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 D7.2.3

Operational logs and their seasonal analysis – Slovenian pilot

Project Acronym	3Smart
Grant Agreement No.	DTP1-502-3.2-3Smart
Funding Scheme	Interreg Danube Transnational Programme
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Project Duration	36 months
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Code name	**Version:** 1.1 Final ☒ Final draft ☐ Draft ☐
Type of deliverable	Report
Security	Public
Deliverable participants	UNIZGFER, IDRIJA, E3, ElektroP
Authors (Partners)	Mario Vašak, Anita Martinčević, Nikola Hure, Hrvoje Novak, Danko Marušić, Paula Perović, Marko Kovačević (UNIZGFER), Tadej Rupnik (IDRIJA), Marko Baša (E3)
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. 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 Slovenian pilot	Mario Vašak, Anita Martinčević, Nikola Hure, Danko Marušić, Marko Kovačević, Hrvoje Novak (UNIZGFER)
1.1	15 February 2020	Final checking and tuning of the descriptions	Mario Vašak (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 Slovenian pilot, focussed on particular characteristic days in the heating season and in the summer period. 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 Slovenian pilot consists of the school building and sports centre in Idrija, owned by Idrija municipality, and of the pilot electricity distribution grid of Elektro Primorska around these two buildings. 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 D7.2.2 [1].

This deliverable concerns the operational logs obtained by operation of the 3Smart modules on the setup of the Slovenian 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 buildings are analyzed in conditions specific for different season – 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 a specific of several tenths of zones?
    - When and how much to heat the centrally prepared medium for heating of zones?
    - How to engage the heat exchanger and the electric heaters in providing the correct temperature in the Domestic Hot Water (DHW) tank
    - When and how much to engage the Combined Heat and Power (CHP) system?
    - From which initial condition should the buildings start at the beginning of the day?
    - What should be the amount of offered flexibility from the buildings 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 **Error! Unknown switch argument.** the operational logs and seasonal analysis for the school and sports centre buildings is presented. In both chapters 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. School and sports centre buildings operational logs and seasonal analysis

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

2.1 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:

- 20:30-21:00
- 21:15-22:00.

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

- reservation price: 0.0793 EUR/kW/15 min;
- activation price: 0.317 EUR/kWh;
- penalty price: 0.634 EUR/kWh.

The expected day-ahead electricity pricing is as follows:

- High price tariff: 0.0631 EUR/kWh, valid in period 07-21;
- Low price tariff: 0.0438 EUR/kWh, valid in period 21-07.

The heating energy costs amount at 0.018 EUR/kWh. The building is not reimbursed for any electricity provided to the grid.

Additional parameters taken into account are consisted of the relevant meteorological conditions, namely outdoor air temperature profile (shown in Figure 2.1) and direct and diffuse solar irradiance profiles (shown in Figure 2.2), as well as the non-controllable consumptions on the central HVAC system level (thermal energy consumption profile shown in Figure 2.3) and the microgrid level (electrical energy consumption profile shown in Figure 2.4).

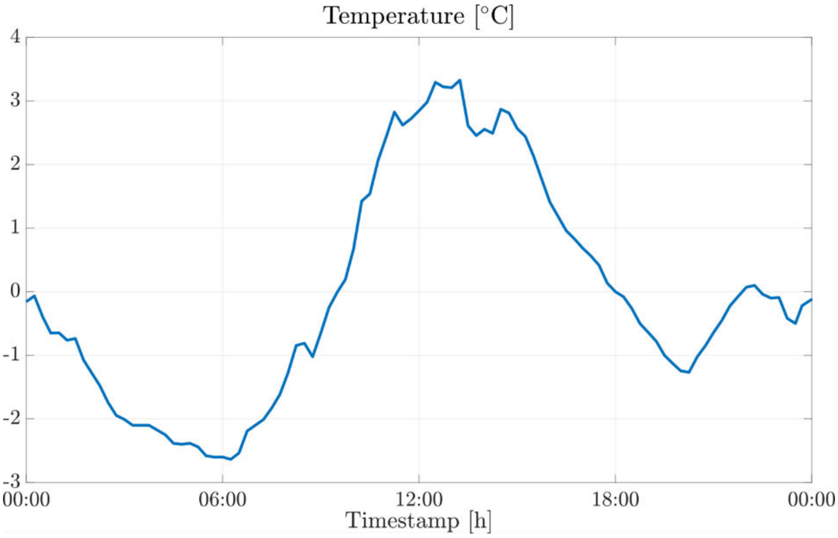


Figure 2.1. Outdoor air temperature for a sunny day in November at the pilot location in Idrija.

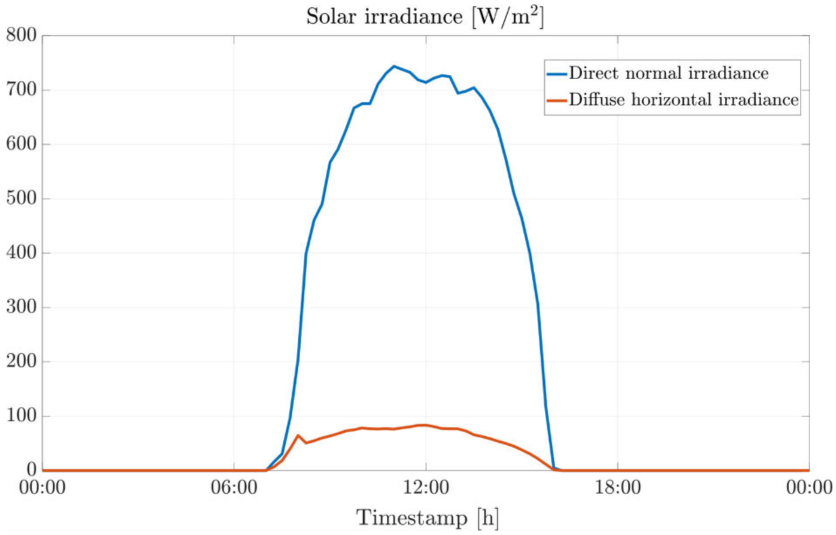


Figure 2.2. Direct (normal) and diffuse (horizontal) solar irradiance for a sunny day in November.

The non-controllable thermal energy consumption on the central HVAC level (Figure 2.3) accounts for the consumption of radiators throughout the buildings in rooms that are not equipped with 3Smart controls. The non-controllable electrical energy consumption on the microgrid level (Figure 2.4) is consisted of the energy consumption of lighting, kitchen, computers and school electricity equipment. Also the PV plant predicted electricity consumption for a sunny day in November is provided in Figure 2.5.

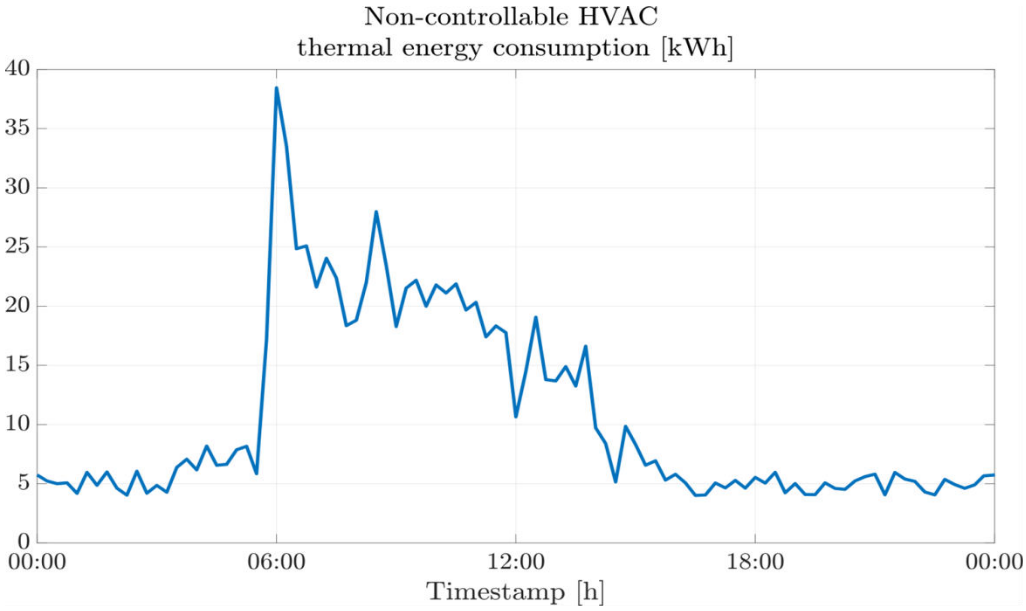


Figure 2.3. Non-controllable consumption of thermal energy on the central HVAC system level, for a sunny workday in November.

