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 D7.5.3

Operational logs and their seasonal analysis – Hungarian pilot

Project Acronym	3Smart
Grant Agreement No.	DTP1-502-3.2-3Smart
Funding Scheme	Interreg Danube Transnational Programme
Project Start Date	1 January 2017
Project Duration	36 months
Work Package	7
Task	7.5
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, EON, UNIDEBTTK
Authors (Partners)	Mario Vašak, Anita Martinčević, Nikola Hure, Hrvoje Novak, Danko Marušić, Marko Kovačević, Paula Perović, Tomislav Capuder (UNIZGFER), Arpad Racz, Andras Mucsi (UNIDEBTK), Gabor Peter, Tibor Beni (EON)
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 Hungary. 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 Hungarian 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 Hungarian 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 Hungarian pilot consists of a pilot building of EON in Debrecen and of the pilot electricity distribution grid of EON 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 D7.5.2 [1]. This deliverable concerns the operational logs obtained by operation of the 3Smart modules on the setup of the Hungarian 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 analysed 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 the centrally prepared medium for heating/cooling of zones?
  - When and how much to heat each of the 6 building rooms with electric heaters?
  - How much electricity to produce from the photovoltaic 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 2 the operational logs and seasonal analysis for the EON 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. EON 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 August as a representative for the cooling season operation of the building and sunny workday in January 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 August.

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

- 13:45-16:15.

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

- reservation price: 0.015 EUR/kW/15 min;
- activation price: 0.061 EUR/kWh;
- penalty price: 0.122 EUR/kWh.

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

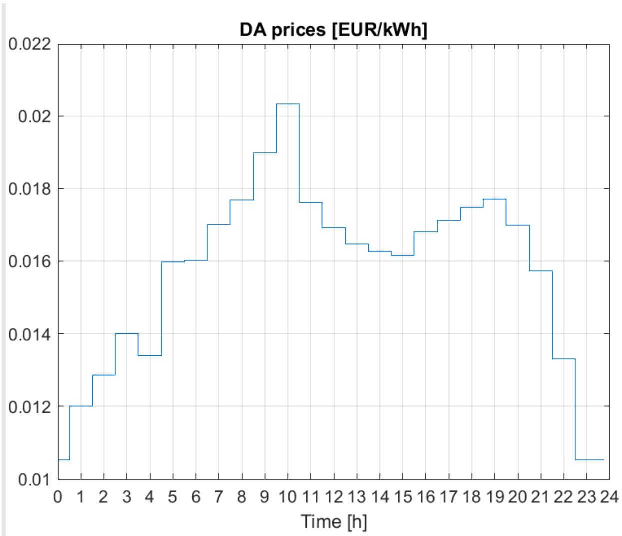

Figure 2.1. Day-ahead electricity pricing for a sunny workday in August.

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 profile, 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). The influence of the direct and diffuse solar irradiances is directly incorporated through the profiles of HVAC and microgrid level non-controllable consumptions as well as through the PV power plant production profile shown later. Since the solar irradiance has no further influence on the building operation, the irradiance profiles are not shown here.

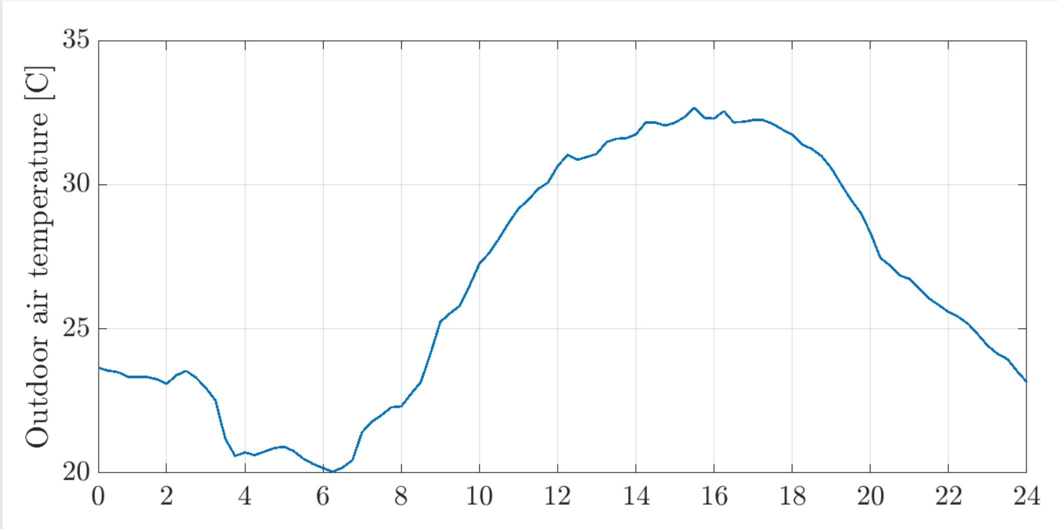

Figure 2.2. Outdoor air temperature for a sunny day in August.

Non-controllable thermal energy consumption on the central HVAC system level accounts for the consumption of rooms in the building that don't have sensing equipment installed and which are not integrated within the 3Smart platform. 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 either to the indoor climate system controllable/monitored by the 3Smart platform (electric heaters on the microgrid level included) or to the photovoltaic system of the building.

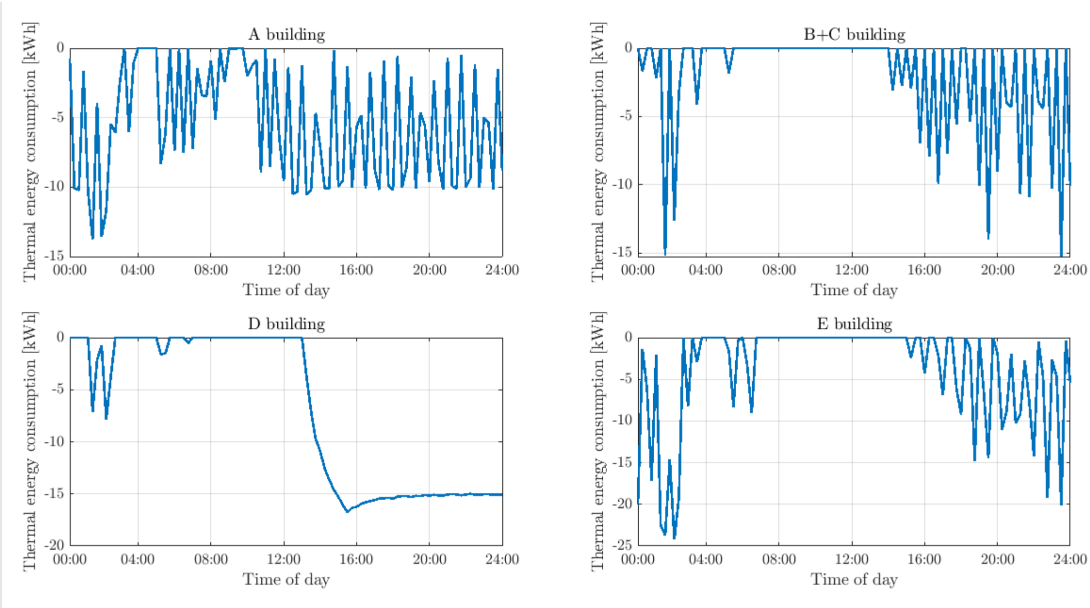

Figure 2.4. Non-controllable thermal consumption on the central HVAC system level, for a sunny workday in August.

