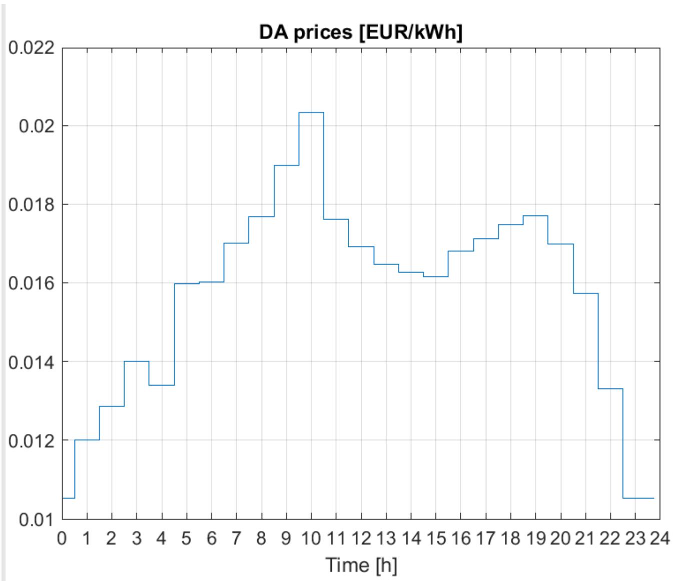

Figure 2.1. Day-ahead electricity pricing for a sunny workday in July.

Additional parameters taken into account are consisted of the relevant meteorological conditions, namely outdoor air temperature profile (shown in Figure 2.2) and direct and diffuse solar irradiance profiles (shown in Figure 2.3), as well as the non-controllable consumptions on the HVAC level (thermal energy consumption profile shown in Figure 2.4) and the microgrid level (electrical energy consumption profile shown in Figure 2.5).

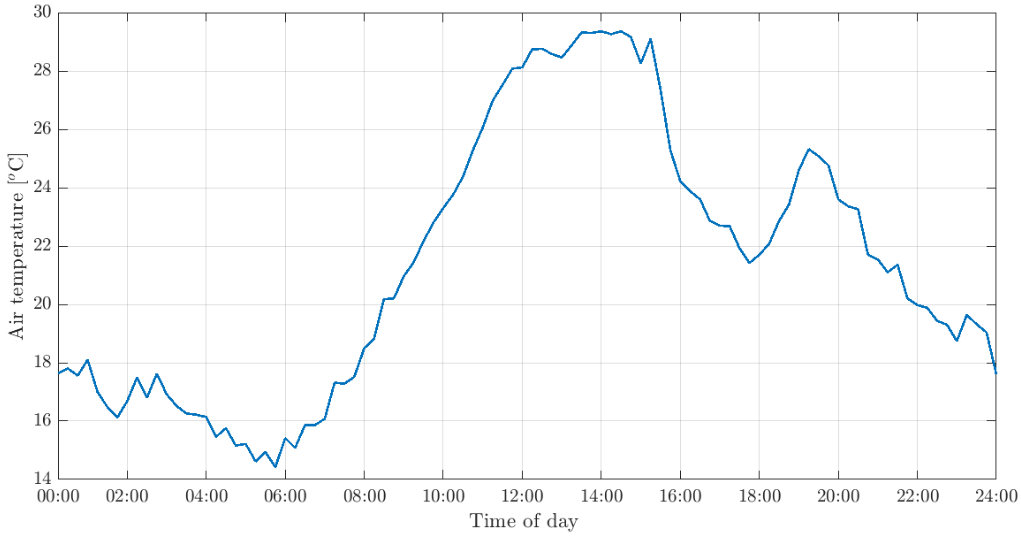

Figure 2.2. Outdoor air temperature for a sunny day in July.

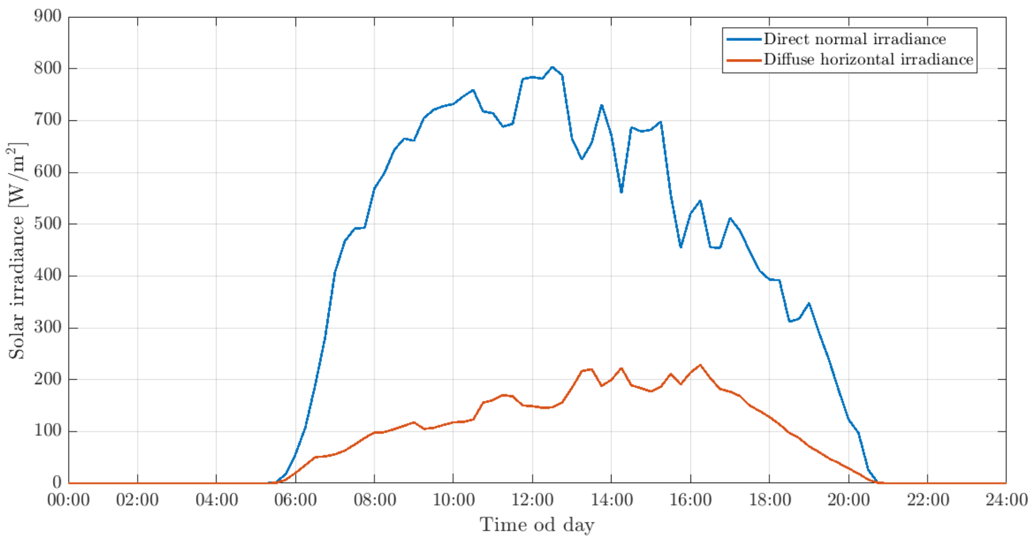

Figure 2.3. Direct (normal) and diffuse (horizontal) solar irradiance for a sunny day in July.

Non-controllable thermal energy consumption on the HVAC level accounts for the consumption of the air handling units which are not under 3Smart system reach. However, during the cooling period the air handling units are not used resulting in the lack of HVAC level non-controllable consumption. The non-controllable electrical energy consumption on the microgrid level is consisted of the energy consumption of the office lighting, computers, and all other loads which are not belonging to the part of the indoor climate system controllable by the 3Smart platform. Non-controllable electrical energy consumption also includes the PV system power production which is for presentation purposes shown separately.

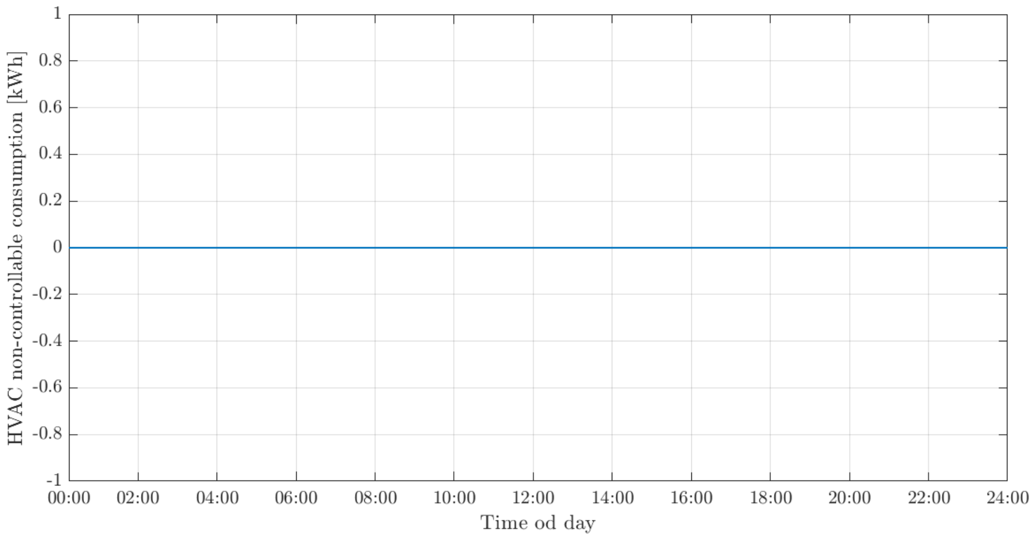

Figure 2.4. Non-controllable consumption of thermal energy on the HVAC level, for a sunny workday in July.