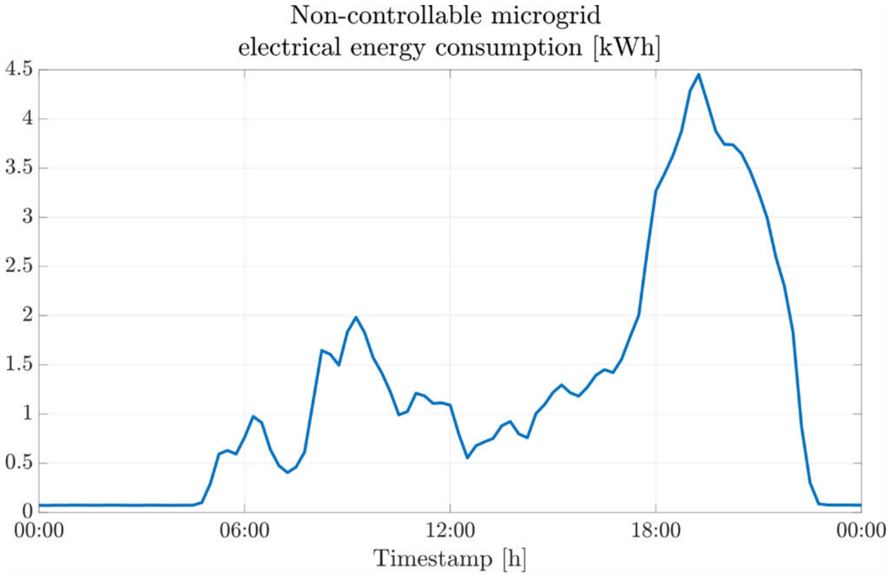


Figure 2.4. Non-controllable electrical energy consumption on the microgrid level, for a sunny workday in November.

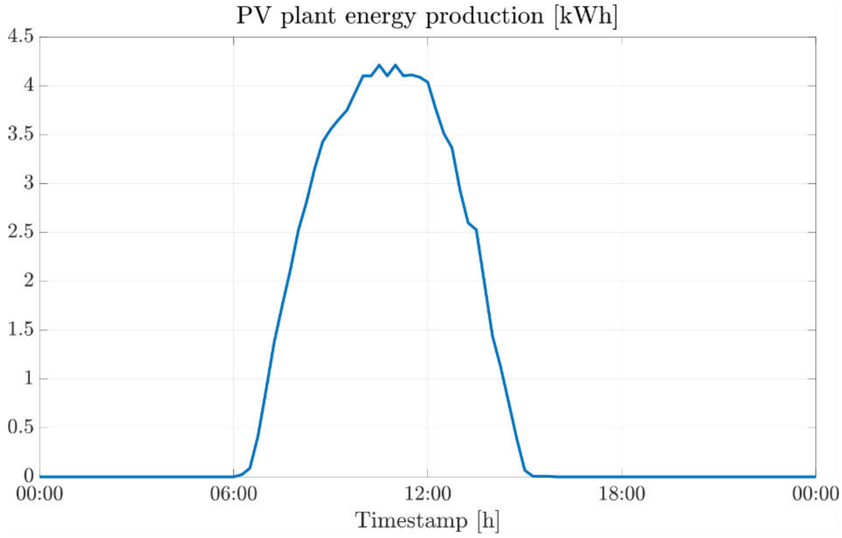


Figure 2.5. PV plant electricity generation, for a sunny workday in November.

2.2 The optimized building operation – heating season

The presentation of the optimized school and sports centre behaviour will be given by passing through different levels of the 3Smart system and analysing the optimized behaviours computed. We consider three different modes of operation on each leve:

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

With distinction that on some level the potential for flexibility provision might be too small compared to the overall electricity consumption and then it is disregarded.

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 controller with valve opening change proportional to the difference between the room reference temperature and the achieved temperature in the room. The reference temperature for all rooms is set on 24°C, and it is valid within the occupancy interval from 08:00 to 18:00. Conventional control is initiated time-based – it starts with heating of rooms at 04:00 such that the comfort is achieved in all rooms by 08:00. 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 system level. In Figure 2.6. one may see a typical temperature profile of one of the 45 controllable zones of the Idrija pilot buildings. With conventional control (blue line) the air temperature in the zone is kept within [23.5,24.5]°C during the operating hours. The 3Smart operation on rooms level does not differ for the cases when flexibility is called and not called in the heating season. This point will be explained in more detail later when the microgrid level will be elaborated. Thus 3Smart operation here follows the same principle irrespective of the flexibility calls.

The following figure, Figure 2.7, shows the behaviour of the return medium temperature on radiators for predictive control operation.

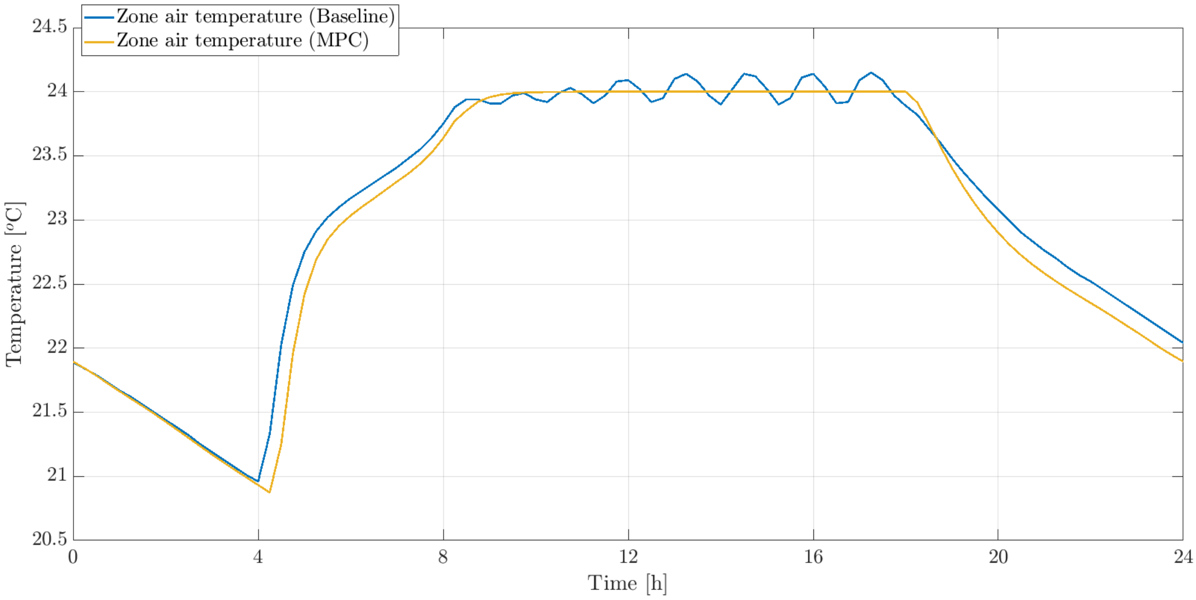


Figure 2.6. Temperature response of zone 1 in the pilot buildings.

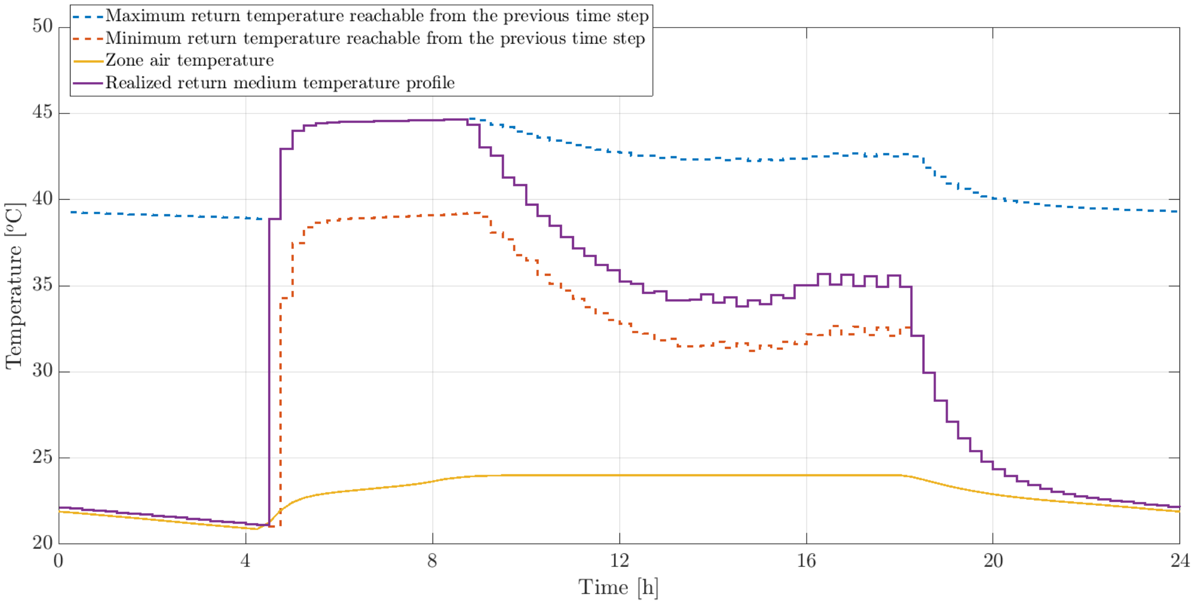


Figure 2.7. Dynamic behaviour of the return medium temperature on radiators in zone 1 of the pilot buildings.

Figure 2.8 shows a temperature response in one zone with a significant volume, that is the zone no. 13. In it the heating must be planned well in advance to ensure proper temperature in the morning and minimal overheating during the sunshine in the middle of the day. One may see that the repeatability constraint enforced with MPC ensures that proper preparation for the next day starts already after 21:00. For this room subject to predictive control, Figure 2.9 shows the radiator return medium temperature behaviour. Predictive control takes into account the dynamic behvaiour of this temperature in order to deliver the heating energy to the room at minimum operational costs.

