Experiences of using monitoring system in buildings

EFFECT4buildings Toolbox:

Technological solutions; Annex 3

EFFECT4buildings

EFFECT4buildings

The project "Effective Financing Tools for implementing Energy Efficiency in Buildings" (EFFECT4buildings) develops in collaboration with public building managers a comprehensive decision-making support toolbox with a set of financial instruments: Financial calculation tools; Bundling; Funding; Convincing decision makers; Energy Performance Contract; Multi Service Contract; Green Leasing Contract; Prosumerism. The tools and instruments chosen by the project has the biggest potential to help building managers to overcome financial barriers, based on nearly 40 interviews with the target group. The project improves these tools through different real cases.

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Project Overview

Foreword by the Customer

State Real Estate Ltd is a project partner in the Interreg Baltic Sea Region cooperation project "EFFECT4Buildings" (http://www.effect4buildings.se/), which aims to increase the energy efficiency measures implemented by public buildings in the Baltic Sea region. The target group is public property owners, who are aware of technically possible activities and calculations to demonstrate the profitability of investments but are not able to implement them due to financial barriers.

The project results in funding methods that can improve profitability, facilitate funding and reduce the risk of public real estate investments. Examples of instruments are cost-benefit calculations, activity packages, EPC (energy service), multifunctional agreements, green rents and economic models for simultaneous energy production and consumption.

Under the Technological Solutions tool, the State Real Estate Ltd tested the possibility of two energy monitoring, which aims to manage a large building portfolio and measure the energy savings achieved by an energy efficiency project.

All new non-residential buildings have building automation system designed to automatically control the indoor environment (e.g. ventilation, heating, cooling). The main purpose of these software`s is to operate the climate systems of the building, it means to put the building service systems to work in an efficient way. The big concern is that the automatic system will provide an error message, when the functionality of the device is disrupted, but the system does not notify, if it is running ineffectively. The monitoring software aim is continuously defect’s energy fluctuations in real-time.

During the Energy Monitoring test project, we obtained monitoring for the 12-month period to 5 buildings (3 schoolhouses and 2 office buildings) as a service.

The main challenge of the test project and the desire was to get answers to the following questions:

- How will the linking of local energy meters to the cloud-based platform and data harvesting be performed on different buildings (different building automation systems)?
- Can tracking hourly energy usage data provide a faster response to possible overconsumption?
- Does the "energy monitoring" service contribute to the rising and energy efficiency of internal climate?
- Will energy monitoring enable the efficiency of the energy efficiency project to be measured?
- How much does energy monitoring in building manager and technical staff work daily? To what extent does this facilitate the management of the building?
- Do different IT-systems (e.g. Elering Data Warehouse) contribute to and enable energy monitoring?
- Feedback for used technological solutions.

This test report provides a more precise overview of the activities carried out and the results achieved. Chapter 4 “Customer and user Feedback“ gives direct feedback from the building's technical and administrative staff on the possible added value of the daily work.

Introduction and description of activities

In demo-project, five comparatively modern buildings were selected by the contracting authority, with a number of technological solutions integrated (e.g. building automation, heat recovery ventilation system etc.) (the items are described in detail in chapter0), which either has been built or renovated. All selected buildings can be operated and controlled by automatic systems and all have high energy consumption.

Main aim of the project is to find out how the monitoring of energy consumption through a remotely readable metering system could help to reduce energy consumption in the building and whether it is reasonable and cost effective.

A description by the client of the project:

"The purpose of procurement is to test the energy monitoring system. If the impact of a novel technological solution and the possible positive effect on the optimal management of the property, to measure the feasibility of investment in energy efficiency and to improve the indoor climate of the room air. The contracting authority wishes to obtain a demo period from three schoolhouse, a single office building and one internal security building with an energy monitoring.

As the BMS in all buildings was equipped with remotely readable meters, the first task was to develop solutions on how to perform the information transfer from the existing metering systems and securely deliver the data to the Energy monitoring platform. Five buildings had three different BMS software`s.

- Niagara AX.
- Siemens Desigo.
- Metasys.

After the data transmission channels were set up and the demand for consumption was carried out, monitoring of energy consumption was carried out through the power monitoring platform. A report on consumption data was carried out on a monthly basis: the activities performed, the results and energy consumption (interim reports) were summarized quarterly. This final report is prepared on the basis of the interim reports and information gathered during the project.

The contractor participated in the project by specialists and parties.

- Tõnis Vanaveski, Certified energy efficiency specialist, Level 7 (Invitation no 112340); Civil engineer (Heating and ventilation), Level 4. Role in the project: monitoring of

BMS Systems, Development and implementation of energy efficiency measures , project management.

- Kristjan Hiob, Diploma electrical engineer, Level 7 (Invitation no 151006). Role in the project: Integration of measurement systems, data harvesting, setup, project management.
- Kristjan Kookmaa, project manager with extensive experience (electricity, automation, KVJ). Role in the project: project management and counselling in developing technical solutions.
- Kristen Lalin, automatic specialist. Role in the project: Integration of measurement systems, data retrieval, BMS Setup.
- Martin Mäemees, automatic engineer. Role in Project: data retrieval, systems setup.
- Kalvin Juurik, enlightenments engineer. Role in the project: Assessment of lighting solutions.
- Vaido Velt, project manager. Role in the project: coordinating detailed mapping of buildings.
- Pristis AS. Role in the project: BMS interfaces with the monitoring system, programmatic and logical changes on objects with Niagara AX BMS systems.
- Extech DESIGN OÜ. Role in the project: BMS interface with monitoring system on the Metasys BMS system.
- Clik AS. Role in the project: THE BMS interfaces with the monitoring system on the Siemens desigo BMS System.