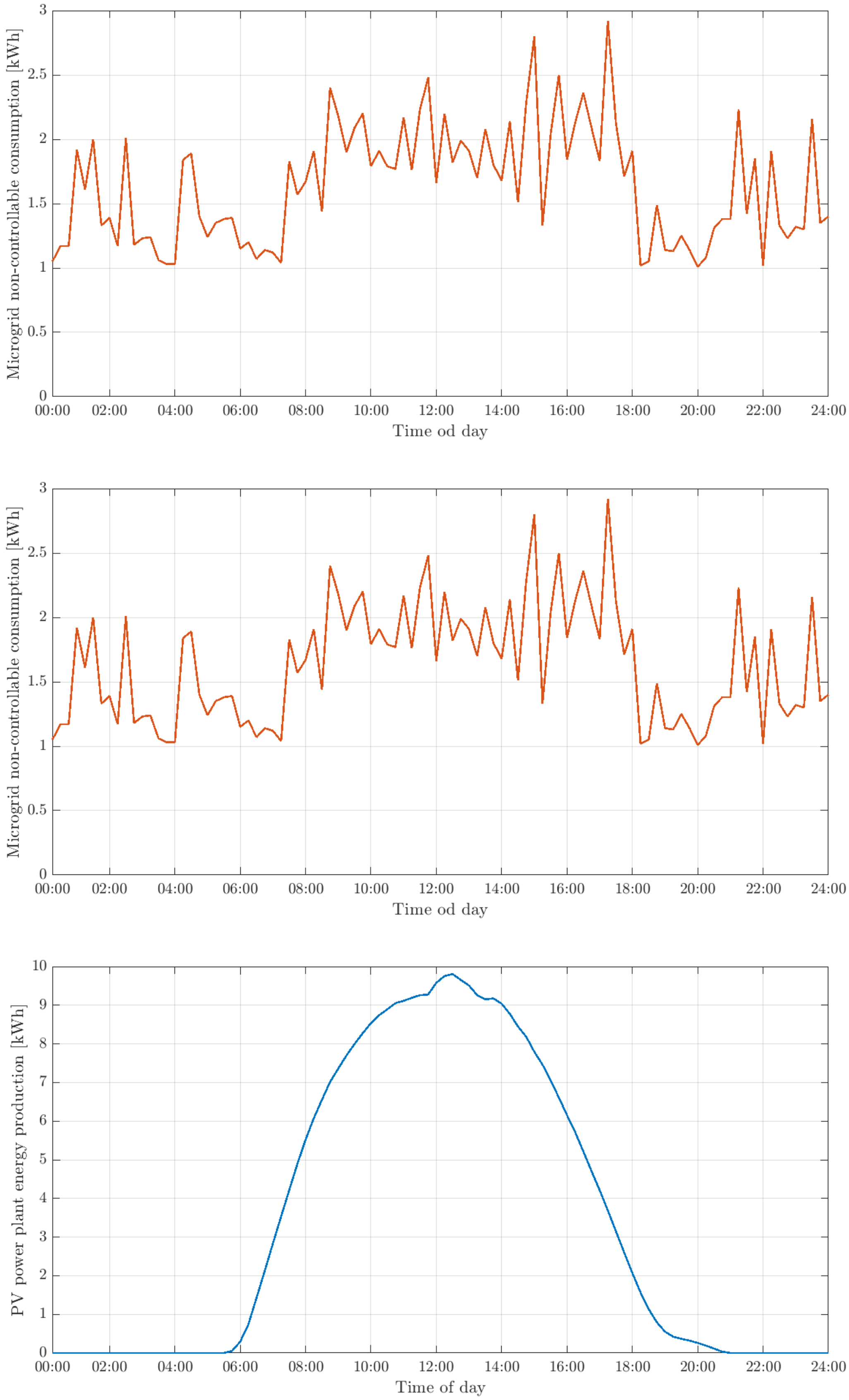

Figure 2.5. Non-controllable electrical energy consumption on the microgrid level, for a sunny workday in July (upper) and PV system power production (lower).

2.2 The optimized building operation – cooling season

First the responses on the zone level are analysed. In baseline control on the zone level we consider that in each zone exists a simple hysteresis controller that switches progressively the fan coils fan speeds to higher when the temperature of the room rises more and more above the set point and vice versa when the opposite is the case. This way of operation is actually the state-of-the-art conventional control algorithm for rooms temperature regulation. The lowest fan speed switches on when the reference temperature, set in this analysis to 24°C, is surpassed above by 0.5°C. Conventional control on the zone level is leaned also to conventional control on higher levels, i.e. meaning that for the conventional control response on the zone level the cooling medium is prepared by following the conventional control algorithm on the central HVAC level. In Figure 2.6. one may see a typical temperature profile of one of the 24 zones of the EPHZHB building. The 3Smart operation, also shown in Figure 2.6, maintains the comfort in the zone such that zone temperature is set to the upper bound of zone temperature limits in intervals in which outside weather conditions can be utilized.

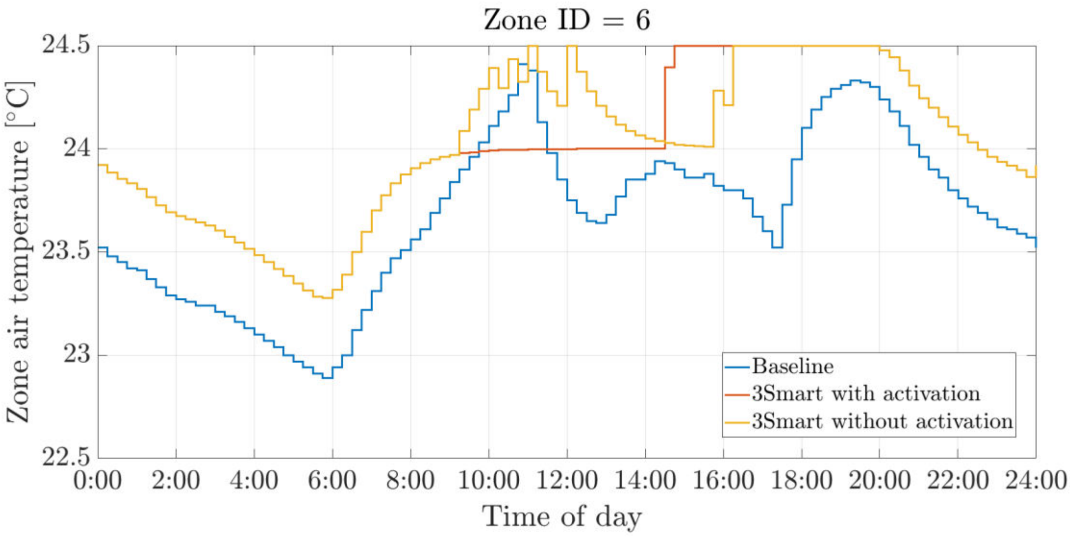

Figure 2.6. A typical response of temperature for a room in EPHZHB building within the analysed day -- 3Smart vs baseline operation.

Figure 2.7 shows a typical response of air side thermal energy for a room in EPHZHB building within the analysed day.

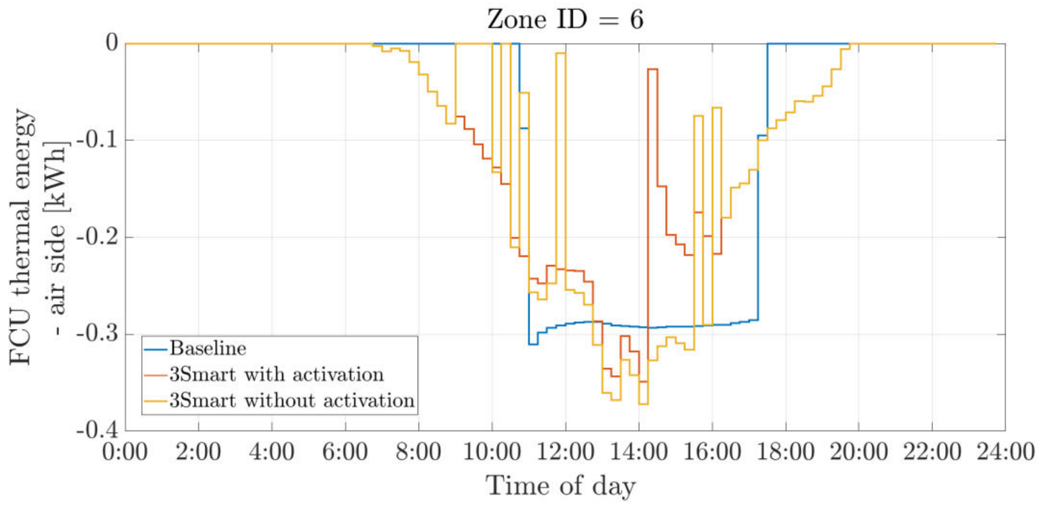

Figure 2.7 . A typical response of air side thermal energy for a room in EPHZHB building within the analysed day -- 3Smart vs baseline operation.

In Figure 2.8 the sum of required energies for exertion to rooms air for all the 24 controllable zones is shown.

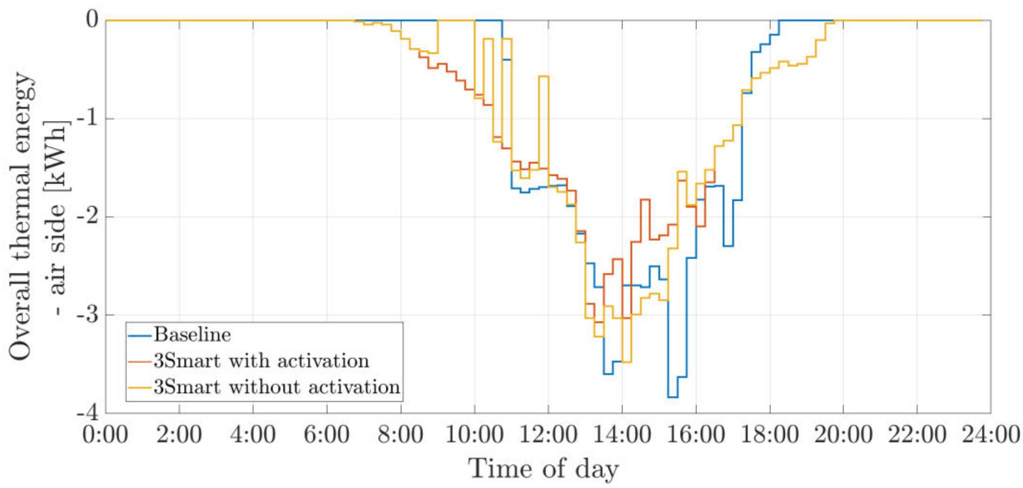

Figure 2.8. Overall cooling energy needs for all the zones (sum of energies that should be exerted in zones air).

On the central HVAC level manipulated variable of the system is the temperature of the medium coming out of the chiller. It must be set above the lower bound of 10°C. With it the buffer tank is supplied and the medium temperature in it is kept close to 10 °C. For saving reasons, taking into account that enough energy can be extracted to rooms' air with much higher starting temperature, the 3Smart system poses much higher starting temperatures in the buffer tank which reduces the consumption of the overall cooling system significantly, especially considering also the losses in supply ducts.