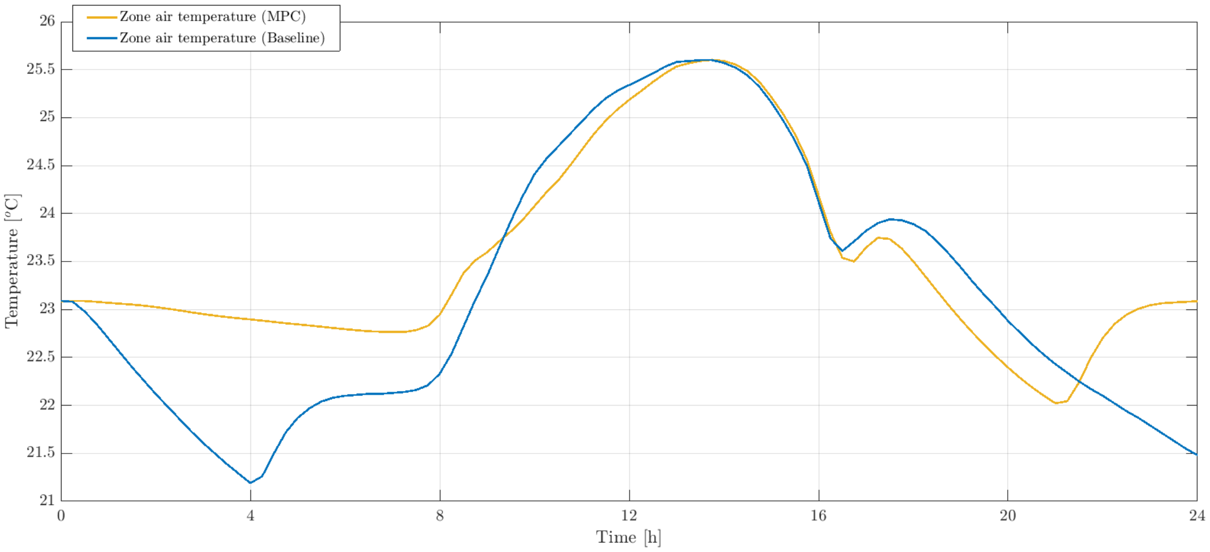


Figure 2.8. Temperature response in Zone 13 of the pilot buildings.

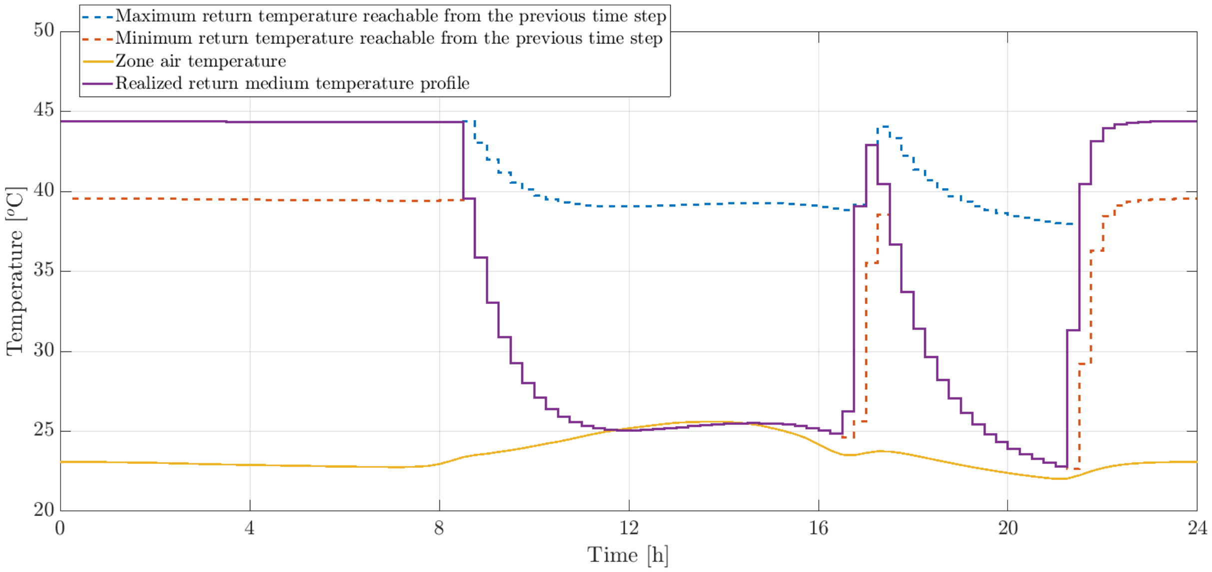


Figure 2.9. Return medium temperatures on the radiator in Zone 13 of the pilot building.

The overall thermal energy required for zones air in all controllable zones in the pilot buildings is provided in Figure 2.10.

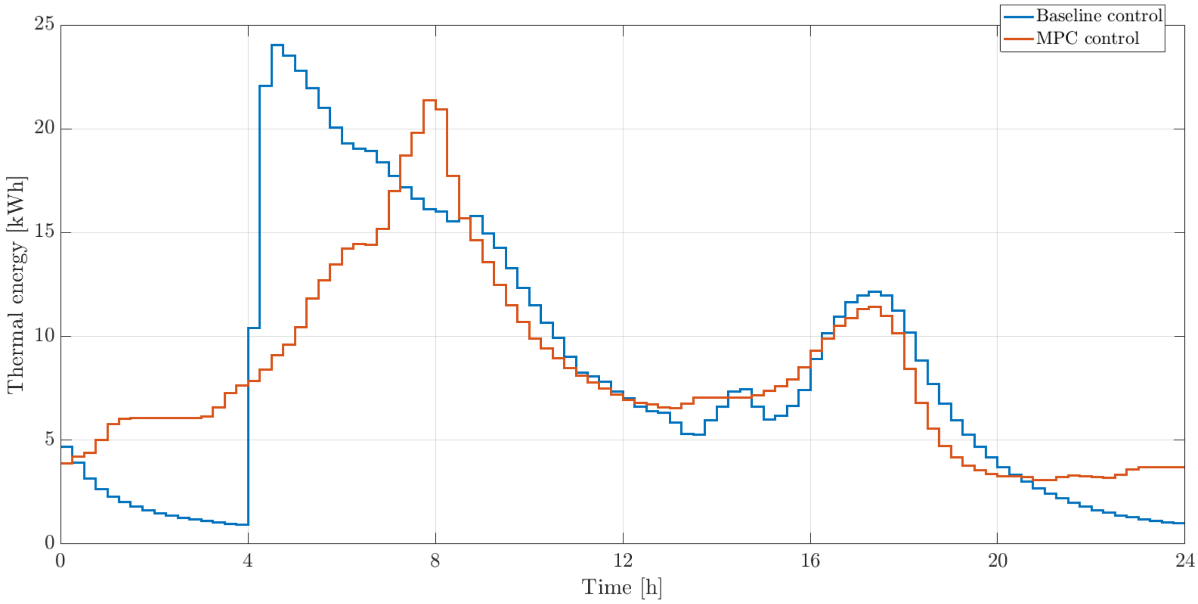


Figure 2.10. The overall required thermal energy for zone airs in the pilot buildings.

Thermal energy savings achieved from 0:00 up to the end of the occupancy interval at 18:00 with the 3Smart system amount to 2%, and the users' comfort is improved by 10.67%.

On the central HVAC system level the 3Smart system decides on the starting medium temperature for the radiators in controllable zones. The planned profiles over the day are provided in Figure 2.11, upper graph. The conventional control keeps the temperature constantly at 50°C. The lower diagram shows the corresponding supply flow towards the radiators. It depends on valve openings applied over all zones.

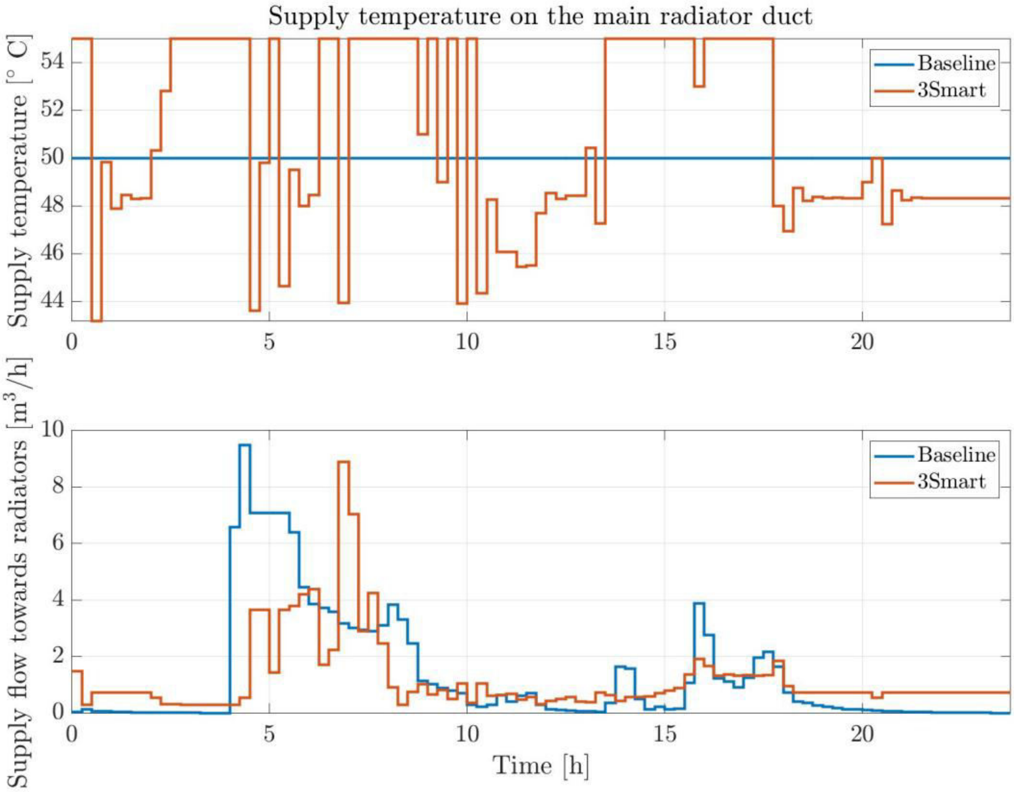


Figure 2.11. Supply medium temperature computed on the central HVAC system level and the corresponding medium flow towards the radiators.