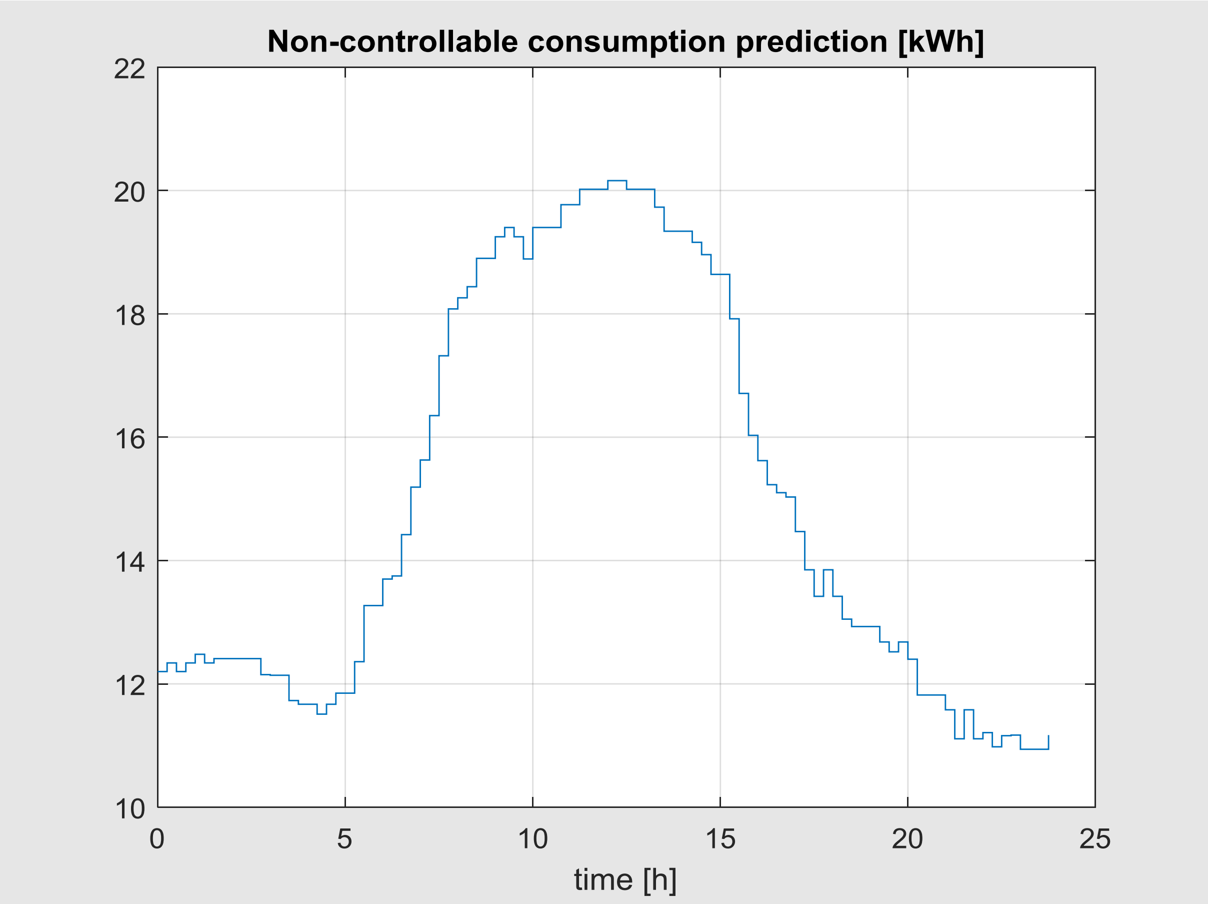

Figure 2.5. Non-controllable electrical energy consumption on the microgrid level, for a sunny workday in August.

2.2 The optimized building operation – cooling 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).

Within the EON building's 3Smart platform instance only the central HVAC system and microgrid level have the control possibility, while on the zone level only the predictions are made regarding energy needed for rooms comfort keeping and the room temperature prediction.

First the predicted responses on the zone level are shown. In Figure 2.6. one may see a typical temperature profile of one of the 104 monitored zones within the EON building complex.

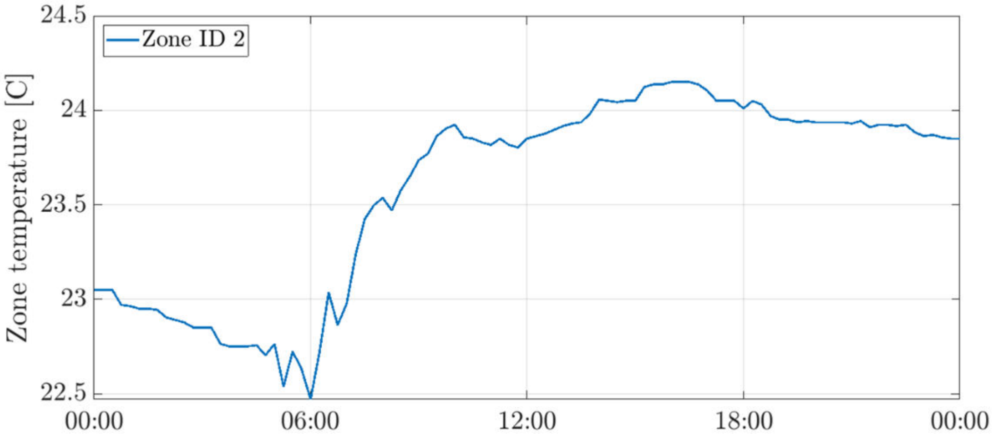

Figure 2.6. A typical response of temperature for a room in EON building with ID 2 within the analysed day.

In Figure 2.7 one may see for the same zone as provided in Figure 2.6 the predicted cooling energies provided from the fan coil to room air.

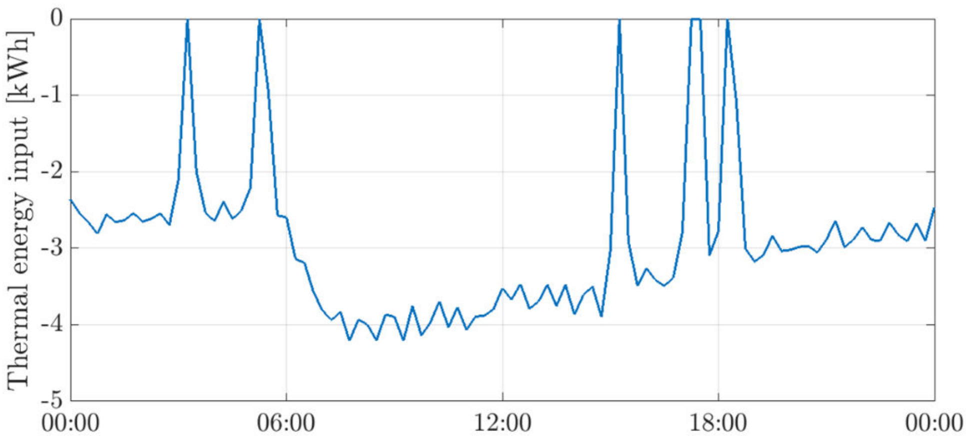

Figure 2.7. Cooling needs for the EON building room with ID 2 within the analysed day.

The EON building complex consists of five buildings – A, B, C, D and E – where the rooms in them are organized to be supplied from 4 different chillers – for A, B+C, D and E. Figure 2.8 shows the overall thermal energy requests predicted on the named 4 cooling circuits within the analysed day.

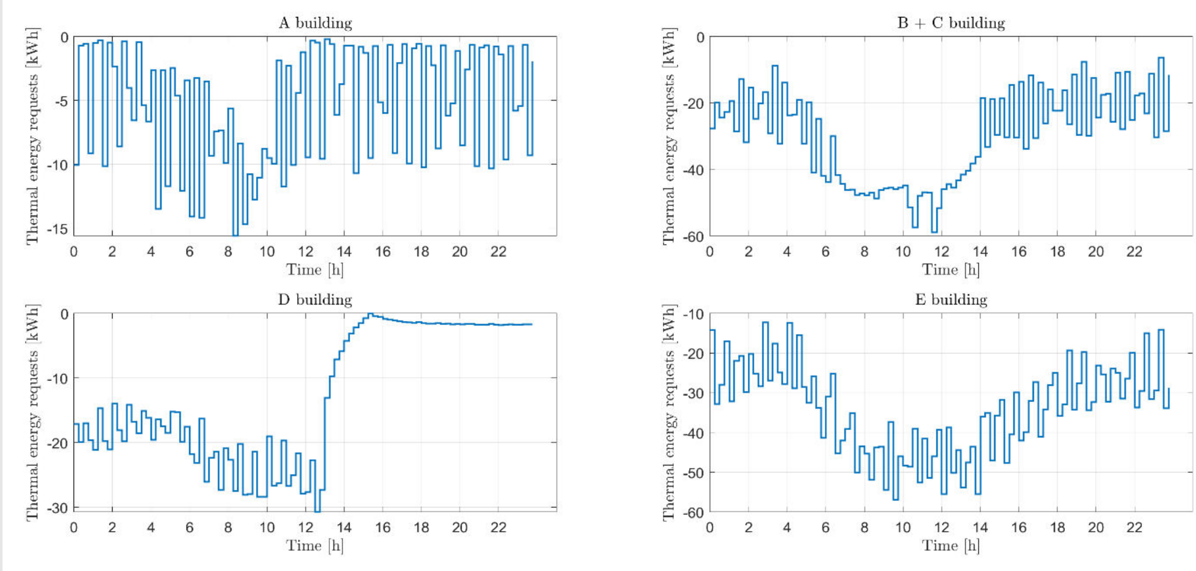

Figure 2.8. Overall cooling energy needs for the four main cooling circuits of the EON building complex.

On the central HVAC level manipulated variable of the system is the temperature of the medium coming out of the chiller and out of the mixing valve. The central HVAC system level computes a separate temperature reference for each of the 4 cooling circuits. In conventional control the chiller is controlled such that the following temperatures are kept in the buffer tank (blue lines on subgraphs in Figure 2.9): 12°C for A building cooling circuit, 12°C in B+C building cooling circuit, 15°C in the morning / 17°C in the afternoon in the D building cooling circuit and 10.5°C in E building cooling circuit. 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 which reduces the consumption of the overall cooling system significantly, especially considering the losses in supply ducts. Also buffer tank is used on EON site which needs to be taken into account.

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. Additionally, these spikes are used for flexibility provision. Figure 2.9 and Figure 2.10 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 2.10 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. Additionally, one may see a difference between the energy consumption profiles for cooling without activation of flexibility and with activation of flexibility. For the case when flexibility is not activated, consumption before flexibility intervals is reduced and pumped up in the flexibility intervals. For the case of activation, it is vice versa, more is consumed before and then consumption maximally decreased in the flexibility interval. In this way the flexibility provision potential of the building is maximized. In Figure 2.10 only the 3Smart planning without activation is shown, as the initial planning of the behaviour with activation provided by the central HVAC level at the end was not selected by the microgrid level as the best central HVAC behaviour for flexibility provision.