At particular times of the day the temperature of the cooling medium is significantly lowered to provide the needed cooling load to keep the temperatures in all the rooms in the required temperature span. Figure 2.8 and Figure 2.9 show the behaviour of the supply temperature from the buffer tank and the behaviour of the electricity consumption profile of the entire HVAC system – meaning the consumption of the chiller and of the fans of fan coils. Figure 2.9 shows a significant possibility of reduction of consumption by using more favourable operating points for chiller operation, in accordance with the cooling needs of all the zones – the temperature of the medium supplied towards the zones is always such that all cooling requests of all the zones can be served.

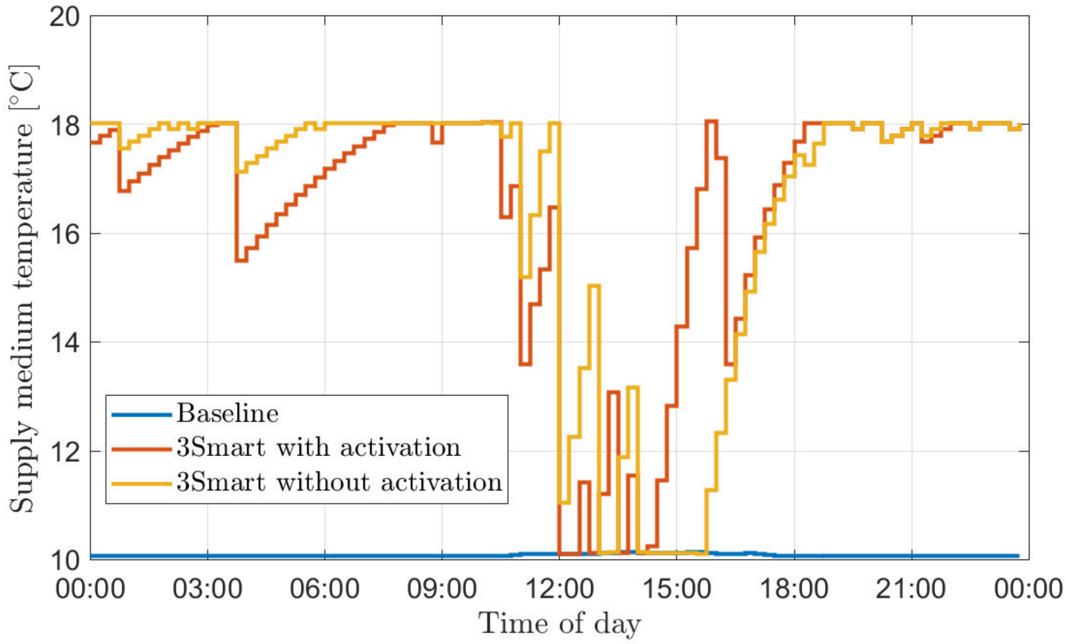

Figure 2.8. Profile of medium temperatures towards the zones (from the buffer tank).

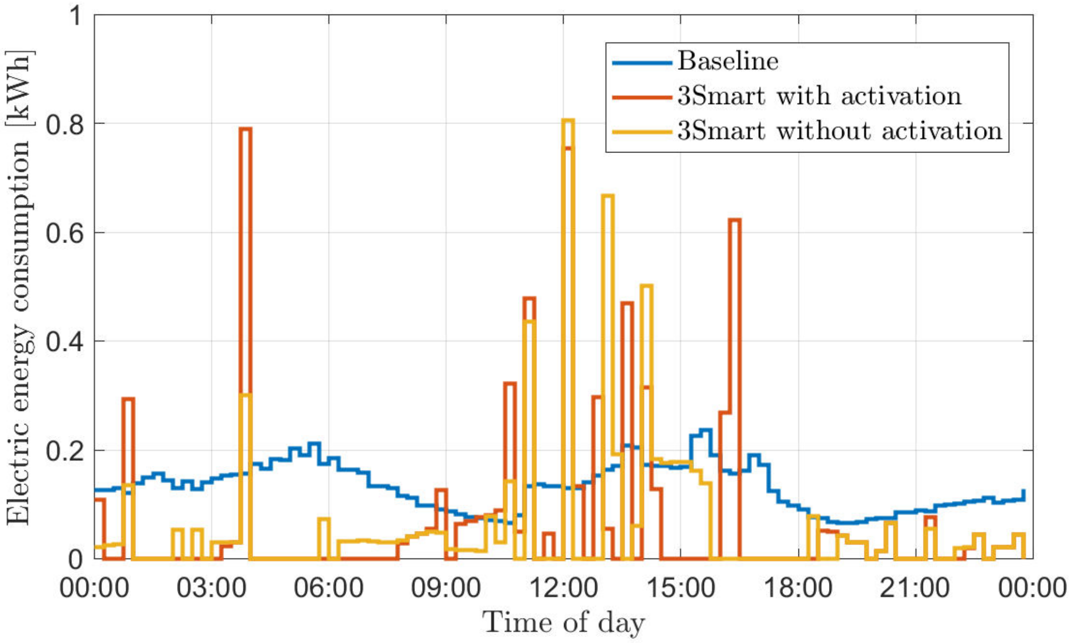

Figure 2.9. Electricity consumption of the HVAC system (chiller + fans of fan coils).

On the microgrid level controllable component is the battery system with whose charging or discharging the overall electricity exchange profile between the building and the grid can be modified. Figure 2.10 shows the operation of the battery system for the conventional control and for the 3Smart operation case.

For the case of conventional control (blue line in Figure 2.10), the algorithm applied corresponds to the usual way of closed commercial battery storage systems operation which is actually flattening the energy exchange profile, in order to minimize the peak power payments.

When operated with 3Smart, the microgrid level also tries to exploit the demand response opportunities, but the battery degradation price is such that it does not pay off for the building, and thus the building achieved flexibility using only HVAC.

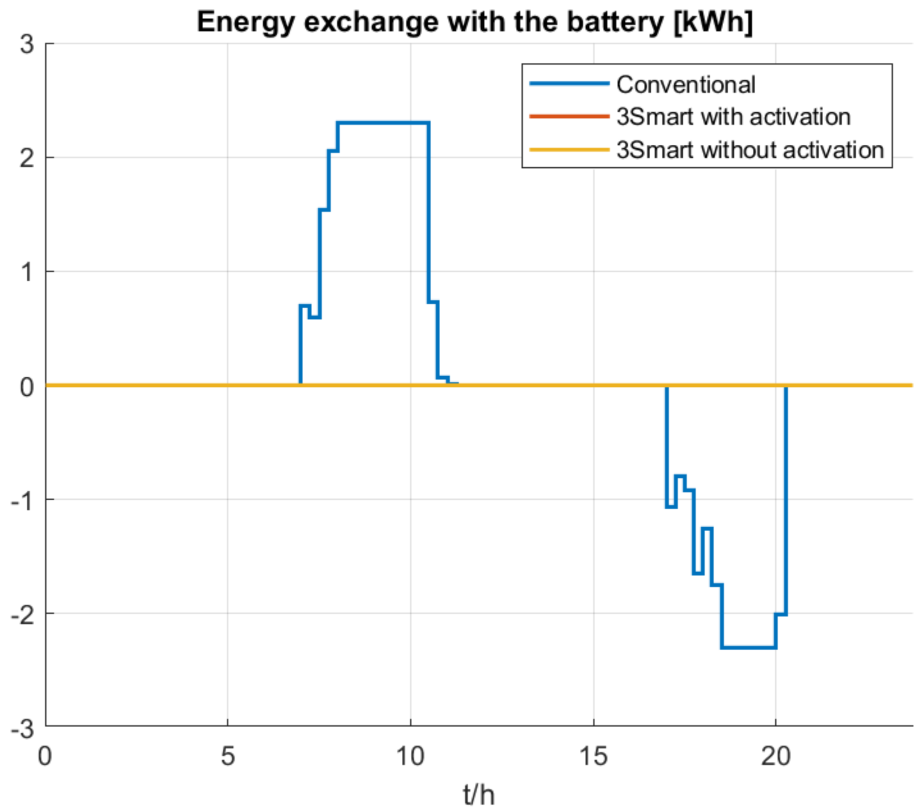

Figure 2.10. Battery system energy exchange

The overall electricity exchange profile with the grid is given in Figure 2.11. Significantly lower electricity consumption comes dominantly from more efficient cooling with a higher supply temperature. Also intensive cooling in the morning with favourable COP leads to smaller needs for cooling in the middle of the day.