Closely related to the supply medium flow is also the electricity consumption of the circulating pump. It is shown in Figure 2.12. Higher starting temperatures and preheating behaviour reduce the peak pump consumption.

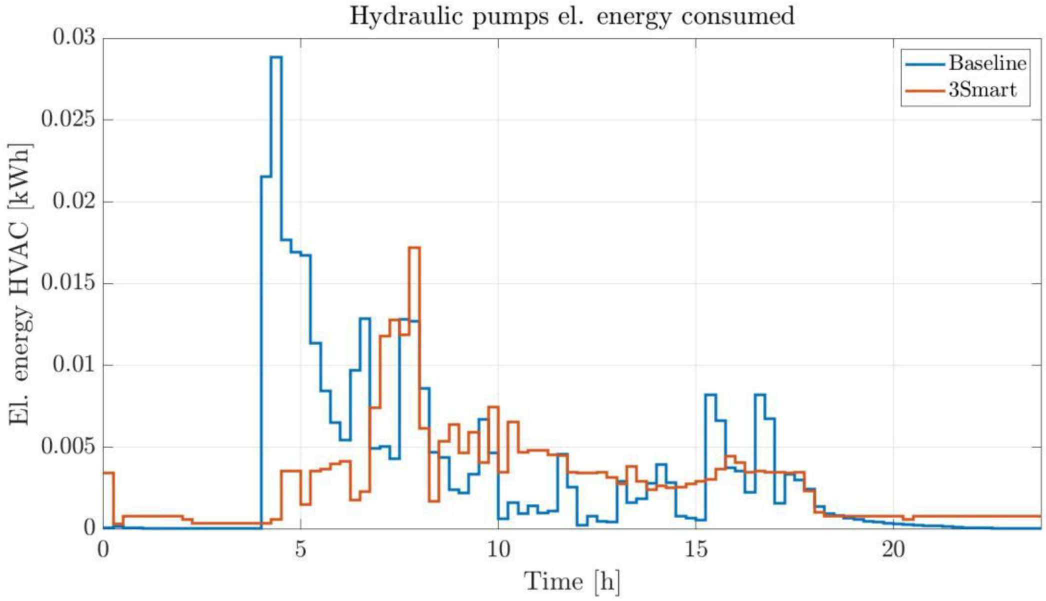


Figure 2.12 Electricity consumption on the hydraulic pumps for the radiators

The overall thermal energy consumption on the water side to heat the 45 controllable zones is shown in Figure 2.13.

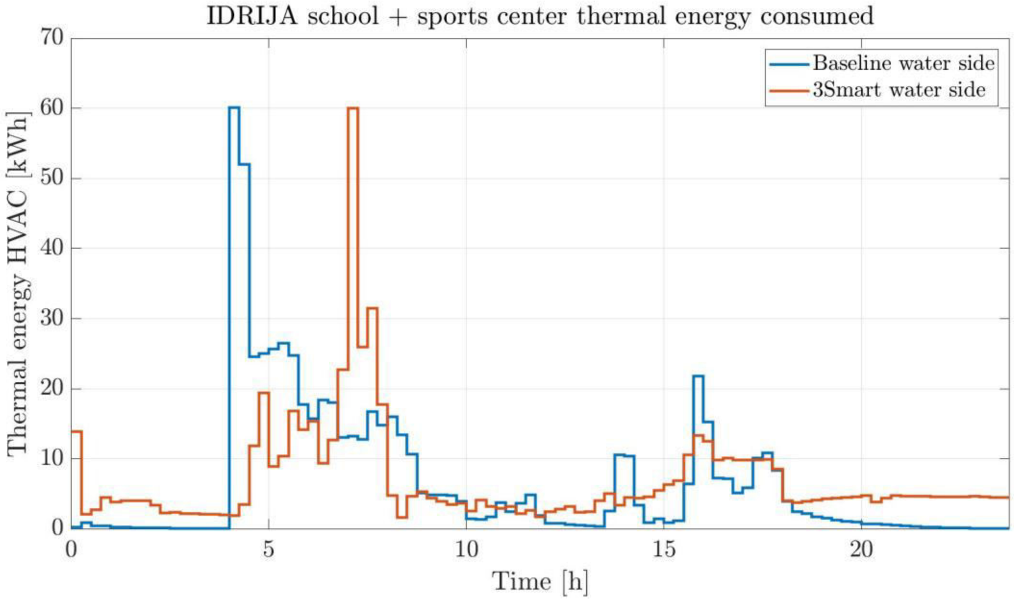


Figure 2.13. The overall controllable thermal loading on the water side (for 45 controllable zones)

The comparison of heating energy consumptions with conventional and 3Smart controls is given in the following table. The comparison is performed just for the period between 0:00 and end of the occupancy period at 18:00 since after that time MPC already performs preparation of the room conditions for the start of the next day to ensure repeatability while the conventional control stops the heating. The savings are on the level of 7%.

Table 2.1. Comparison of heating energy consumption (water-side) between 0:00 and 18:00

	Controllable thermal energy [kWh] 0:00 – 18:00	**Controllable electric energy [kWh] 0:00 – 18:00**	**∑ EUR 0:00 – 18:00**
3Smart	556.54 (9.74 EUR)	0.26 (0.0142 EUR)	9.75 (-7.32%)
Baseline	599.54 (10.50 EUR)	0.32 (0.0162 EUR)	10.52

On the microgrid level in Idrija is present a very interesting combination of systems with controllability on a CHP unit, on heat exchanger for delivering heat in the DHW tank and an electricity heater. Majority of the heat is produced with boilers that are non controllable – they provide all the surplus heat needed that is not provided by the CHP, and the heat is also exported in the neighbourhood. The heating energy consumption of the district is shown in Figure 2.14, also in it the HVAC system thermal requests for the pilot buildings are shown to make a comparison.

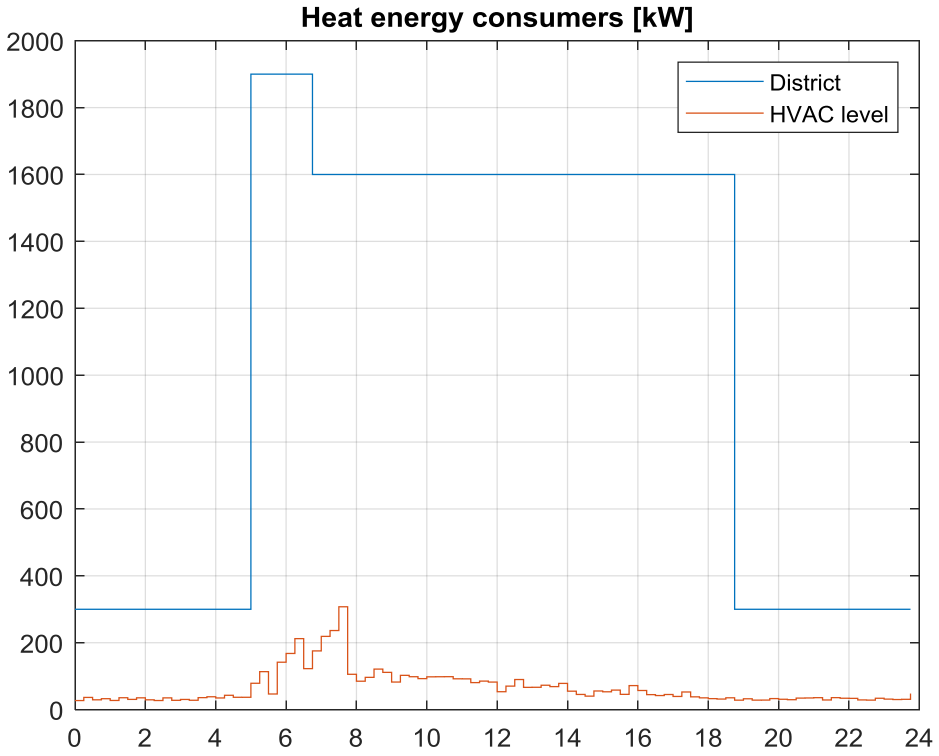


Figure 2.14. Consumption of heat in the remainder of the district given together with the overall consumption for heating at the pilot buildings.