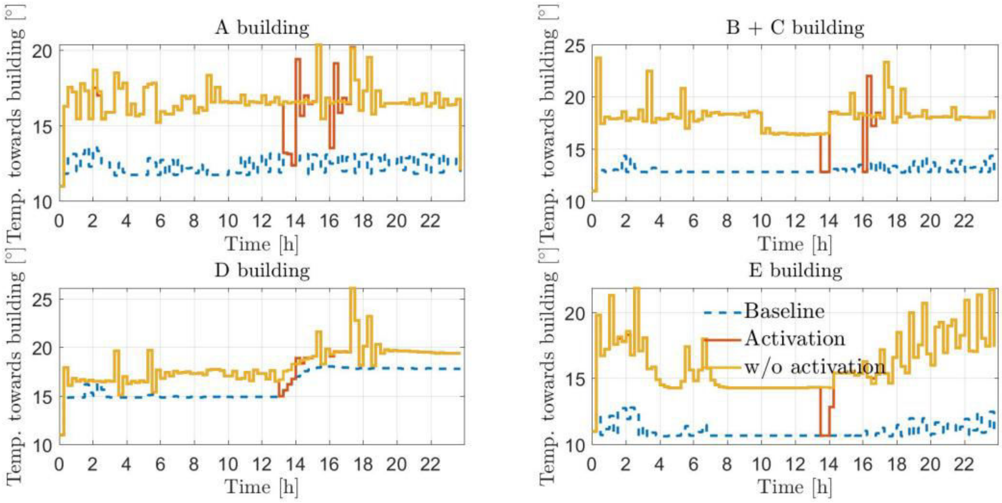

Figure 2.9. Profile of medium temperatures towards the zones (from the buffer tanks of the cooling circuits)

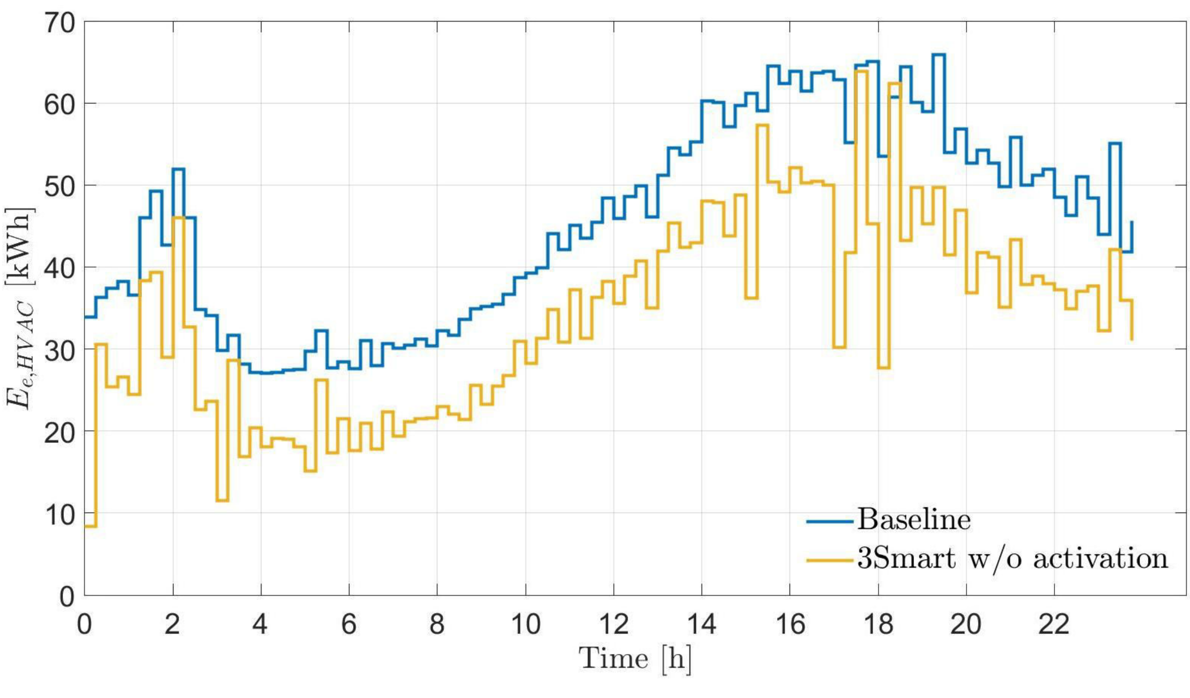

Figure 2.10. Electricity consumption of the central HVAC system (chillers + fans of fan coils of all four cooling circuits).

On the microgrid level controllable components are the electric heaters in six rooms in the cellar and the dimmable PV inverter. Figure 2.11 shows the operation of the PV system for the conventional control and for the 3Smart operation cases, without and with flexibility activation.

For the case of conventional control (blue line in Figure 2.11), the algorithm applied corresponds to the usual way of PV systems operation which is actually maximization of its power output. Rooms with electric heaters are kept within the allowed temperature span by using a simple hysteresis control.

When operated with 3Smart, the microgrid level exploits the demand response opportunities offered by the grid in flexibility intervals and also takes care about the peak pricing of power, and computes the optimal flexibility bid of the building towards the grid for the flexibility interval.

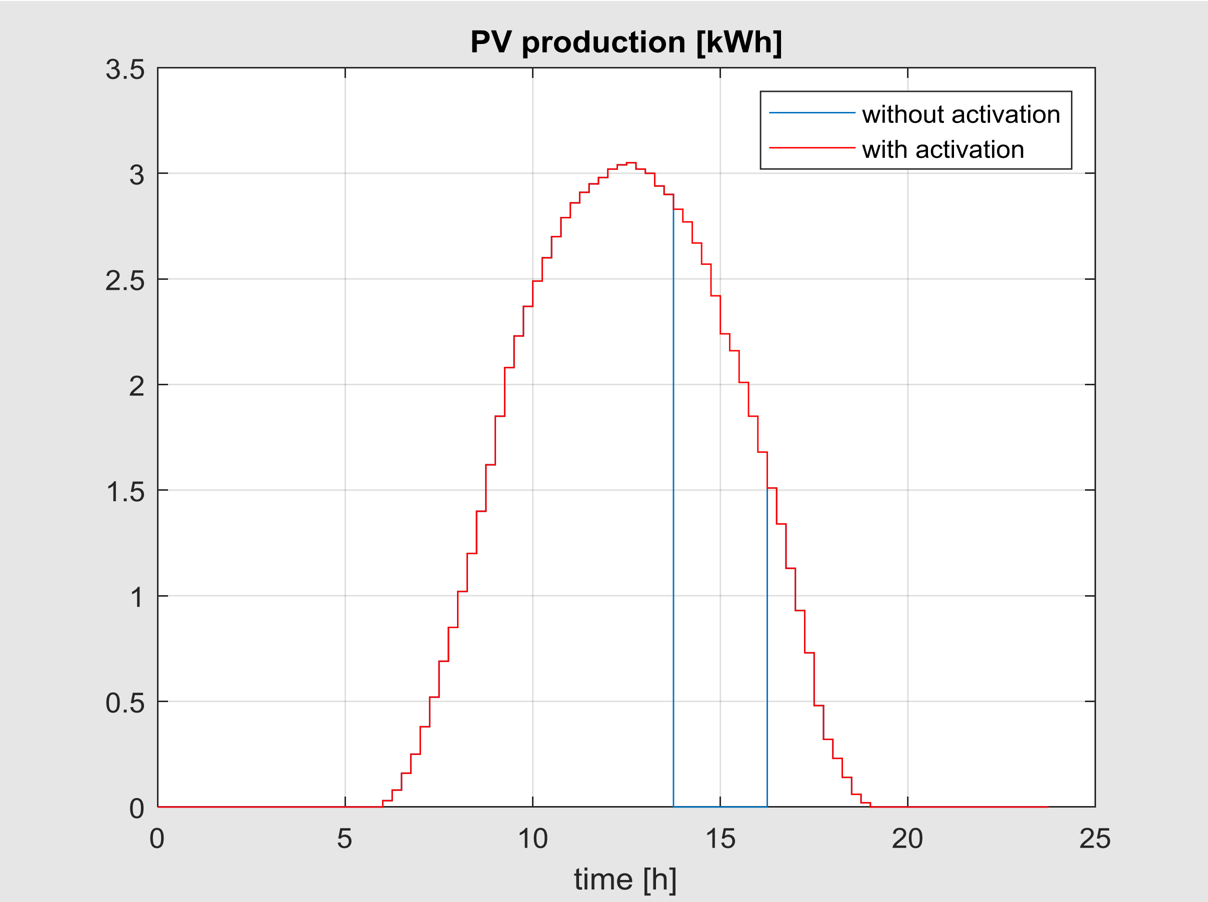

Figure 2.11. PV system power production.

The overall electricity consumption by the electric heaters in six basement rooms is given in Figure 2.12. Significantly lower electricity consumption comes dominantly from more efficient cooling with higher supply temperature that lowers losses in piping. Also one may see the available flexibility amounts as the difference between the 3Smart with activation and 3Smart without activation energy exchange profiles.