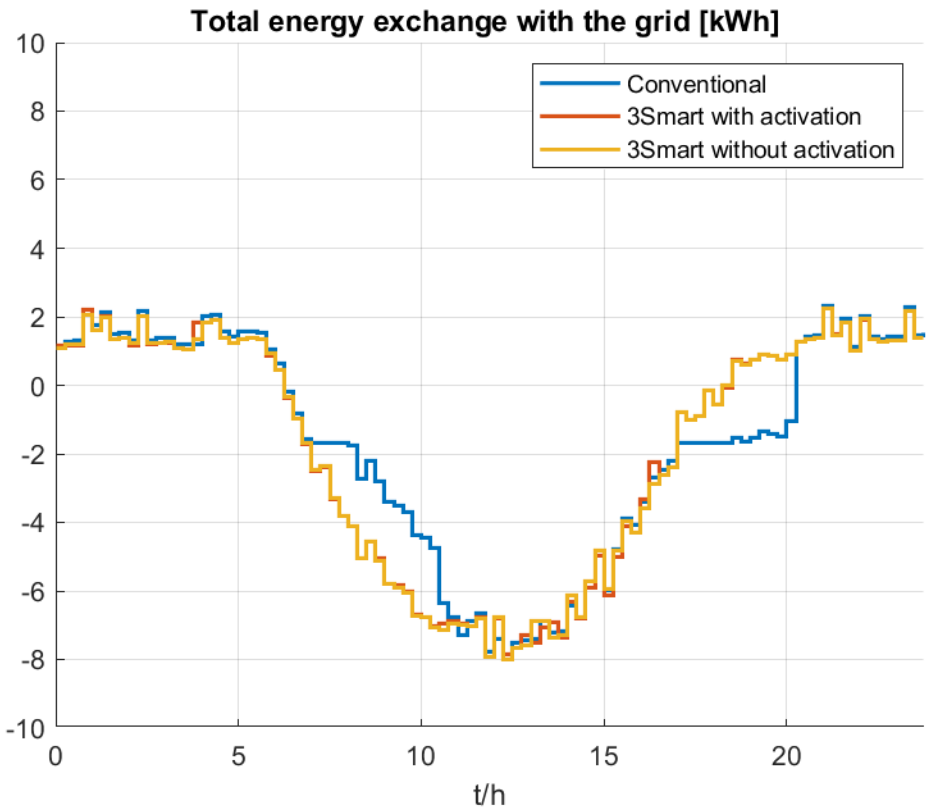

Figure 2.11. Electricity exchange with the grid.

The flexibilities offered by the building for specific flexibility intervals are shown in Figure 2.12.

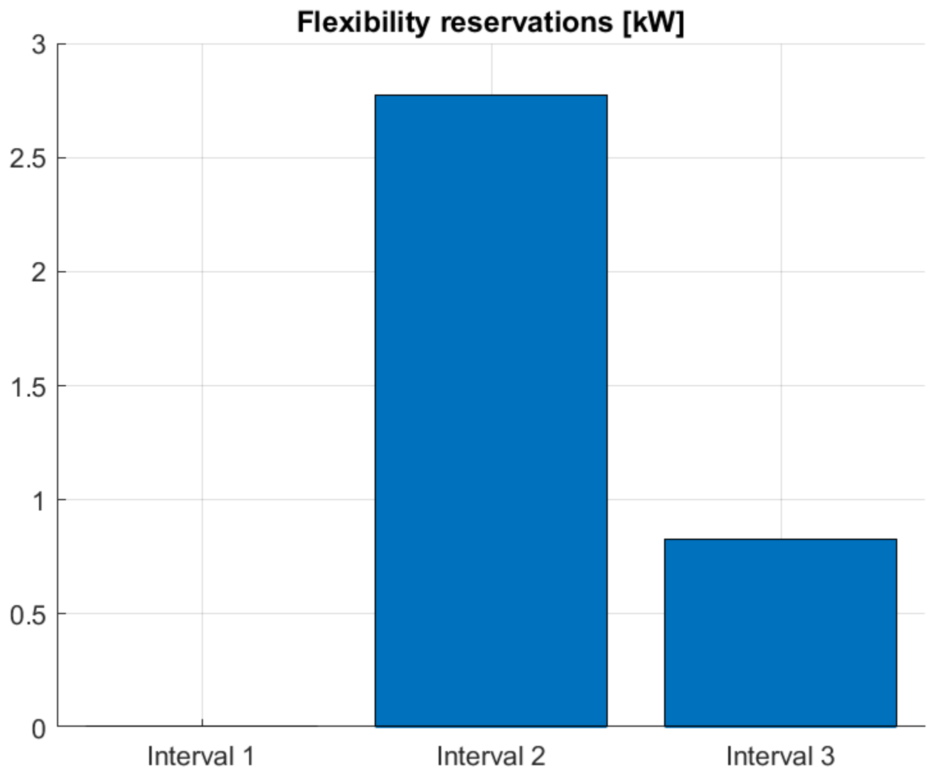

Figure 2.12. Electricity exchange with the grid.

The overall operational costs of the building for the sunny workday in July are provided in Figure 2.13: 1.14 EUR for conventional control, and -11.61 EUR for 3Smart control with activation and -11.57 EUR with activation. This means that the average daily gain of using the 3Smart system roughly amounts at 12 EUR.

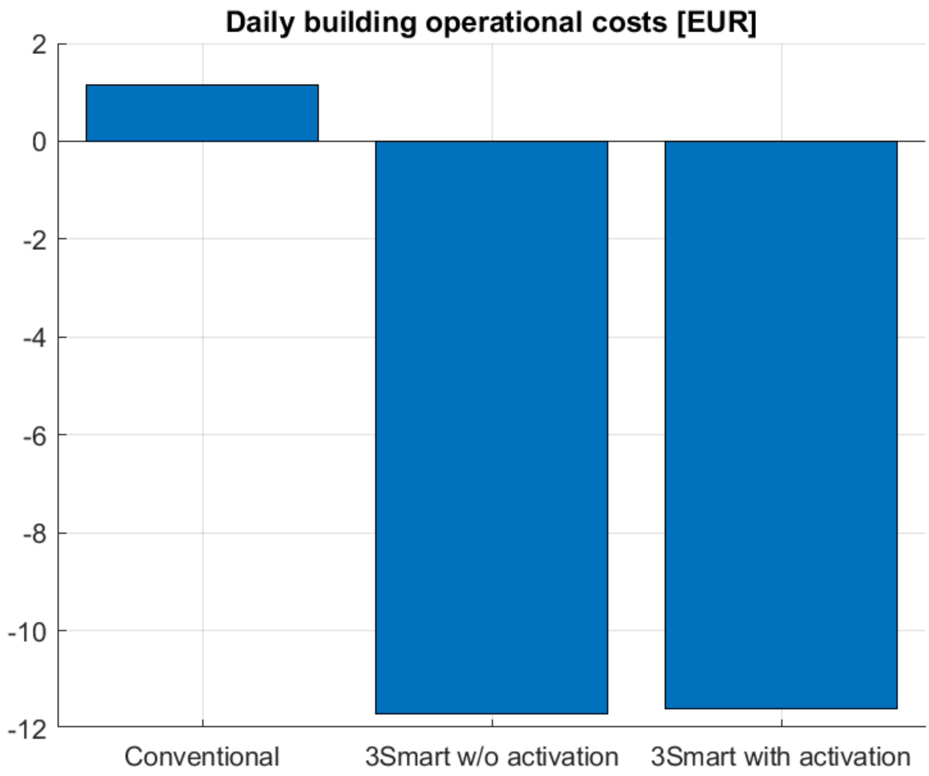

Figure 2.13. Overall building operational costs for the sunny workday in July.

2.3 Grid-side and boundary conditions for the building operation – heating season

The explanation of the operational logs is started by presenting the conditions provided by the grid for a sunny workday in November.

The needed flexibility time window for the grid within the analysed day is as follows:

- 8:30-8:45;
- 9:15-12:15;
- 13:00-21:00.

The pricing conditions computed by performing the calculations by long-term grid-side modules are as follows:

- reservation price: 0.0021 EUR/kW/15 min;
- activation price: 0.0084 EUR/kWh;
- penalty price: 0.0168 EUR/kWh.

The expected day-ahead electricity pricing is shown in Figure 2.14.

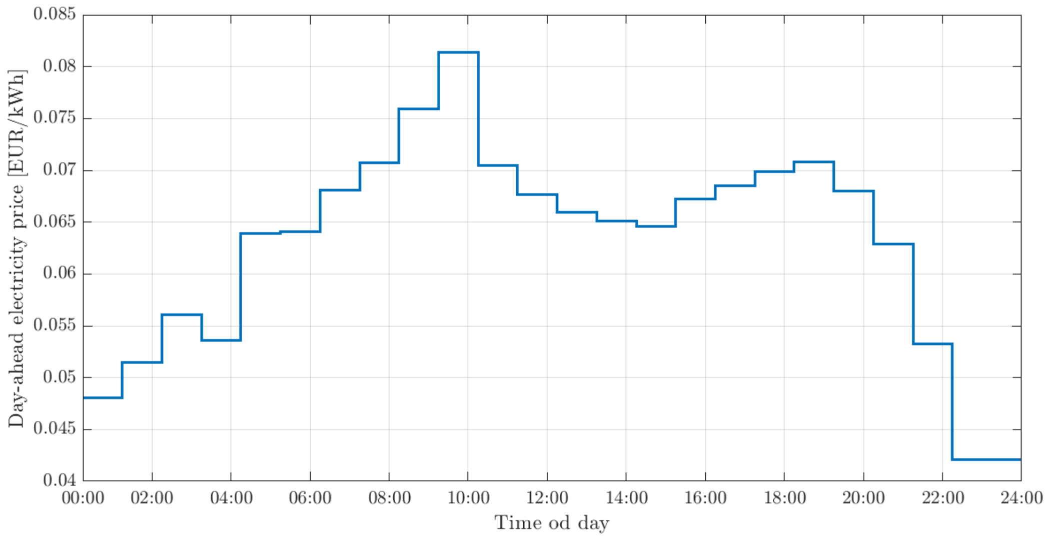

Figure 2.14. Day-ahead electricity pricing for a sunny workday in November.

Additional parameters taken into account are consisted of the relevant meteorological conditions, namely outdoor air temperature profile (shown in Figure 2.15) and direct and diffuse solar irradiance profiles (shown in Figure 2.16), as well as the non-controllable consumptions on the HVAC level (thermal energy consumption profile shown in Figure 2.17) and the microgrid level (electrical energy consumption profile shown in Figure 2.18).