The conventional control operates in the following way: hysteresis control is applied to the DHW temperature with 45°C as setpoint temperature and allowed temperature deviation of +- 5˘C. Legionella protection may be included once a week – it was not included in the scenario considered. With conventional control the CHP is working on fixed schedule from 05:00 to 23:00. The CHP also has a constraint that, when operating, it must work on 60% or higher of the full power rating.

The microgrid level led with 3Smart optimal controls exhibits quite interesting behaviour to ensure pilot buildings optimal gain when providing the demand response service to the grid. The operation of the CHP unit is shown first, in Figure 2.15.

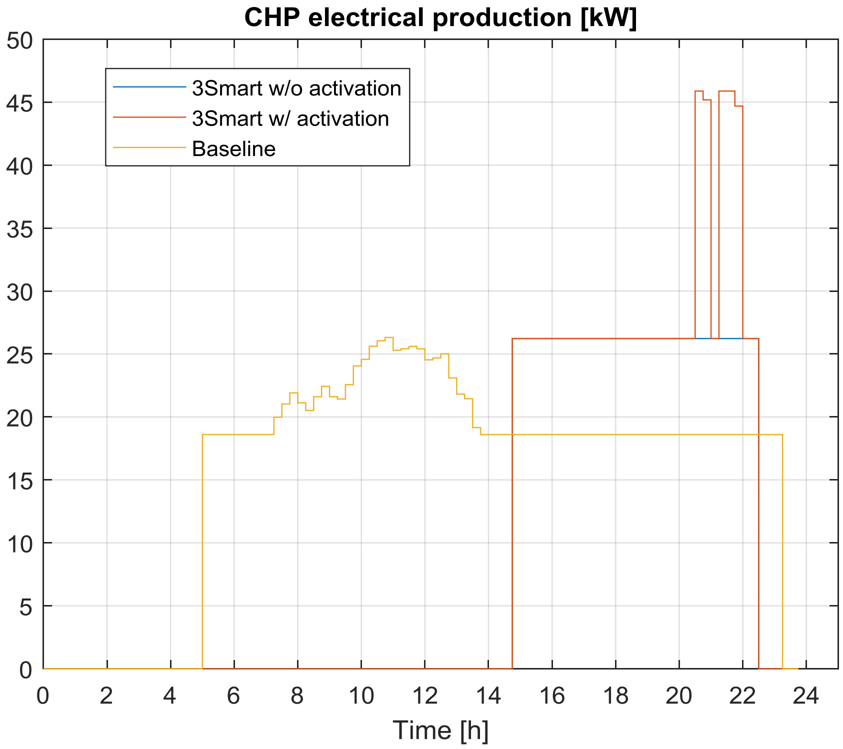


Figure 2.15. CHP operation for a sunny workday in November.

CHP operation schedule is shortened with predictive control – until 15:00 the PV system production is sufficient to cover building's electrical energy demand. After that, CHP is engaged. It is namely a loss of money to run the CHP whole day, since the building is not rewarded for the energy returned to the grid. So, in 3Smart, CHP will cover the building consumption in order not to pay more than contracted for the peak power. In flexibility intervals, CHP will operate near full power. In 3Smart operation, DHW heater is using excess electricity produced by the PV system. In case of flexibility reservation, building's consumption will be augmented using the electric heater. In case of activation, the electric heater will be turned off and water will be heated using the heat exchanger instead. The operation of the electric heater for the DHW is shown in Figure 2.16, and of the heat exchanger in Figure 2.17.

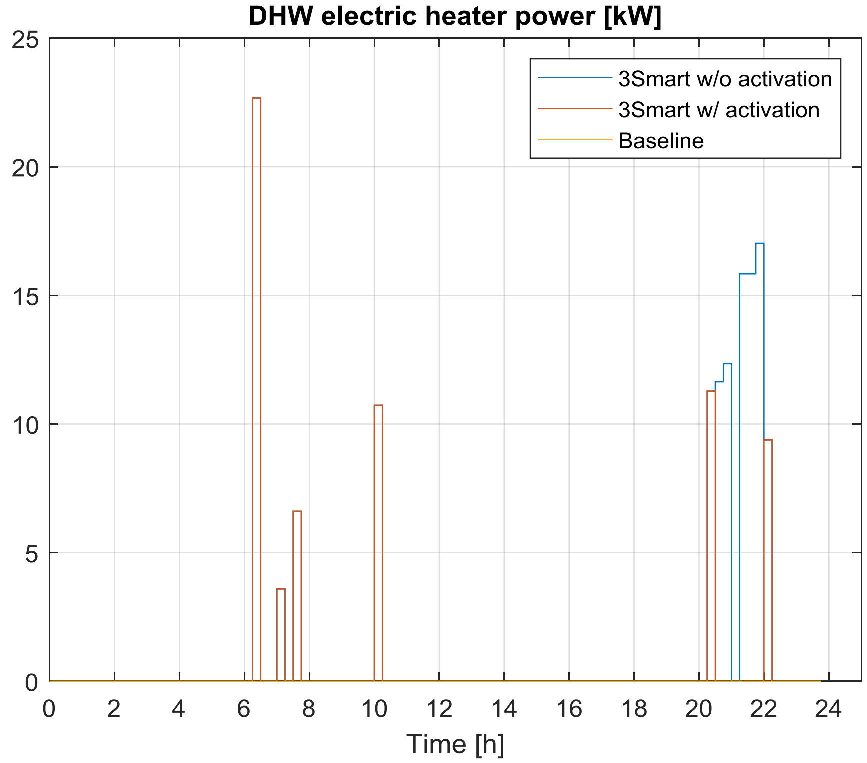


Figure 2.16. DHW tank electric heater operation.

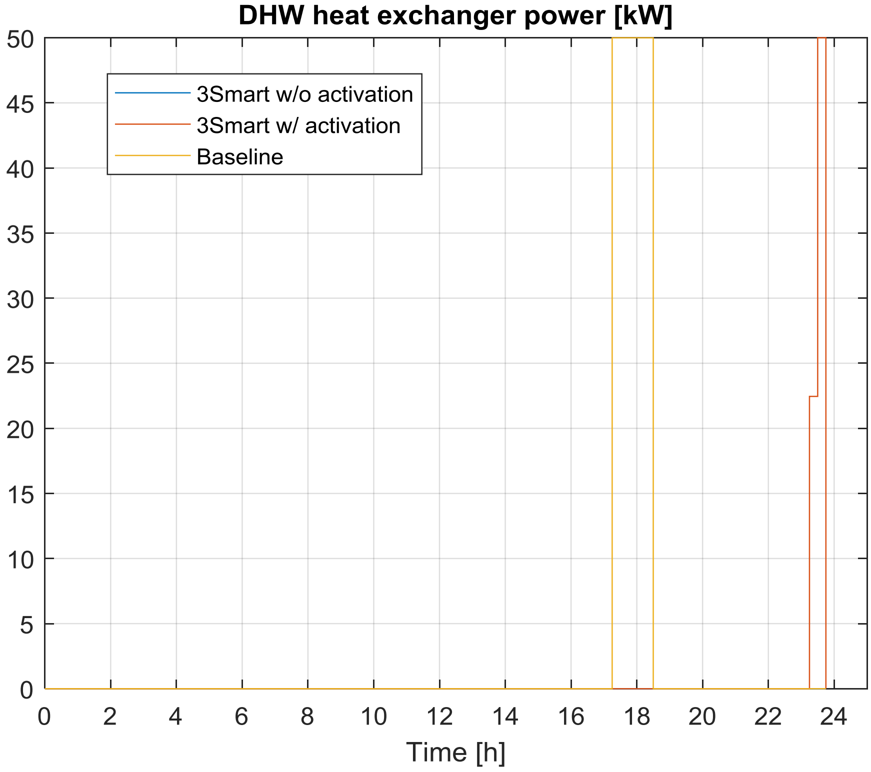


Figure 2.17. DHW tank heat exchanger operation.

The achieved DHW tank temperature profile is shown in Figure 2.18. One may see that the 3Smart energy management system ensures daily repeatability of the temperature profile.