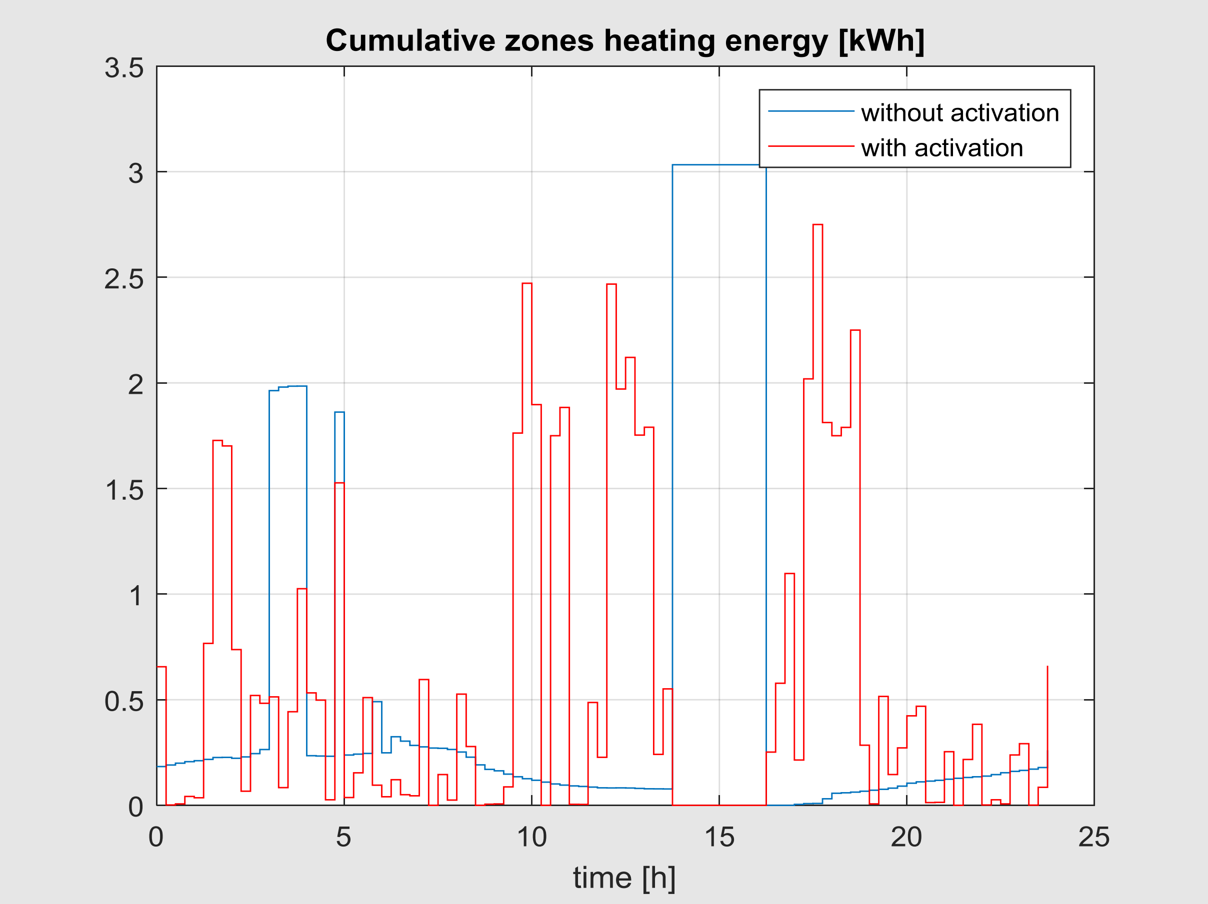

Figure 2.12. Cumulative electric heaters operation in terms of electricity consumed.

The exhibited electricity exchange with the grid is shown in Figure 2.13. One may see the important contribution of the PV system in providing the flexibility potential for the building.

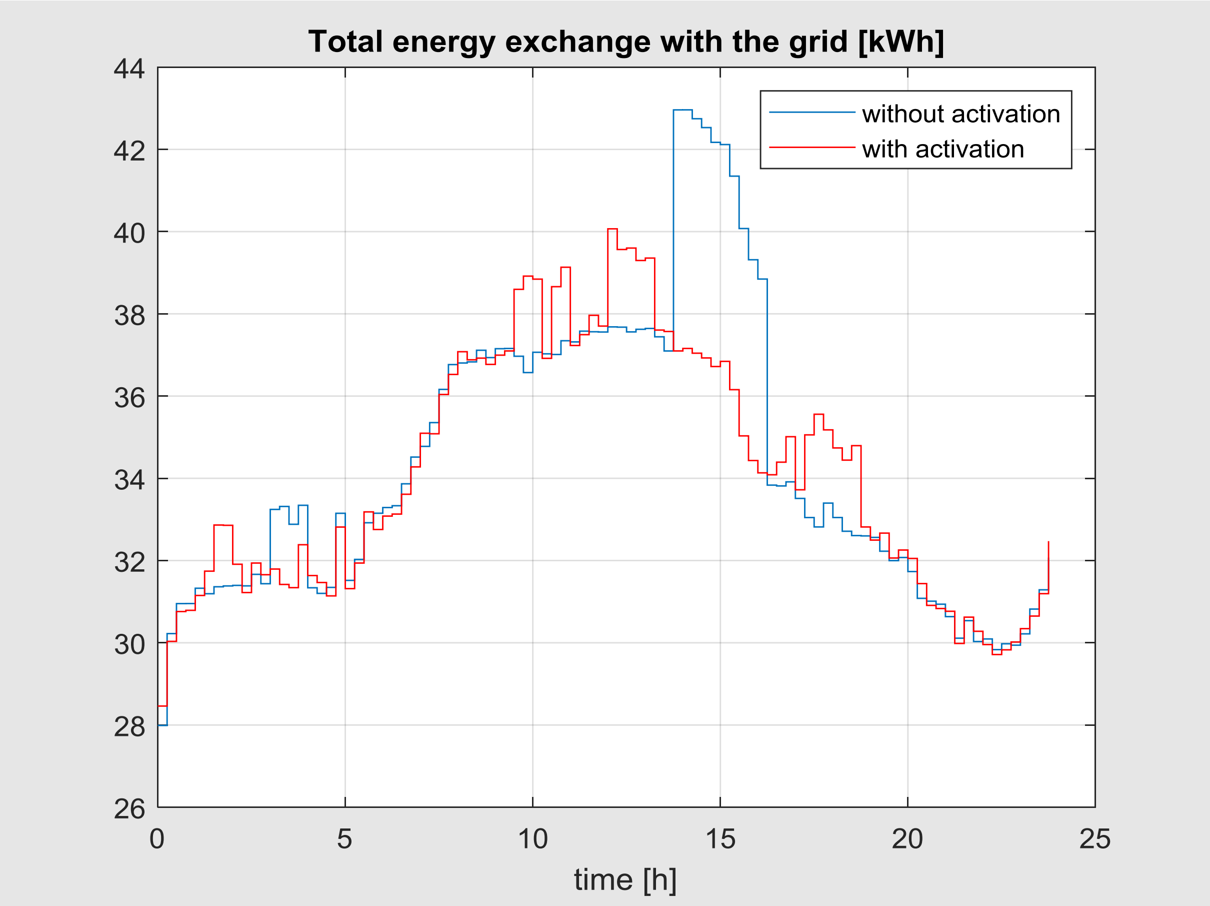

Figure 2.13 Electricity exchange with the grid.

The flexibility offered by the building complex amounts at -22 kW. The overall operational costs of the building for the sunny workday in August, and thus the gains achievable by using 3Smart, are provided in Table 2.1.

Table 2.1. Daily cost comparison between conventional and 3Smart controls.

	Conventional control	3Smart – w/o activation	3Smart – with activation
Total (electricity + operational costs)	229.58 €	186.28 €	174.46 €

The overall benefit of the 3Smart platform in cooling can be estimated by assuming that the activation will happen in 50% of cases. The daily benefit is thus the average between 43.30 EUR (gain without activation) and 55.12 EUR (gain with activation). The average daily benefit in the cooling season is thus estimated and rounded at 49 EUR.

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 January.

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

- 06:30-09:45,
- 12:30-17:00.

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

- reservation price: 0.015 EUR/kW/15 min;
- activation price: 0.061 EUR/kWh;
- penalty price: 0.122 EUR/kWh.

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

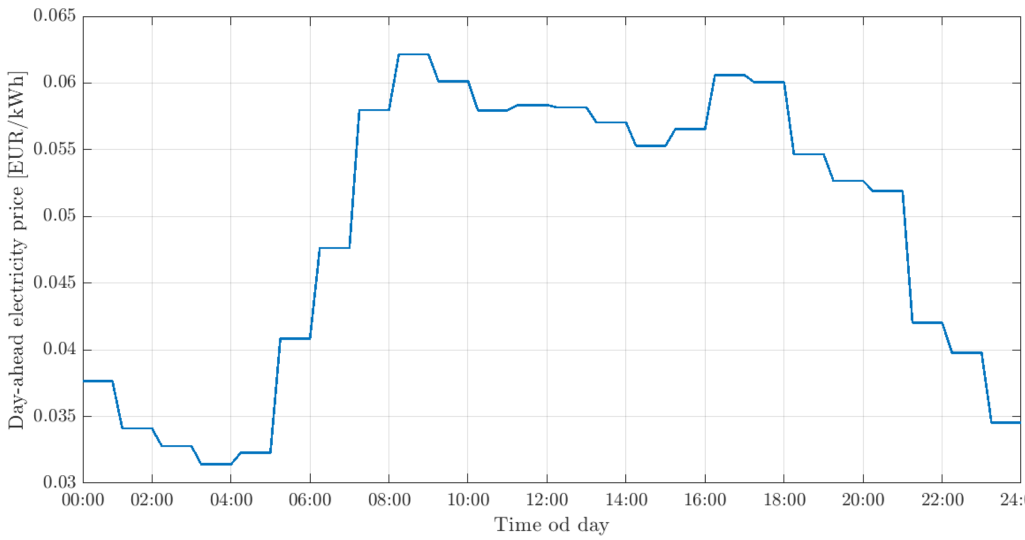

Figure 2.14. Day-ahead electricity pricing for a sunny workday in January.