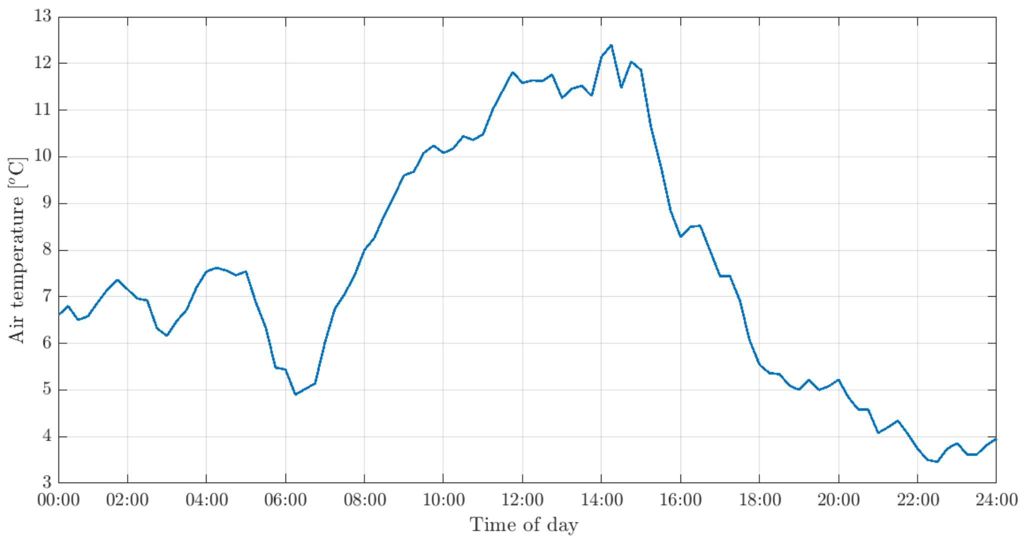

Figure 2.15. Outdoor air temperature for a sunny day in November.

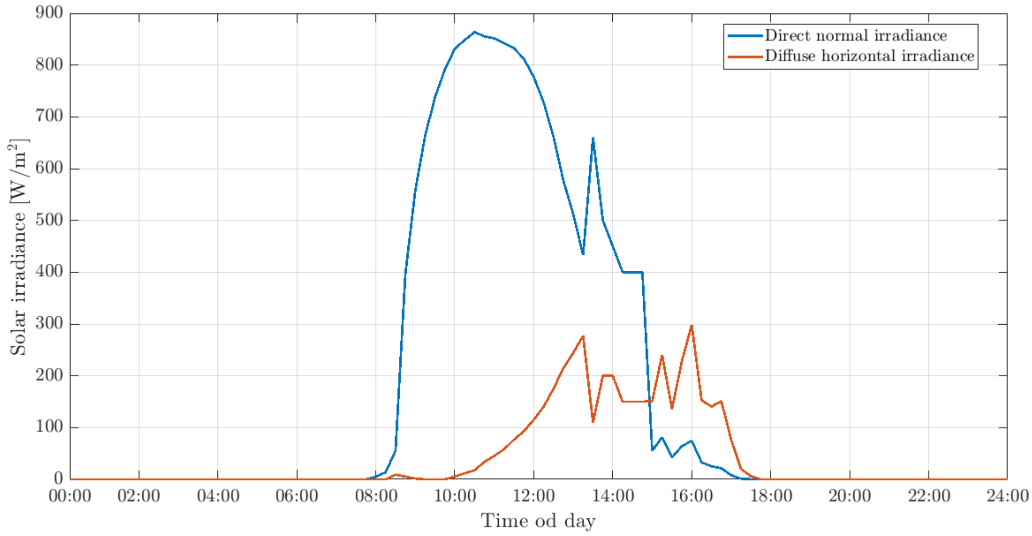

Figure 2.16. Direct (normal) and diffuse (horizontal) solar irradiance for a sunny day in November.

The non-controllable thermal energy consumption on the HVAC level (Figure 2.16) accounts for the consumption of air handling units which are not under 3Smart controls. The non-controllable electrical energy consumption on the microgrid level (Figure 2.17) is consisted of the energy consumption of the office lighting, computers and other equipment which does not belong to the controllable parts of the indoor climate system. Non-controllable electrical energy consumption also includes the PV system power production which is for presentation purposes shown separately.

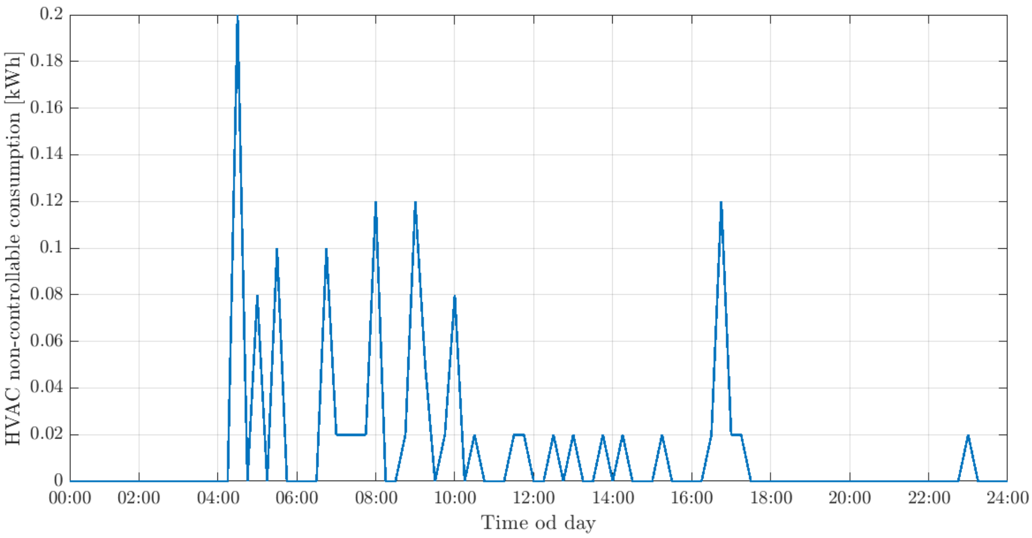

Figure 2.17. Non-controllable consumption of thermal energy on the HVAC level, for a sunny workday in November.

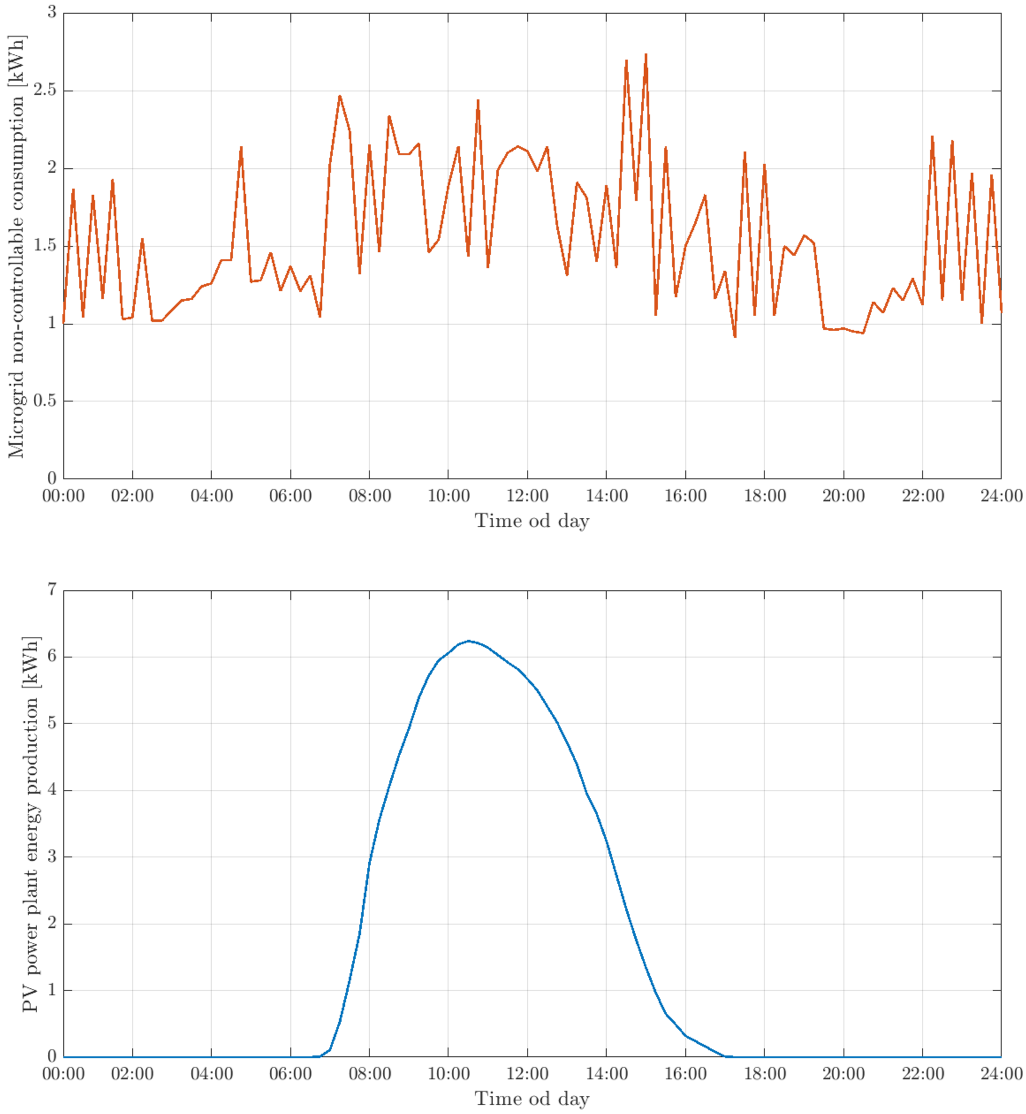

Figure 2.18. Non-controllable electrical energy consumption on the microgrid level, for a sunny workday in November (upper), and PV system power production (lower).