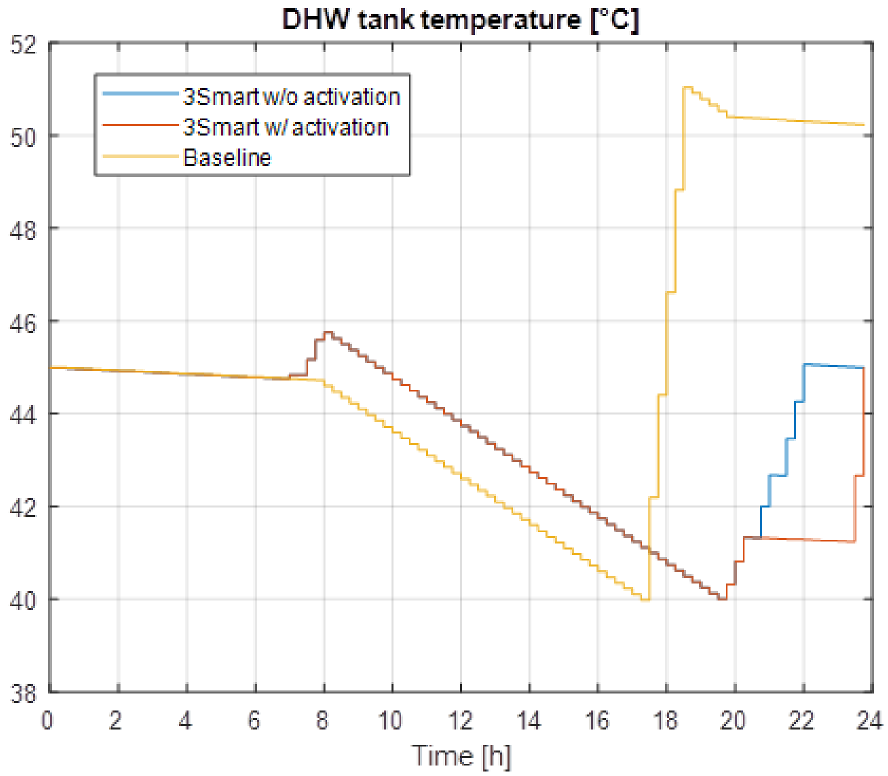


Figure 2.18 Daily behaviour of the water temperature in the DHW tank.

The boilers thermal energy production is provided in Figure 2.19.

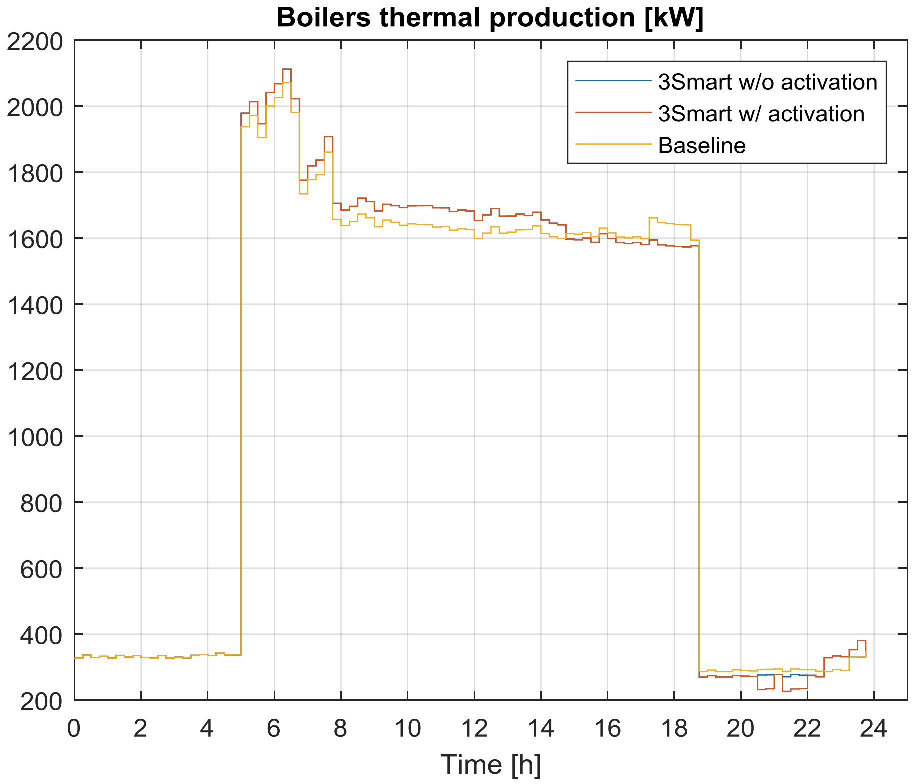


Figure 2.19. Boilers thermal energy production.

One may see that in 3Smart boilers are used more since the CHP is operating yet as of 15:00. Also one may see that if activation occurs during which CHP produces electricity intensively, the heat on the CHP is used to reduce the needed heating power from the boilers.

The electrical energy exchange with the grid, exhibited with 3Smart and with conventional control is provided in Figure 2.20.

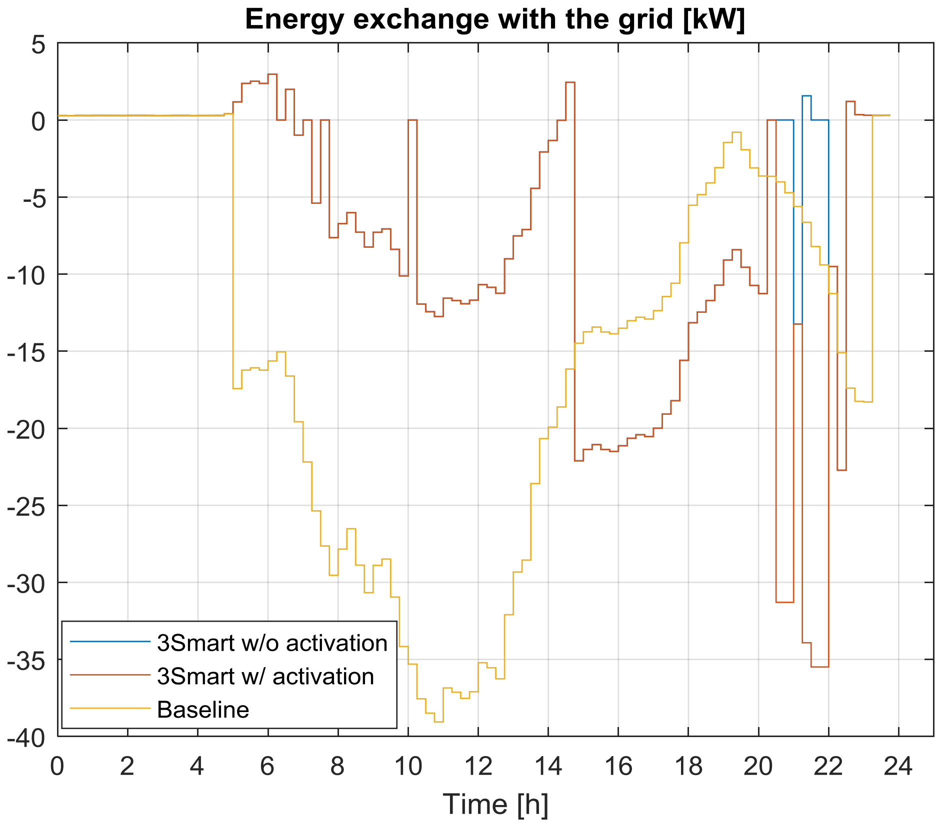
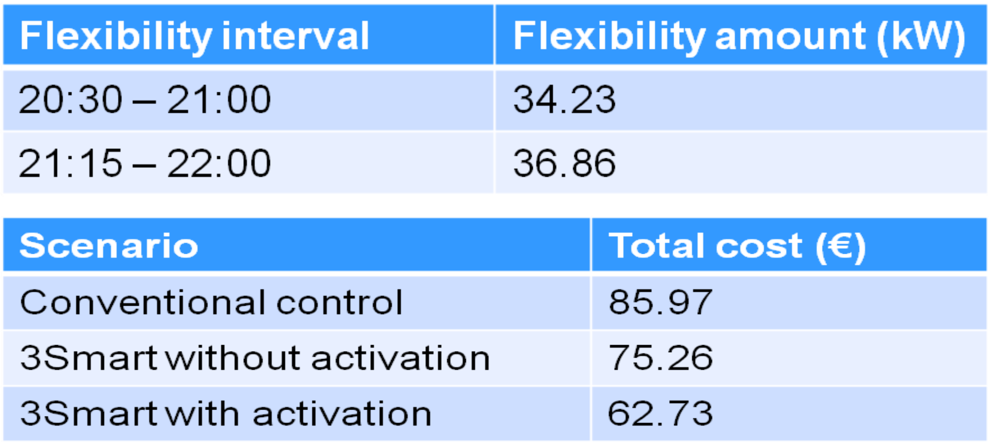


Figure 2.20. The overall electricity consumption profile of the pilot buildings in Idrija for a sunny workday in November.

From this graph one may clearly see the amount of flexibility provided, as the difference between the electricity exchange under 3Smart management with and without activation in the flexibility intervals.

A short financial and technical overview is given in Table 2.2, for the conventional control and for 3Smart controls that also exploit demand response opportunities. Flexibilities offered are significant – around 35 kW -- and mostly can be attributed to the CHP. The peak power to be contracted with the grid for the case of 3Smart amounts at 2.94 kW. For the baseline the electricity is permanently exported towards the grid which is not economically favourable since the electricity provided to the grid is not reimbursed.

Table 2.2. Flexibility powers and financial comparison of the 3Smart system operation vs. Conventional control



Flexibility interval	Flexibility amount (kW)
20:30 – 21:00	34.23
21:15 – 22:00	36.86

Scenario	Total cost (€)
Conventional control	85.97
3Smart without activation	75.26
3Smart with activation	62.73

The operational costs reductions are at the level of quite attractive 27%. The average daily gain, taking into account that e.g. activation would occur for 50% of days can be quantified as the mean between the activation and non-activation gains, so at about 16 EUR.