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, 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). The influence of the direct and diffuse solar irradiances is directly incorporated through the profiles of HVAC and microgrid level non-controllable consumptions as well as through the PV power plant production profile shown later. Since the solar irradiance has no further influence on the building operation, the irradiance profiles are not shown here.

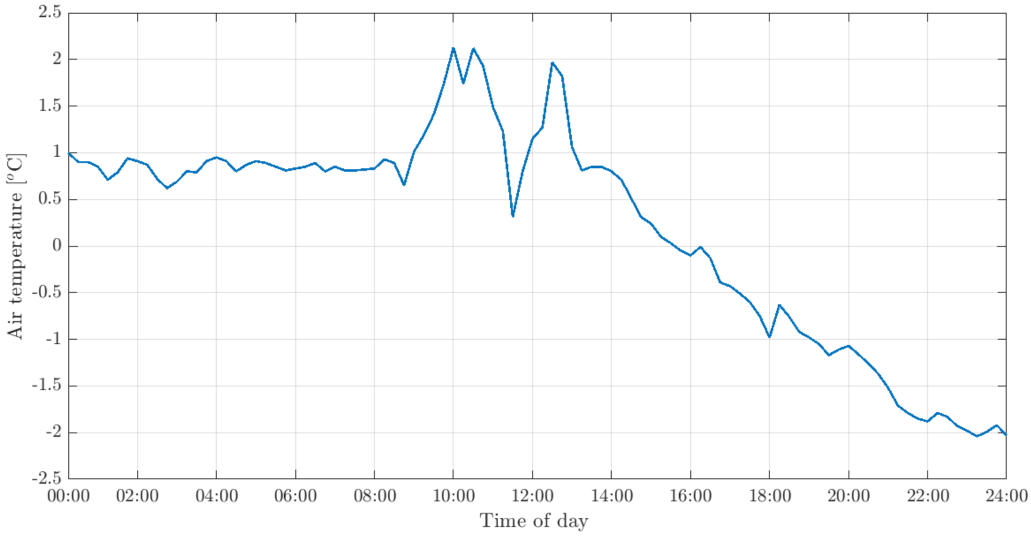

Figure 2.15. Outdoor air temperature for a sunny day in January.

The non-controllable thermal energy consumption on the central HVAC system level (Figure 2.16) accounts for the consumption of rooms that are not monitored with 3Smart. 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.

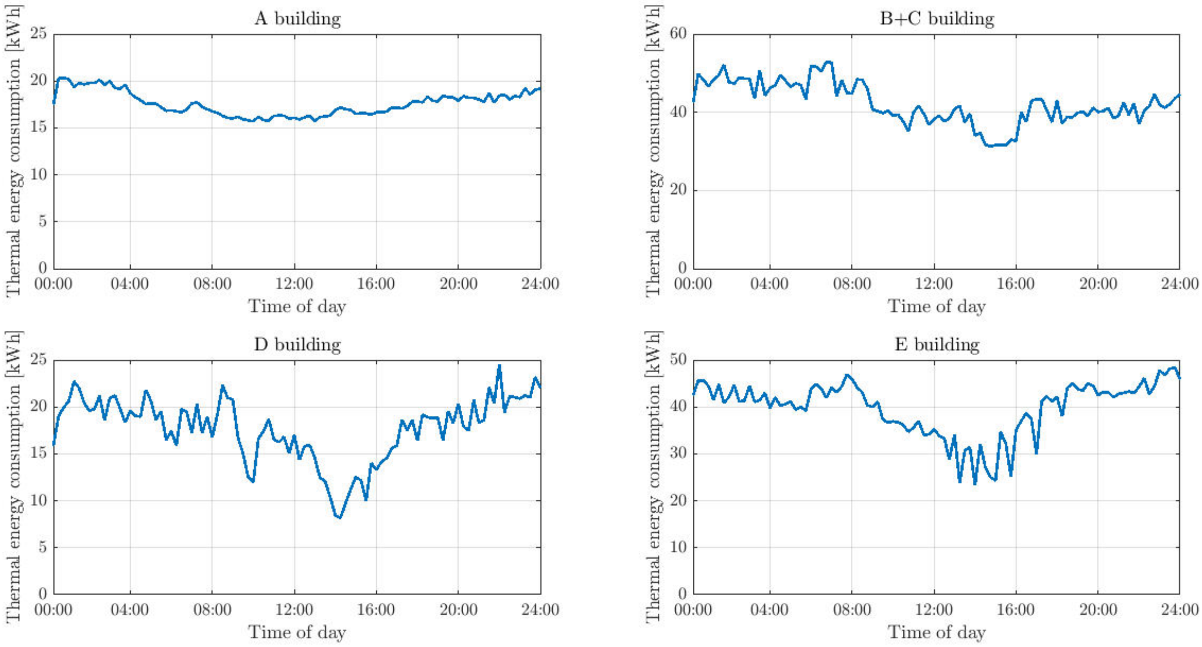

Figure 2.16. Non-controllable consumption of thermal energy on the HVAC level, for a sunny workday in January.

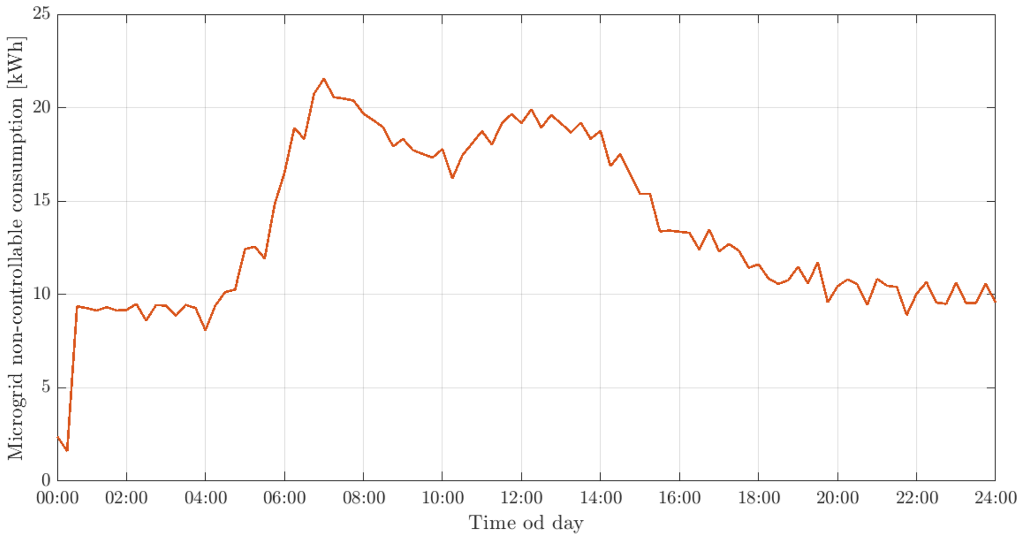

Figure 2.17. Non-controllable electrical energy consumption on the microgrid level, for a sunny workday in January.

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).

Within the EON building's 3Smart platform instance only the central HVAC system and microgrid level have the control possibility, while on the zone level only the predictions are made regarding energy needed for rooms comfort keeping and the room temperature prediction.

First the predicted responses on the zone level are shown. In Figure 2.18 one may see a typical temperature profile of one of the 104 monitored zones within the EON building complex.

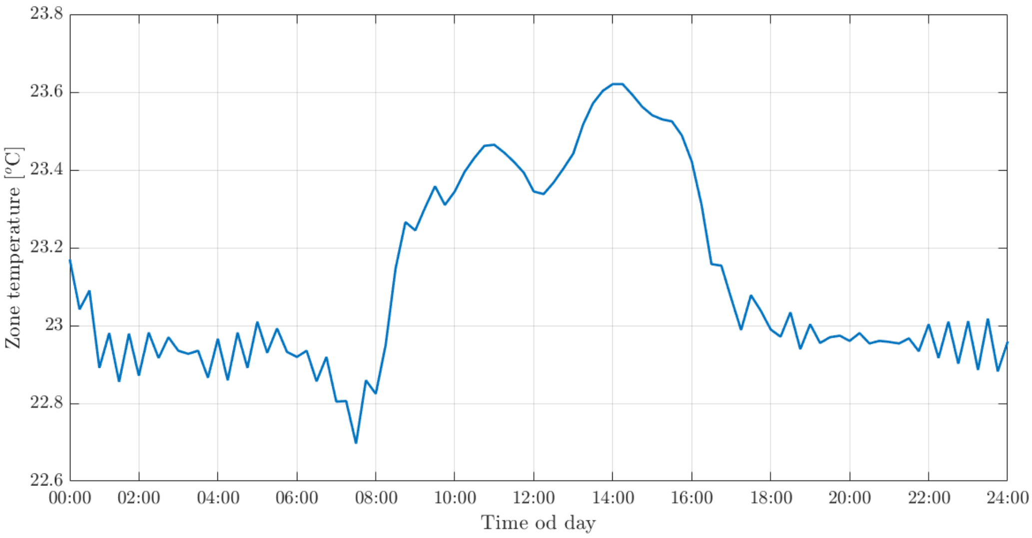

Figure 2.18. A predicted response of temperature for a room ID 9 in EON building within the analysed day.

In Figure 2.19. one may see for the same zone as provided in Figure 2.18 the predicted heating energies provided from the fan coil to room air.