2.4 The optimized building operation – heating season

The presentation of the optimized building behaviour will be given by passing through different levels of the 3Smart system and analysing the optimized behaviours computed. For each level three responses are given corresponding to the three different modes of operation:

- conventional control;
- 3Smart system operation when flexibility is not called (or, without activation);
- 3Smart system operation when flexibility is called (or, with activation).

First the responses on the zone level are analysed. In conventional control on the zone level we consider that in each zone exists a simple hysteresis controller that switches progressively the fan coils fan speeds to higher when the temperature of the room falls more and more below the set point and vice versa when the opposite is the case. This way of operation is actually the state-of-the-art conventional control algorithm for rooms temperature regulation in heating. The lowest fan speed switches on when the reference temperature, set in this analysis to 24°C, is surpassed below by 0.5°C. Conventional control on the zone level is leaned also to conventional control on higher levels, i.e. meaning that for the conventional control response on the zone level the heating medium is prepared by following the conventional control algorithm on the central HVAC level. In Figure 2.18. one may see a typical temperature profile of one of the 24 zones of the EPHZHB building. With conventional control (blue line) the air temperature in the zone is kept within [24.5,25.5]°C during the operating hours. Heating is available during the entire day, but the temperature is required to be within the comfort limits only within the occupancy periods, i.e. between 06:00 and 20:00.

The 3Smart operation when flexibility is called is the optimized building response exhibited to obtain maximum power consumption reduction from the declared consumption profile exactly in the flexibility intervals. One may see in Figure 2.19 that the system overheats the space before the flexibility interval such that in them the heating system can remain as silent as possible, in extreme case completely switched off, to give the highest consumption difference compared to the declared consumption profile. So, in this scenario the zone is kept on 25.5°C which is the higher edge of the flexibility interval such that when the flexibility interval occurs the zone starts to cool down as the heating is reduced to also reduce the consumption according to the flexibility request. In order to well prepare for provision of flexibility, the building is pre-heated during the night such that also its internal states (walls, furniture) are heated up to give then the possibility for the building to slowly cool down almost during the entire flexibility interval and that the heating needs and fan coil fan usage are reduced as much as possible. Thermal energy request, for the room whose temperature response is given in Figure 2.19, is provided in Figure 2.20.

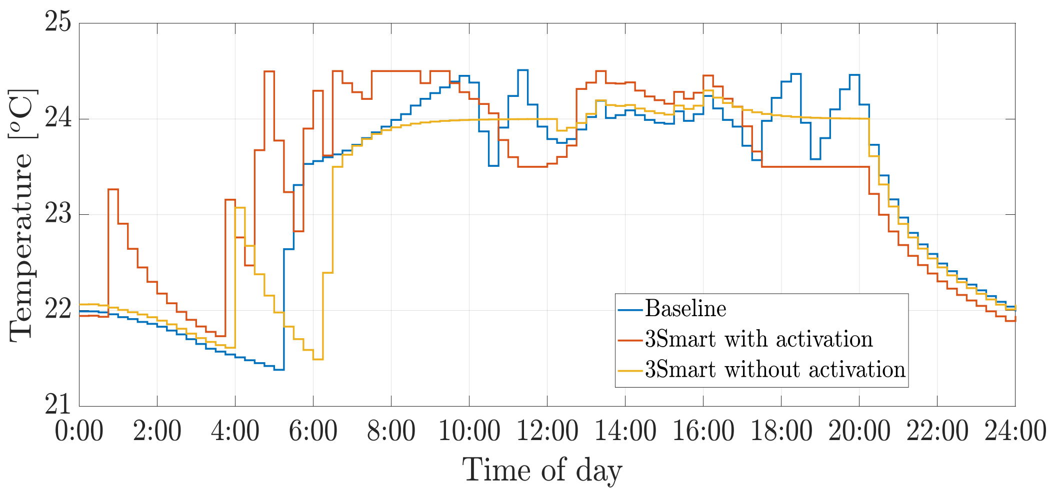

Figure 2.19. A typical response of temperature for a room in EPHZHB building within the analysed day

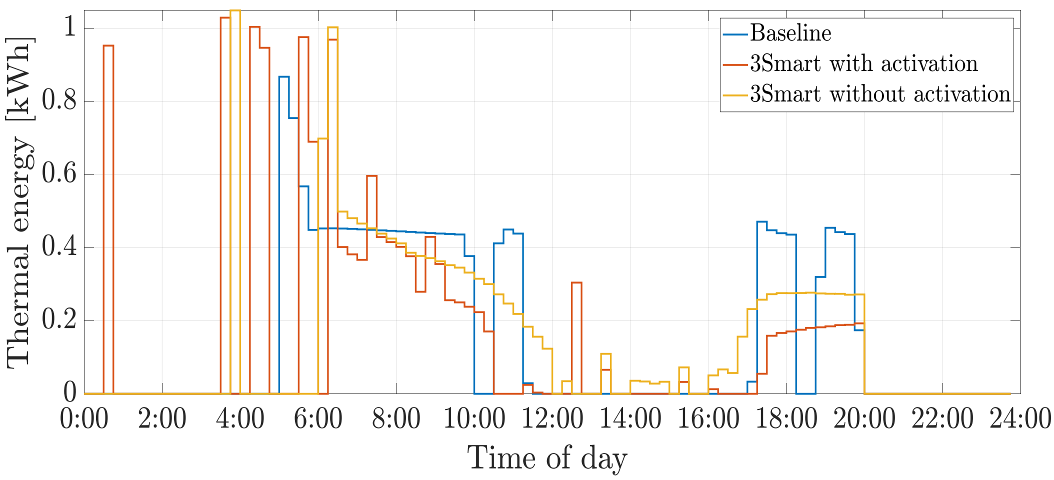

Figure 2.20. Thermal energy exerted to air of the considered room in EPHZHB building within the analysed day.

Figure 2.21 shows the cumulated thermal energy needs of all 24 controllable zones within the EPHZHB building.

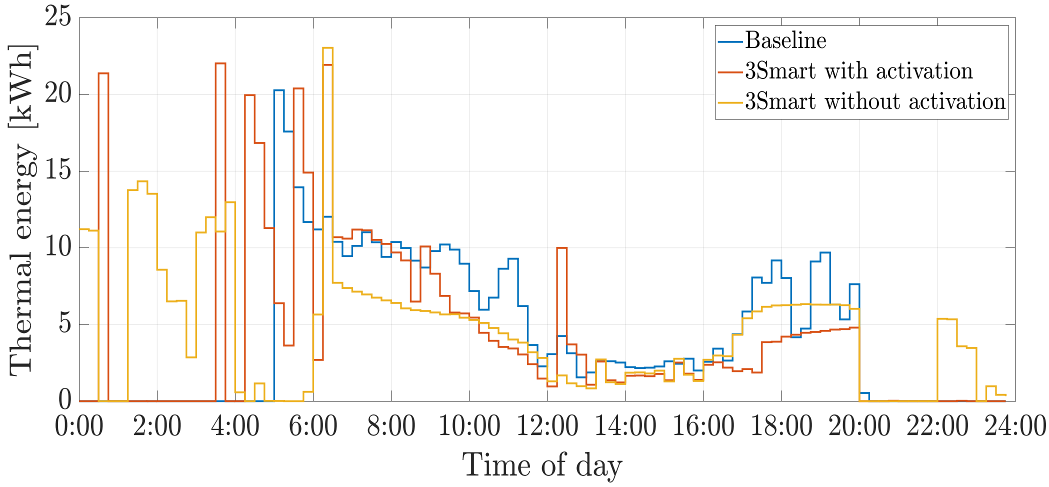

Figure 2.21. Overall heating energy needs for all the zones (sum of energies that should be exerted in zones air).

The central HVAC system level in the heating season on EPHZHB building decides on the combined engagement of the heat pump and the heating block in order to set proper temperature profile for the buffer tank. Baseline in this case is fixed to 45°C. The exhibited responses are shown in Figure 2.22 for the supply medium (buffer tank building output) temperature and in Figure 2.23 for the actuation of the heat pump and the heating block. The heat tank output is through the main supply duct connected with the thermal loads in the controlled zones. In the activation scenario is the medium temperature of the heat tank output kept at higher values in the flexibility intervals in order to minimise the cumulative electricity consumption on the fan coil units. In the scenario without the activation is the supply medium temperature kept at the values that minimises the cost of HVAC system operation while adhering to the imposed limits of zone comfort and system constraints.