2.3 Grid-side and boundary conditions for the building operation – summer period

The explanation of the operational logs in the summer period is much shorter and simpler. During the summer there is no other heat consumption but the heat consumption for the domestic hot water in the tank. Only the microgrid level is operable.

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

- 20:30-21:00;
- 21:15-22:00;

The pricing conditions remain the same as in the heating season:

- reservation price: 0.0793 EUR/kW/15 min;
- activation price: 0.317 EUR/kWh;
- penalty price: 0.634 EUR/kWh.

The expected day-ahead electricity pricing is as follows:

- High price tariff: 0.0631 EUR/kWh, valid in period 07-21;
- Low price tariff: 0.0438 EUR/kWh, valid in period 21-07.

The building is not reimbursed for any electricity provided to the grid.

2.4 The optimized building operation – summer season

The presentation of the optimized building behaviour will be given by elaborating the microgrid level of the 3Smart system and analyzing the optimized behaviours computed. Again three possible control modes exist:

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

In Figure 2.21 the CHP system reposne is provided – CHP is not engaged since already the residual production of the PV system, not covered by building consumption which is rather small in the summer time, is enough to heat the water in the DHW tank. It is thus not rentable to turn CHP on.

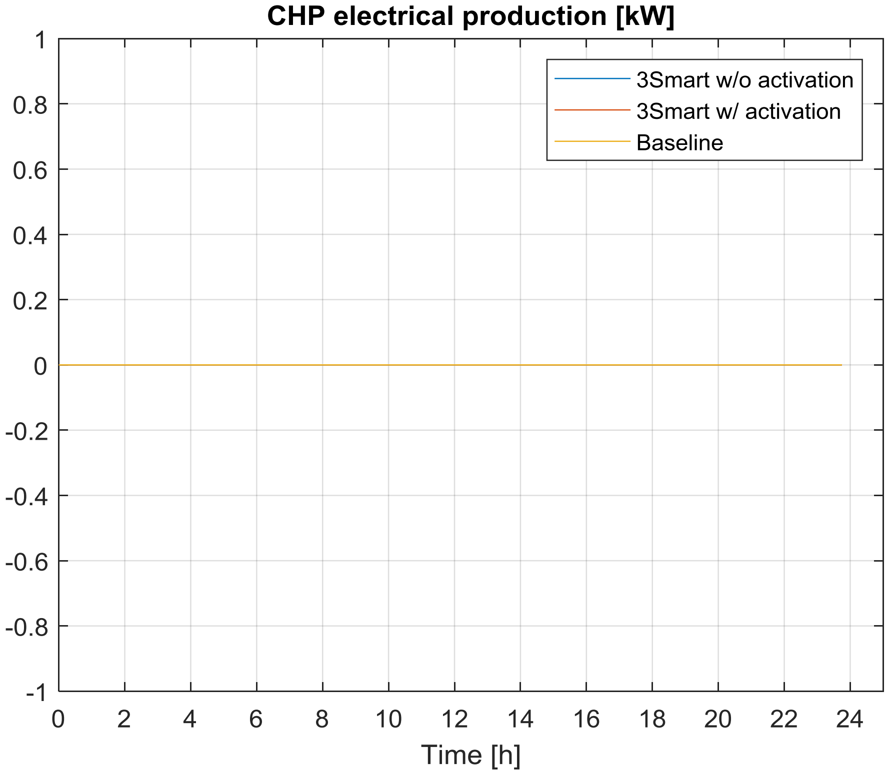


Figure 2.21. CHP operation during the summer workday in June

In Figure 2.22 the actuation of the electric heater for the DHW tank is shown. The heater in conventional control follows a simple hysteresis procedure and turns on just when reaching the lower threshold limit of the water temperature in the tank – on the other hand the 3Smart system tries to exploit maximally the available electricity from the PV system and to export minimum energy to the grid since it is not paid.

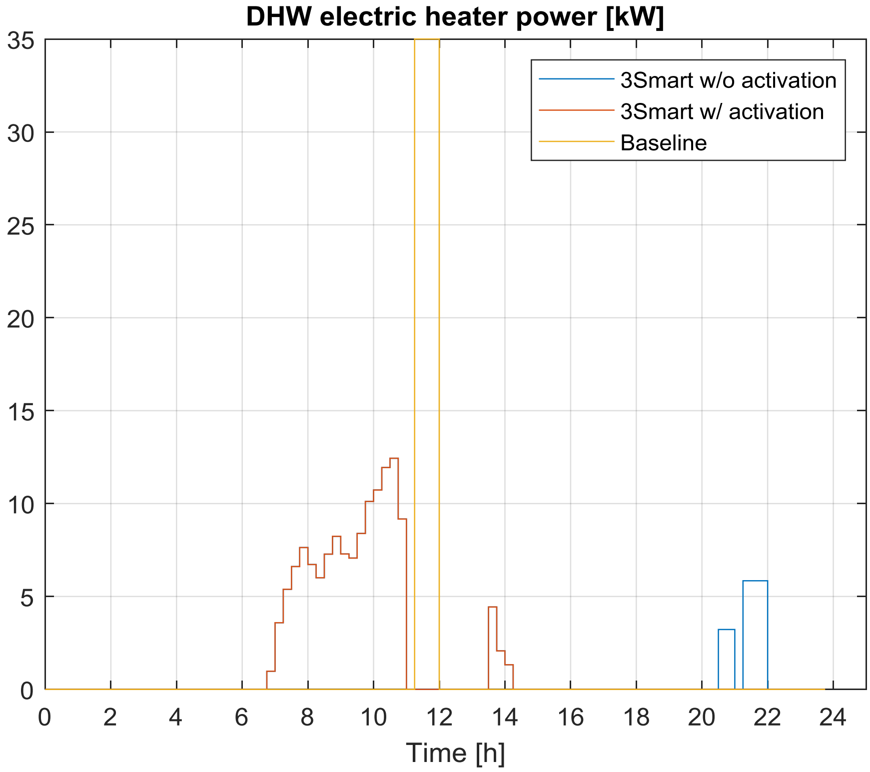


Figure 2.22. Behaviour of the electric heater or DHW during summer

Figure 2.23 provides the response of the DHW heat exchanger. It is namely considered that even in summer the heat from boilers is available when needed. It may be seen that the heat exchanger is not used when activation is not needed -- then all the heating with 3Smart is performed with electricity. When the activation occurs, then electricity heating is replaced with the heat exchanger – just before midnight to ensure repeatable behaviour of water temperature in the tank. The temperature response evidencing that is provided in Figure 2.24.

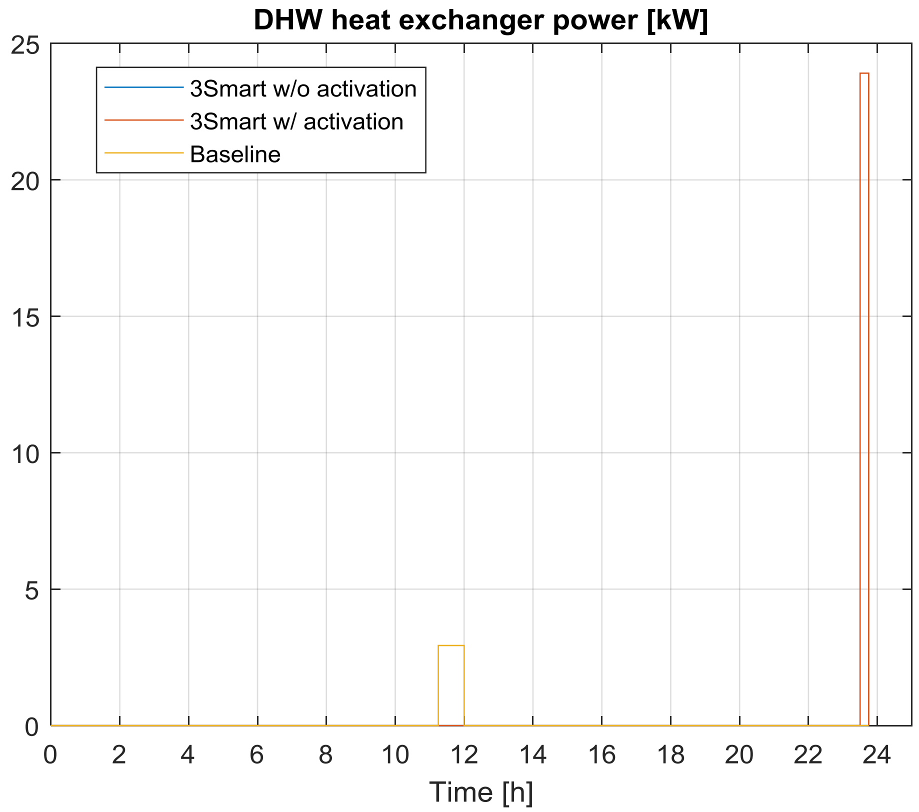


Figure 2.23. The optimized heat exchanger behaviour.