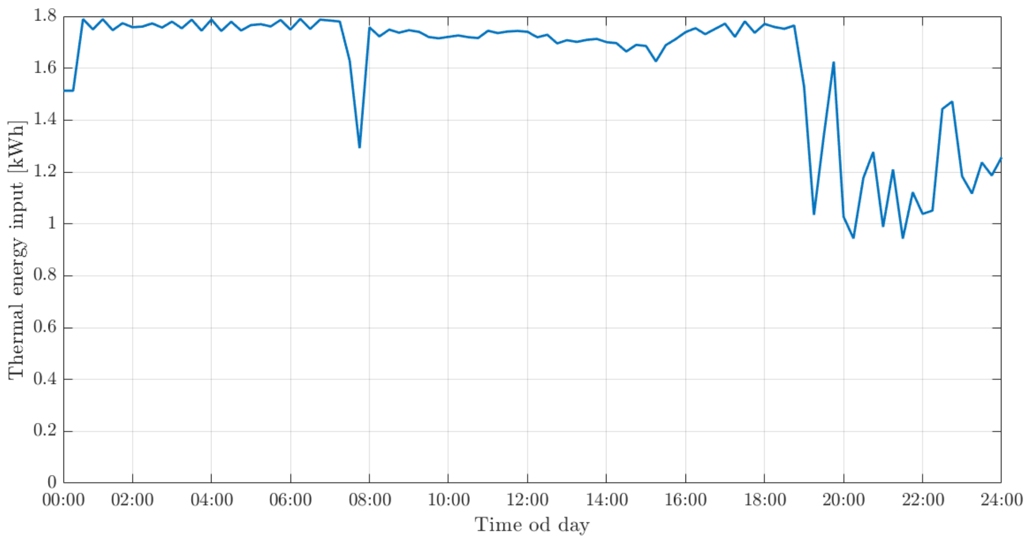

Figure 2.19. Heating needs for the EON building room with ID 9 within the analysed day.

The EON building complex consists of five buildings – A, B, C, D and E – where the rooms in them are organized to be supplied from 4 different heating circuits – for A, B+C, D and E.

On the central HVAC system level manipulated variable of the system is the temperature of the medium coming out of the mixing valves for the four heating circuits (A, B+C, D and E). The temperature setting can be any temperature between the temperature provided at the output of the heating substation and the current return medium temperature. Baseline supply temperature is governed with respect to the environment air temperature. The exhibited responses for the starting temperature in all 4 heating circuits are shown in Figure 2.20. In the time periods of activation, the supply temperature in main supply ducts is instantly increased and kept to the maximum value in order to allow the fan coil units operation with the minimum electricity consumption. Reponses of the supply temperature with 3Smart without activation show lower supply temperature compared to the both baseline and the 3Smart with activation. This temperature is determined to ensure the required thermal energy towards the zones.

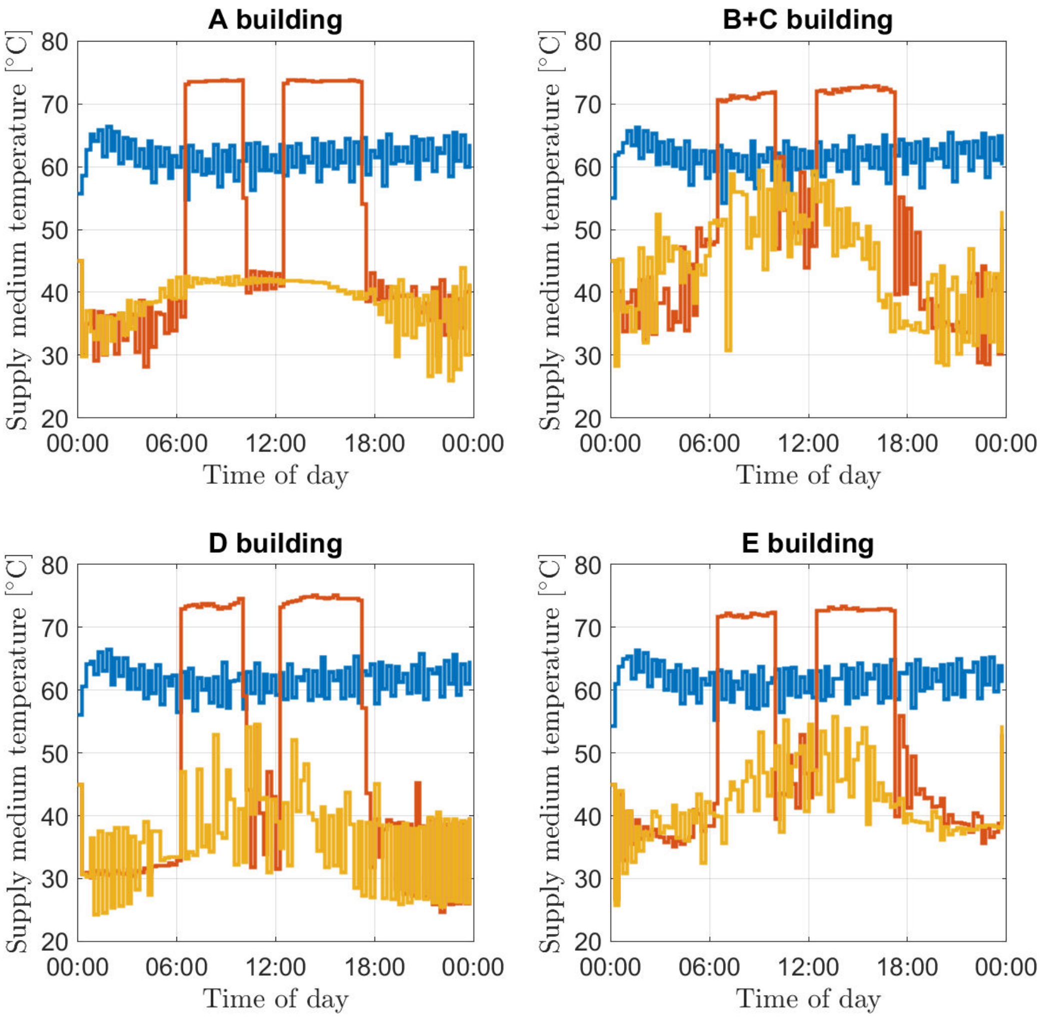

Figure 2.20. HVAC supply medium temperature references for the four heating circuits in EON building.

Figure 2.21 shows the cumulative thermal energy consumptions on the named 4 heating circuits within the analysed day.

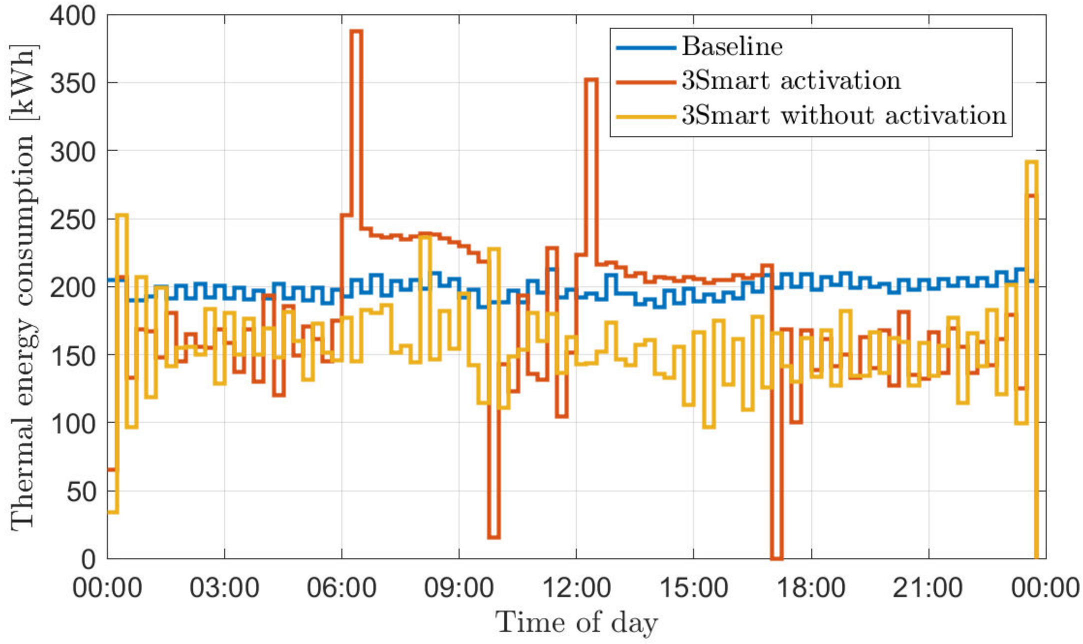

Figure 2.21. Overall heating energy needs for the four main heating circuits of the EON building complex.

The electricity consumption profiles on fan coils fans in 3Smart monitored rooms are shown in Figure 2.22. One may see that in case of activation the electricity consumption is significantly reduced by raising the starting medium temperature in the heating circuits, at the cost of higher thermal energy usage due to higher losses in piping. The profile without activation of flexibility actually shows the best balance between electricity consumption on fan coils and thermal energy dissipation due to losses in piping.