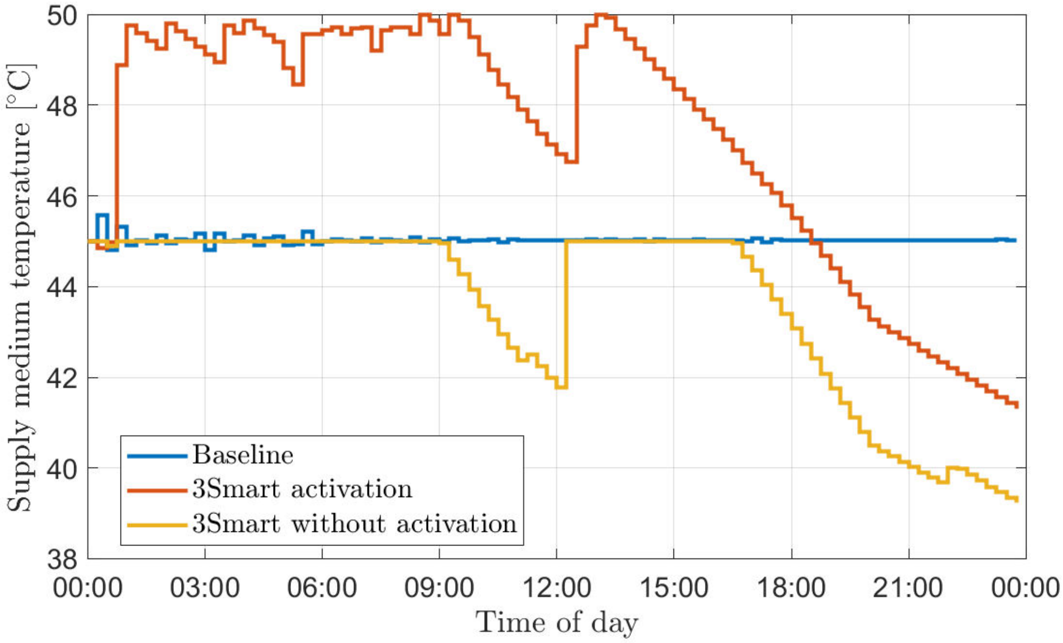

Figure 2.22. HVAC supply medium temperature reference.

The supply medium temperature of the heat pump (upper subfigure in Fig. 2.23) resembles the profile of the heat tank medium outlet temperature. The higher is the difference of the heat pump supply temperature and the heat tank medium outlet temperature the higher is the electrical consumption of the heat pump. The heating block actuation profile (lower subfigure of Fig. 2.23) in the activation scenario has peaks in the time instants one step ahead of the activation intervals. In that way is the thermal energy accumulated in the heat tank additionally increased which allows the lower electrical energy consumption in the activation interval. In the case of 3Smart operation without the activation the heat pump is predominantly employed, since the heat tank has better energy efficiency. The heating block is activated in 3:00, which is the consequence of anticipation of the day ahead electrical energy price.

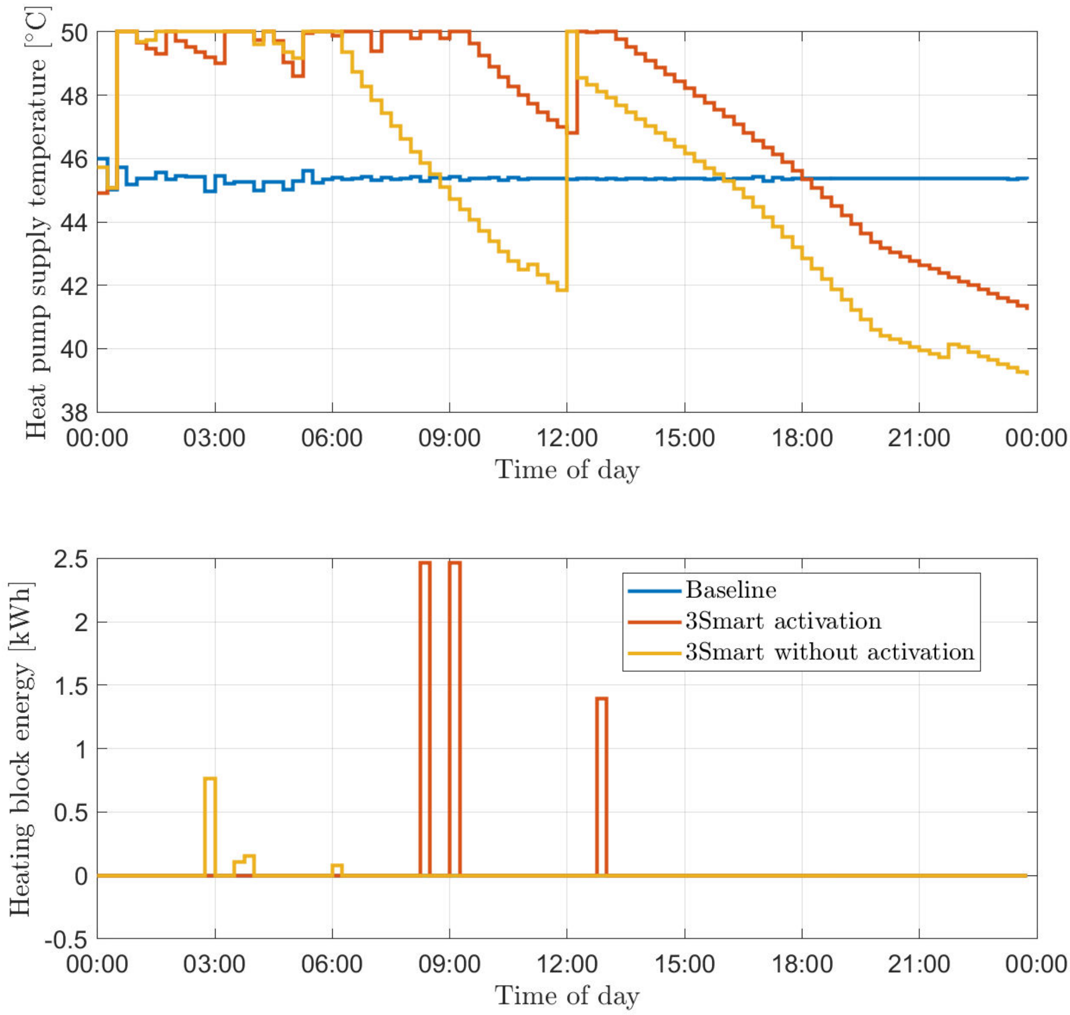

Figure 2.23. HVAC actuation profile of the heat pump and of the heating block.

The overall exhibited electricity consumption profile on the central HVAC system level is shown in Figure 2.24. The 3Smart operation shows greatly reduced electrical energy consumption compared to the baseline. One may see that in case of activation the electricity consumption is significantly reduced, at the cost of higher electricity and thermal energy usage in the early morning.

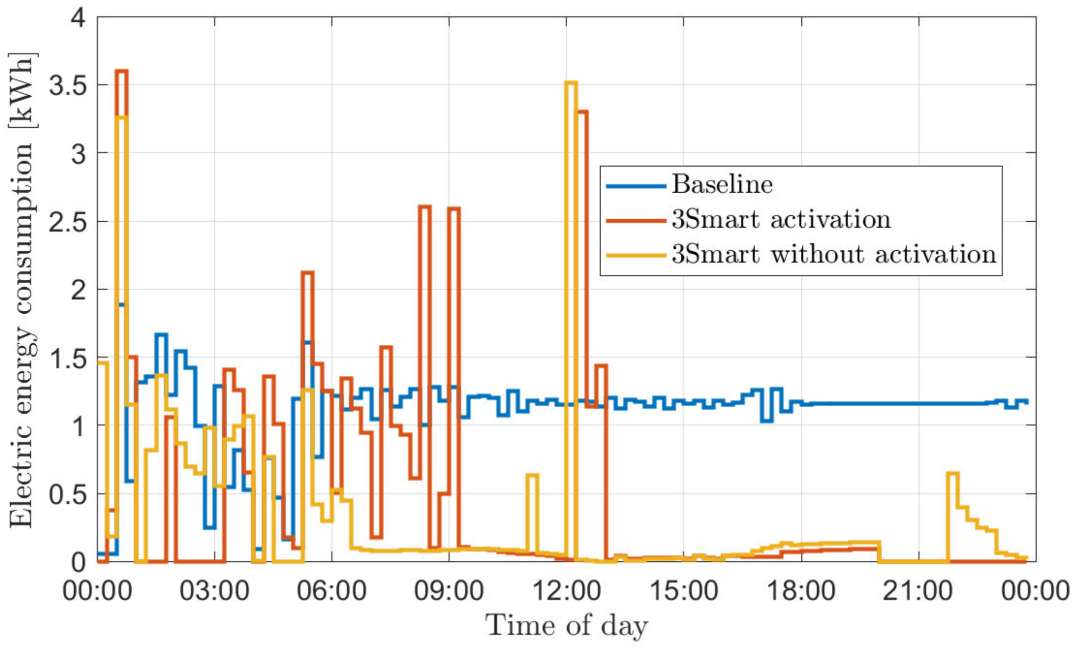

Figure 2.24. HVAC electric energy consumption.

On the microgrid level the battery system is practically not actuated because of high battery degradation cost and low flexibility prices. In the case of conventional control the battery system is used to flatten the electricity demand, see Figure 2.25.