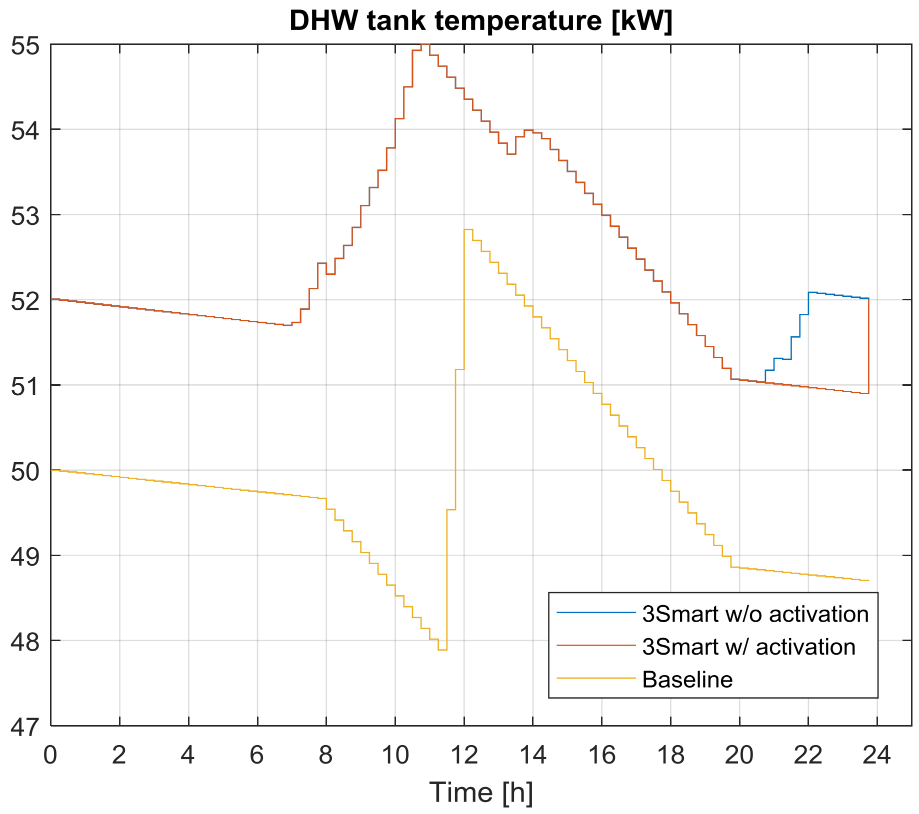


Figure 2.24. The behaviour of the water temperature in the DHW tank.

Figure 2.25 finally shows the exhibited electricity exchange with the grid for all three cases. The contracted flexibilities in flexibility intervals now differ significantly since in the first interval the consumption is not let above the peak value in order not to increase the peak power costs. The contracted peak power with 3Smart is 17.81 kW while for conventional it is much higher – some 23 kW because of not well thought action of electrical heating in the middle of the day with maximum power, as the result of hysteresis control action.

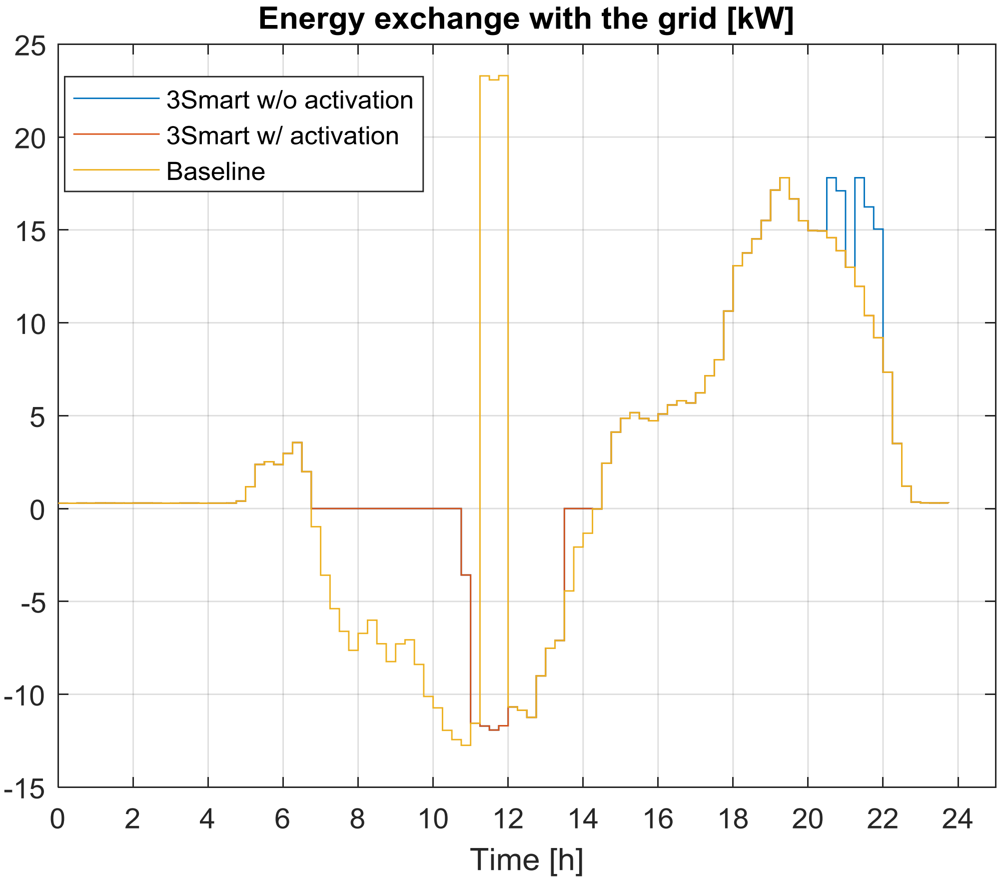


Figure 2.25 The overall electricity exchange with the grid

The CHP is not allowed to kick in as there is no heat consumption for its generated heat since there is no thermal load from the neighbourhood like in winter. It is interesting to stress that now there exists an incentive to turn on heating since it would pay off to have some heating energy consumption and any heating energy need, if exists, would be motivated to be focussed at that time of the day when flexibility should be provided – this would allow CHP to turn on. Figure 2.26 shows how the microgrid level signals that to lower-level central HVAC system. Since the price is negative, it would pay off even to waste this excess heat.

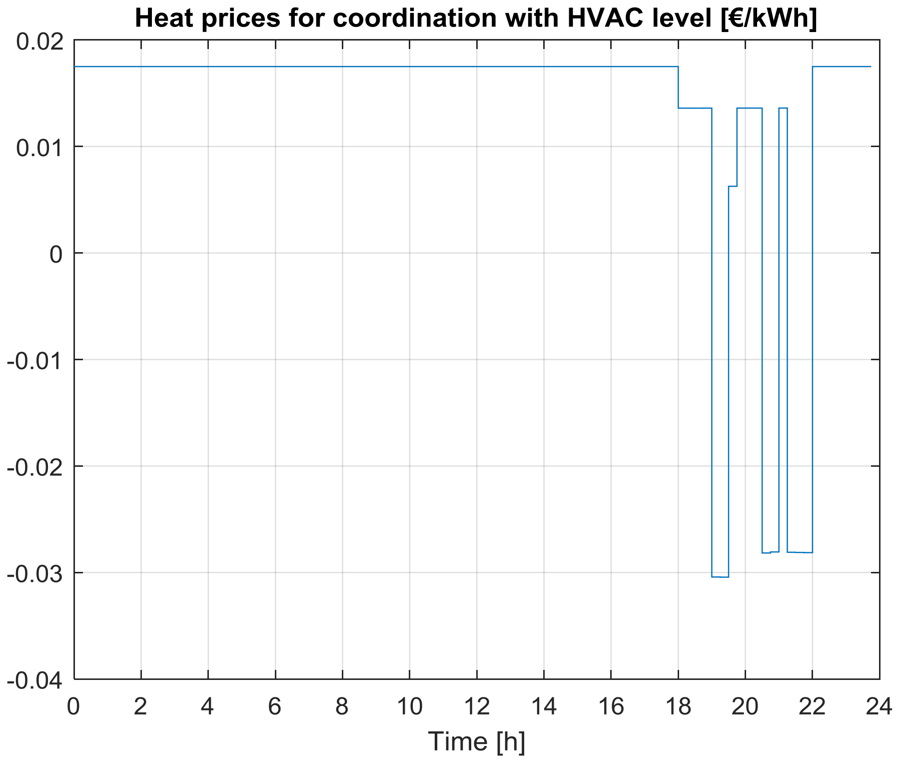


Figure 2.6 Stimulating prices for central HVAC to start consuming electricity

In transitional period, MPC will try to engage HVAC to consume heat, to make space to engage CHP, to increase flexibility, which is payed well. The flexibilities offered and money gains obtain for the buildings functioning in summer are provided in the following table.

Table 2.3 Technical and financial analysis of daily operation of Idrija buildings during summer.

Scenario	Total cost (€)
Conventional control	12.60
3Smart without activation	9.65
3Smart with activation	8.04

Flexibility interval	Flexibility amount (kW)
20:30 – 21:00	3.23
21:15 – 22:00	7.93

The gains are now on the level of 35% which is also quite significant. The average daily gain, taking into account that e.g. activation would occur for 50% of days can be quantified as the mean between the activation and non-activation gains, so at about 4 EUR.

Bibliography

[1] D7.2.2 Integrated planned energy management modules on all the buildings and in the grid for the Slovenian 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

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