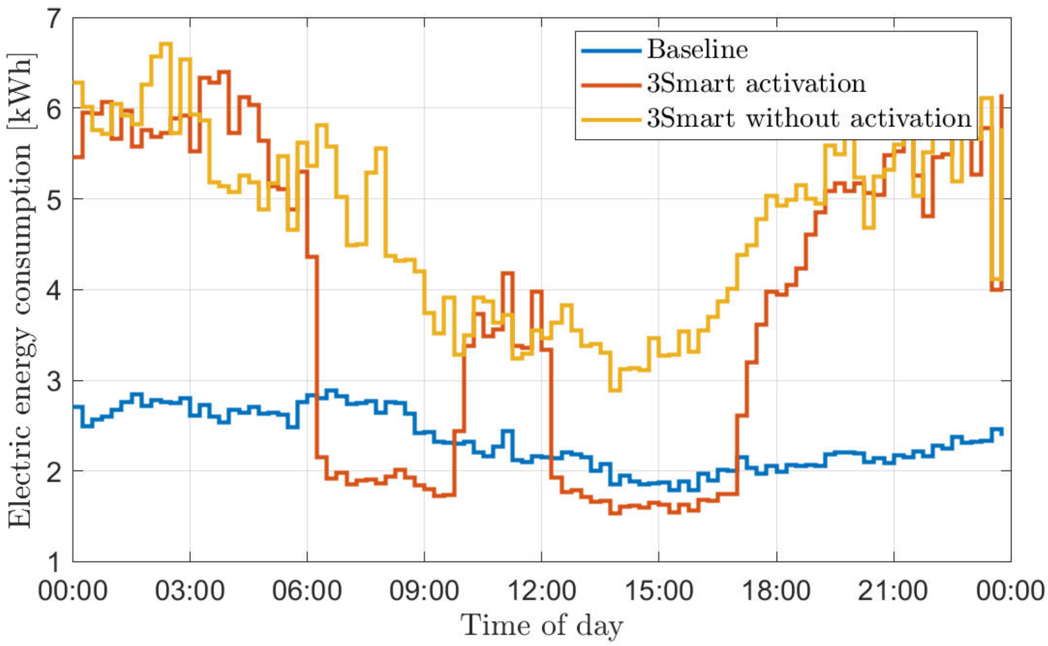

Figure 2.22. Central HVAC system electric energy consumption (consumption of fan coils in monitored rooms).

On the microgrid level the controllable elements are the dimmable PV system power converter and the six rooms in the cellar with electric heaters. For the case of conventional control, the PV system is of course left to produce maximum possible power, i.e. dimming s not applied, and the electric heaters are controlled by conventional hysteresis control such that the temperature is maintained in ±5°C or ±1°C, depending on the room and vicinity around the reference temperature set for each room.

With 3Smart controls the PV system and electric heaters are used to exhibit the optimal electricity exchange with the grid, considering also the demand response functionality, and the microgrid also shapes by proper coordination prices the controllable electricity consumption of fan coils on the central HVAC system; of course the HVAC system balances between heat and electricity consumption based on prices of each to get the most beneficial operation for the building.

When operated with 3Smart, the microgrid level exploits the demand response opportunities offered by the grid in flexibility intervals and also takes care about the peak pricing of power, and computes the optimal flexibility bid of the building towards the grid for the flexibility interval. Figure 2.23. provides the PV system response. Since the flexibility is well paid, the system decides that it pays off to plan the building operation without activation with fully dimmed PV system, to get maximum flexibility margin in reservation and for activation.

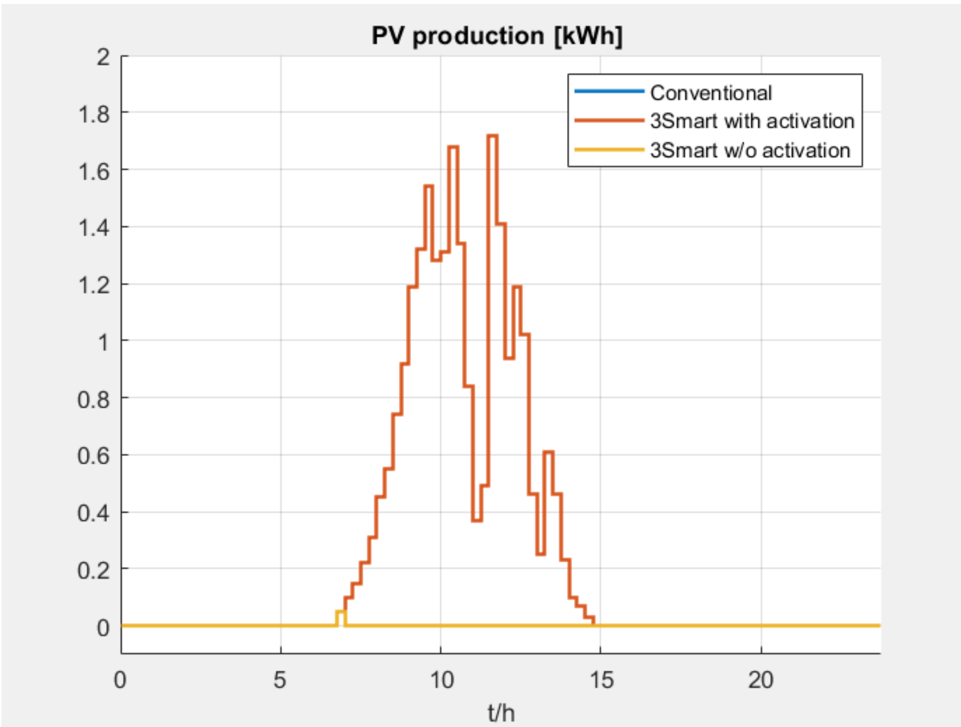

Figure 2.23. PV system power production.

The overall electricity consumption by the electric heaters in six basement rooms is given in Figure 2.24. and the exhibited temperature profiles in one of the six basement rooms with electric heaters are provided in Figure 2.25. Electric heaters 15-minutes heat exertion commands for that particular room are provided in Figure 2.26.

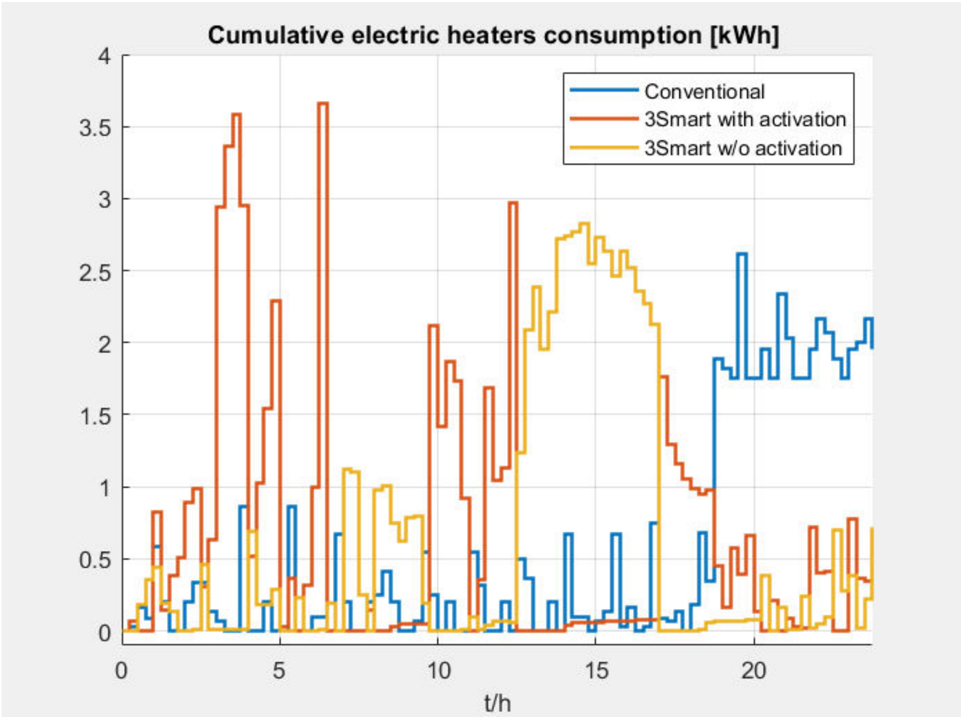

Figure 2.24. Cumulative electric heaters operation in terms of electricity consumed.

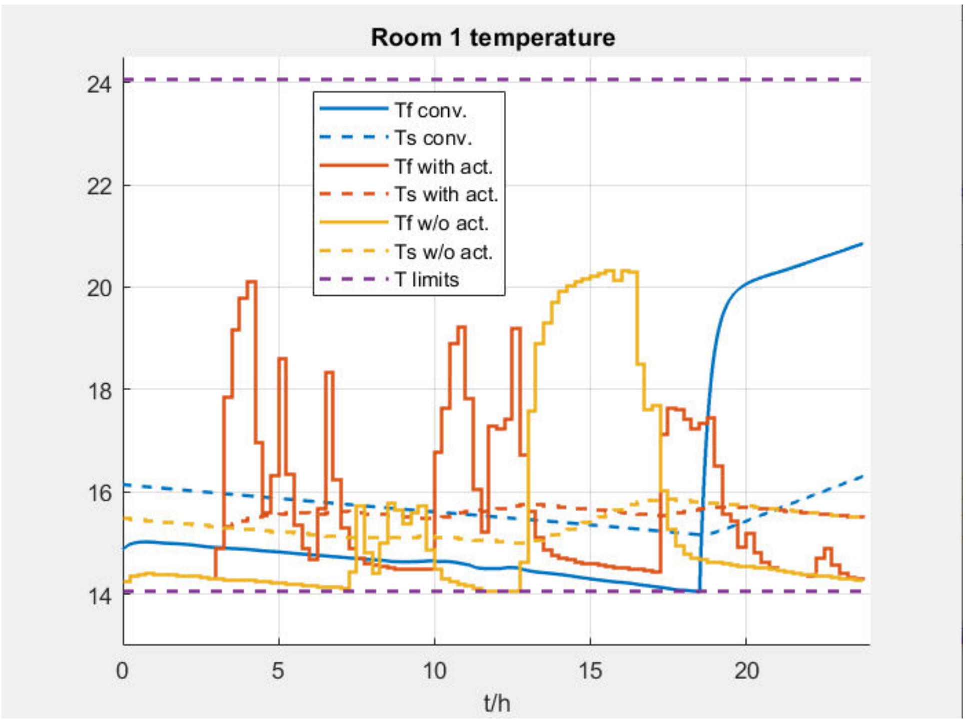

Figure 2.25. Temperature responses of one of the six cellar rooms with electric heaters (Room 1). Annotation Tf denotes the room temperature and the annotation Ts denotes the slow dynamics state of equivalent temperature of walls and furniture in the room. Minimum and maximum temperatures allowed are also depicted (14°C and 24°C).