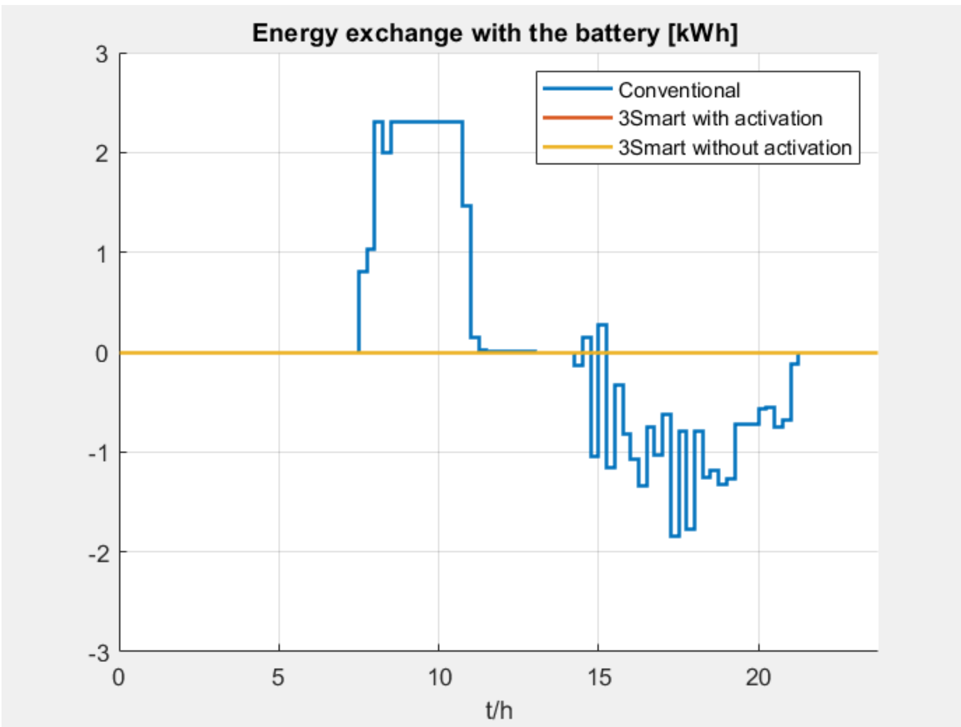

Figure 2.25. Energy exchange with the battery system.

The form of the overall electricity exchange with the grid in the three mentioned cases – conventional control, 3Smart without activation and 3Smart with activation – is shown in Figure 2.26. One may spot that electricity exchange profiles for activation and without activation are the same. Not flexibility offering is consequence of too little flexibility price. It is smaller than intraday cost so there is no benefit in deviating from nominal exchange profile. This also actually means that on the lower levels the system will always react with the response attributed to 3Smart without activation.

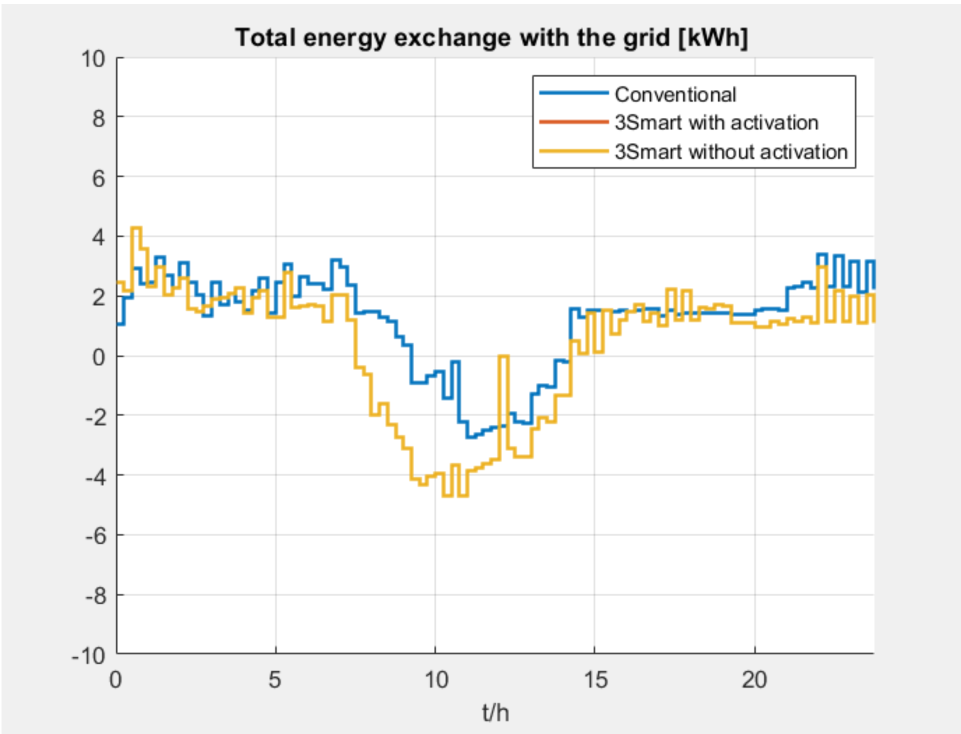

Figure 2.26. Total energy exchange with the grid.

The comparative economical performance assessment of the building operation is provided in Table 2.1. The total daily savings in heating roughly amount to 14 EUR (63,7%).

Table 2.1. Costs comparison for a sunny November workday.

	Conventional control	**MPC – w/o activation**	**MPC – with activation**
Total (electricity + operational costs)	22.57 EUR	8.19 EUR	8.19 EUR

Bibliography

[1] D7.4.2 Integrated planned energy management modules on all the buildings and in the grid for the Bosnia and Herzegovinian pilot, 3Smart deliverable, December 2019.

Output Quality Report

Output title: T5.1 Pilot-deployed modular energy management platform	
Type of output:	☐ Documented learning interaction ☐ Strategy/ Action Plan ☐ Tool ☑ Pilot action
Contribution to PO indicator:	**P25 Number of pilot actions to improve energy security and energy efficiency developed and/or implemented**

Summary of the output (max. 1500 characters)
The output shows how the developed 3Smart tool is applied to 5 diverse pilot sites in 5 countries of the Danube region (HR, SI, AT, BA, HU). It is completed with showing performance of the 3Smart modules on different pilots. Also in this revised output are added now operational logs and seasonal analyses from all pilots. The Croatian pilot consists of two buildings in Zagreb, one of UNIZGFER and another of HEP, and of the pilot electricity distribution grid of HEP around these two buildings. The Slovenian pilot consists of a Primary school building and Sports centre of IDRIJA, with the electricity grid of ElektroP around it. The Austrian pilot consists of two buildings of the municipality Strem, which are the primary school and the retirement and care centre. In addition, the electricity distribution grid of EnergyG is also part of the pilot. Bosnia and Herzegovina pilot consists of a business building in property of EPHZHB in Tomislavgrad and of the pilot electricity distribution grid of EPHZHB around the building. The Hungarian pilot consists of a buildings complex of EON in Debrecen and of the pilot electricity distribution grid of EON around the building. The five individual reports show how the 3Smart tool is organized on pilots, how it operates the buildings and the grids, and show also the seasonal analysis of operation for characteristic days with assessed economical benefits used in Output T4.2 for performing cost-benefit analyses of pilots installations exactly regarding the part of adding-up the 3Smart platform to the automation systems.

Added value
The diverse pilots used for testing and validating the operation of the 3Smart tool have shown that it is adaptable to buildings and grids of different configurations. In zones buildings are equipped either with fan coils or radiators or with floor heating/cooling, in central HVAC level they use heat pumps or heat exchangers and on the level of major building energy flows control (microgrid level) versatile systems are found – batteries, controllable loads, controllable photovoltaic units, combined heat-power units, but even none. In all cases interaction between building levels and with the grid-side modules is established where the grids are also with different configurations and operational challenges. The testing is performed off-line and on-line. Off-line testing reveals the optimal planned daily operation of the building and grid, and the building is through it able to decide how much flexibility power it can offer to the grid. In on-line operation it is validated whether the designed modules can process well the data on-line obtained from the building. Important added value is that all pilots have been explored with a seasonal analysis procedure to obtain their best possible reactions during characteristic days in heating and cooling season, with enforced day-to-day repeatable behaviour. Within this analysis it is also determined how much flexibility it pays off to the building to provide towards the grid in the given pricing conditions. These analyses give full insight how different subsystems of a building cooperate together to yield an economical optimum for building operation while ensuring or improving comfort for their occupants compared to conventional control. All responses obtained are compared for exactly the same scenarios also with state-of-the-art conventional controls performance such that the benefit of 3Smart operation on the site over conventional controls can be assessed and used for cost-benefit analyses for pilots (within 3Smart these are provided as Output T4.2).
Applicability and replicability
This output shows how the 3Smart platform can be organized for a particular configuration of buildings and grids and how it can be tested for economical viability in preliminary studies for performing the investment for 3Smart tool installation, and then how it is commissioned and on-line operated. The results of the project and 3smart platform can be interesting to all stakeholders and other parties in all 5 pilots. In the future, it is expected that proper responses of energy consumption to the demands of grid operators will be rewarded through different demand response schemes, and with time that such operation will also become a legal obligation of the buildings and other end-consumers (like today basic automation systems have become). As demand response is practically impossible without employing predictive control and optimizations, systems like 3Smart will in a longer run become a necessity. All plans and installations concepts are applicable in all countries across the Danube region, and further.
Suggestions for improvement, if applicable
The results obtained on all sites show possibility of significant costs reduction through smart energy management of buildings and through participation in demand response service needed by the grid. It is indeed interesting to see how the optimization modules exploit different dynamic features and lags existing in rooms, their heating/cooling elements, central HVAC system and microgrid to yield optimal behaviour in terms of economical performance while maintaining comfort. It is an interplay of different elements computed automatically, usually far

beyond the reasoning of the most experienced building operators. Interesting is also to see the procedures of identifying different simple models of elements in buildings from basic physics, mathematical modelling, measurements and manufacturers datasheets that capture their major dynamical and energy-related behaviour. They are the key unlocking activities to be able to harness the building in a simplistic way and start performing something in an optimal way for it.

On grid-side it is also interesting and fascinating to see that procedure for determining flexibility prices automatically generates them based on historical load profiles, technical and economical parameters, and how further the buildings can be optimally engaged as flexibility providers to minimize losses and keep grid operation constraints respected.

For sure the developed 3Smart modules, especially the complex ones employing on-line mathematical optimizations, need to be further numerically tested and upgraded to come to the industrial level of reliability and enable massive replication, but a great work is done within 3Smart to start going along this route.

Output Quality Level	☐ Low ☐ Average ☐ Good ☑ Excellent

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Hrpan