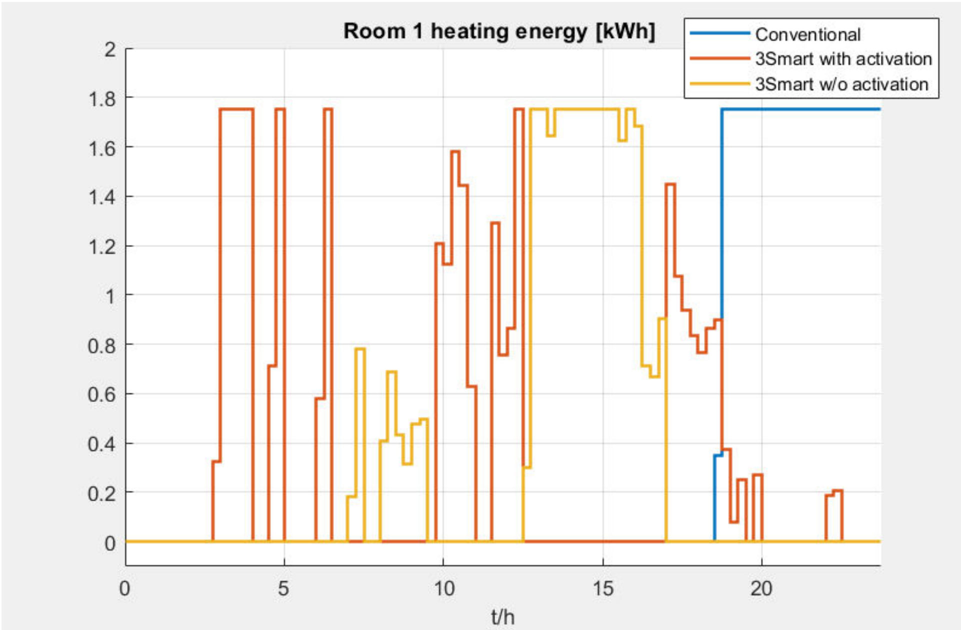

Figure 2.26. Electric heaters actuation profile in Room 1.

The exhibited electricity exchange with the grid is shown in Figure 2.27. One may see that the coordinated action with the HVAC level ensures a continuous power consumption decrease for the case of activation of flexibility in both flexibility intervals. Electricity consumption of the conventional control is smaller for two reasons – one is very high starting temperature in the heating circuits which results in shorter fan coils fans operation cycles, but also in even higher losses in thermal energy; the other is the rooms heaters case where the periodicity of hysteresis control in some of them is higher than one single day, and thus only a part of the heat-up period (electric heaters on) is captured within the analysed day.

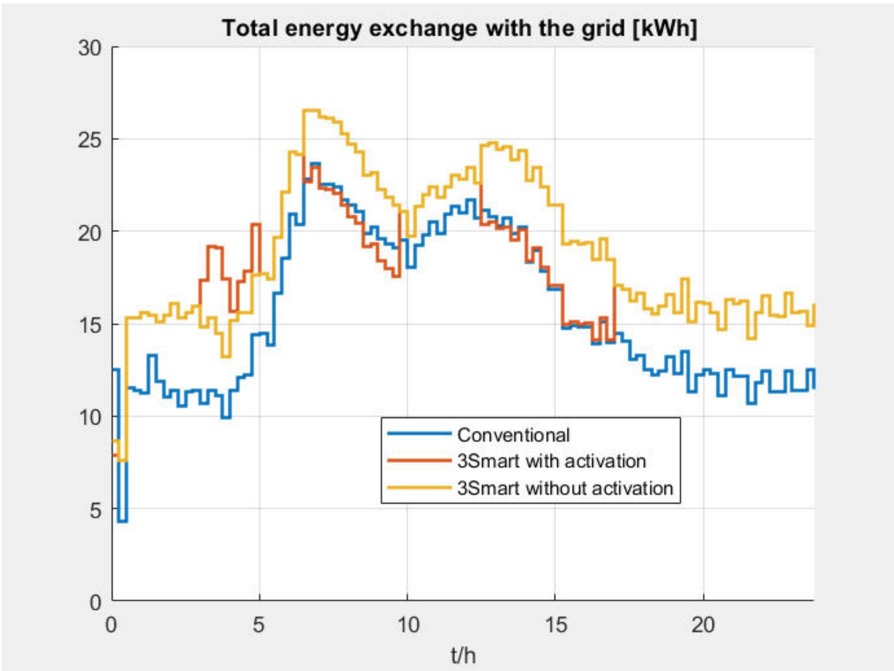

Figure 2.27. Electricity exchange with the grid.

The flexibilities offered to the grid in the two set flexibility intervals are depicted in Figure 2.28. They equal 8.5 kW and 9.3 kW (in negative direction, of course).

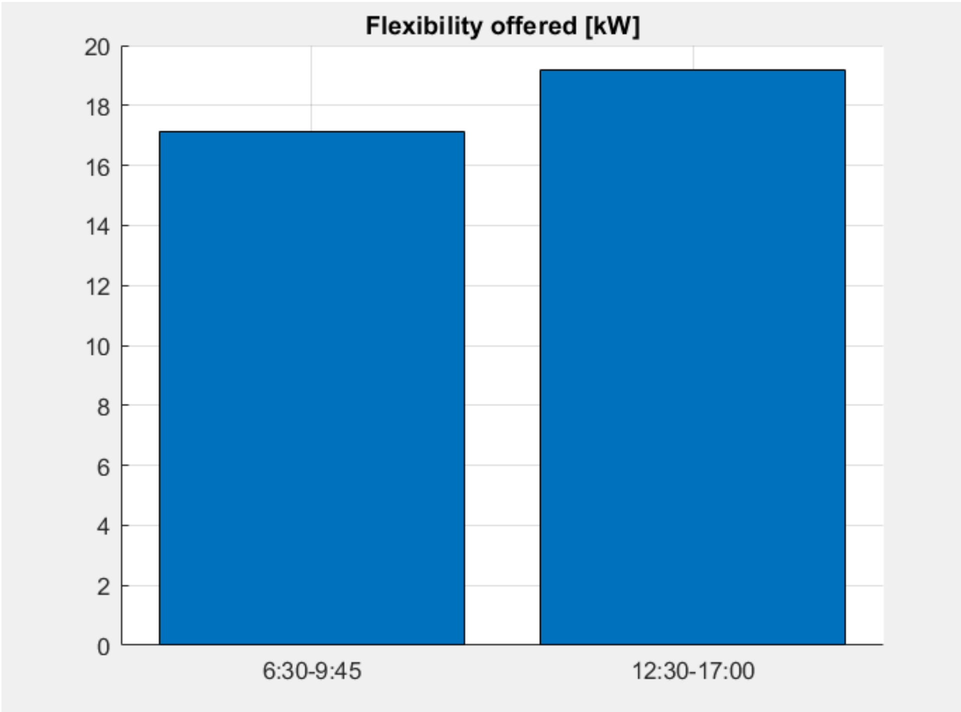

Figure 2.28. The flexibility offered by the EON building complex within the analysed day in January.

The overall operational costs of the building for the sunny workday in January, and thus also the gains achievable by using 3Smart compared to state of the art conventional controls, are provided in Table 2.2.

Table 2.2. Daily cost comparison between conventional and 3Smart controls for the analysed day in the heating season.

	Conventional control	3Smart – w/o activation	3Smart – with activation
Heating energy costs	721.74 €	559.68 €	644.17 €
Electricity costs	93.19 €	102.66 €	98.08 €
Total costs	814.93 €	662.34 €	742.25 €

The overall benefit of the 3Smart platform in heating can be estimated by assuming that the activation will happen in 50% of cases. The daily benefit is thus the average between 152.59 EUR (gain without activation) and 72.68 EUR (gain with activation). The average daily benefit is thus estimated at 114.43 EUR and rounded at 114 EUR for the cost benefit analysis. The reason for such large difference between the prices without activation and with activation is the disregard of thermal losses when the initial HVAC profile for activation was calculated, where primarily it was targeted to get minimum electricity consumption in flexibility intervals. This exhibited behaviour points out that both profile with activation and profile without activation must be iterated between the central HVAC and the microgrid level. But even now with the 3Smart platform as is, the benefits are considerable.

Bibliography

[1] D7.5.2 Integrated planned energy management modules on all the buildings and in the grid for the Hungarian 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

Name of the Quality Manager

Signature of the Quality Manager

Prof. dr. Mato Baotić,

Prof. dr. Hrvoje Pandžić,