In addition to this, the contractor also participated in the project other staff to assist in administrative activities, development of technical solutions and energy efficiency measures, but whose role in the project was not central.

Description of the program

The project provided the following conditions for the energy monitoring software (extract from the procurement documentation).

"The Monitoring system must have built-in algorithms for the automatic use and analysis of energy use, have a degree-days conversion, enable the production of information on energy consumption which can be displayed to building users for the purpose of their cultivation (i.e. be viewable by the HTML Web browser);"

Ecoscada software basic functionality is as follows:

- A Web application that can be accessed by a web-browser and is located on a cloud-server (accessible from anywhere).
- The conversion of consumption to degree-days.
- Generate graphs (possible to create different types of charts, and the user can choose which information is displayed on a particular graph, for example, comparing different measurement points or time periods).
- Automatic monitoring and alarms (sharp changes in consumption, data transmission failure, intake limits, etc.).
- Energy and financial summaries relative to the reference period.
- Automatic reports.
- The ability to create users and user groups with different access rights.

The main arguments for the software selection were its functionality (to ensure that the required functionality was met), previous experience in using smart assets, ease of use, and cost. Other software`s, such as Dexcell Energy Manager and R8, were also considered as alternatives, but the most optimal option for starting the project was Ecoscada.

Description of the Applied alarms logic

The consumption data for the alerts were compared with one day's accuracy. If actual consumption exceeded the alarm threshold, the system sent a notification about it the next day. Alerts about alarms were forwarded by e-mail as a single letter. This means that if one recipient was among the recipients of several alarms, then all the alerts on the alarm were in one letter. A web link was added to each alert message, which could go to a particular alarm-related schedule of consumption, showing actual consumption and projected consumption.

The Alarm energy consumption was generated on the basis of different logic. In large measure, there were two types of alarms, the main difference being the permissible capping rule:

- Fixed consumption limit – the allowed quantity of specific resource consumption was written in the alarm rule,
- Adaptive threshold – The allowed quantity of consumption was calculated on the basis of the percentage of authorized consumption added to the average and alarm rules for the previous week. This means that if, for example, the alarm rule has a threshold of 120%, it 100% will represent the average for the preceding week and 20% will be the acceptable consumption deviation (in this case 20% higher consumption).

For both versions had to be satisfied with the remaining rules. For example, whether it is a working day or weekend. When the alarm rule was in effect on weekdays, the consumption of 7 previous working days was taken into account, and no rest days were counted.

In addition, it was possible for alarms to include rules that took the specific day of the week, time, or ambient air temperature (min, max, range).

The selection of alarm rules was very much dependent on the resource being measured and the nature of its consumption. For example, in Lasnamäe 2, in the case of the floor water submeters of the office building, the adaptive rule did not match because the consumption was very small and could fluctuate to a very large extent. Therefore, it had to use fixed thresholds that would help to detect more leakproof sanitary equipment.

Setting alarms has made it difficult to limit the possibilities of the energy monitoring platform. Therefore, alarms were generated more than would have been needed. The main obstacle was the comparison of thermal energy consumption by the actual external climate of heat consumption. If the consumption of thermal energy was generally converted to a number of days, there was no shortage in setting the alarms and the alarms were generated only as a result of a comparison of actual consumption. This means that during the period in which the outdoor climate and thermal consumption grew, the system sent alarms virtually every day.

In summary, it can be said that the current version of the Ecoscada system fits very well into systems whose consumption does not depend on the external climate. The functionality of alarms for regions with more volatile climate needs (the software owner is actively engaged in software development). The monitoring of all consumption of cooling and heat-consuming systems requires more flexibility in the logic of the Rules, which hopefully will arrive shortly. For the Current version of Ecoscada, more alarms can be configured for different external temperature ranges, which can improve accuracy, but this does not largely resolve the situation.

Energy Monitoring Service Overview

The following is a brief overview of the service and main activities of the energy monitoring process.

Inspection of the implementation documentation

Obtaining an overview of the number and complexity of technical systems. The collection of primary ideas to be explored on the site and discussed with other parties.

Inspection of the building automation systems

Getting an overview of the settings and complexity of utility systems. Identifying the first major issues. The collection of primary ideas that can be discussed with other parties on the subject's review.

Inspection of buildings

RKAS building managers, maintenance staff and end-users of buildings were acquainted with the surveys. The purpose of the inspections was to obtain an overview of the physical situation of the building and HVAC, to obtain an overview of technical systems and internal climate issues from various parties.

Indoor climate measurements and analyses

On all objects, indoor climate measurements were performed for at least one week. The indoor temperature, relative humidity and carbon dioxide concentration of the indoor air were measured. The purpose of the measurements was to obtain a better overview of the indoor climate and the performance of HVAC systems.

Making initial proposals and setting up settings

On the basis of the information, the first proposals were made to resolve or mitigate major indoor climate problems and to change the settings that could cause higher overconsumption. All changes to the settings were coordinated with the user of the building, the RKAS manager, and the maintenance provider. In most cases, the changes were made by the maintenance staff, but the energy monitoring contractor also received the right to do so.

Monitoring period – following EMS and BMS systems

The ongoing process of consulting custodians and techers and, where appropriate, building users, was dealt with different problems and settings.

Configuring consumption alarms in Eco**scada**

One or more alarms were set up for all meters in all buildings. For overconsumption, the system sent a message to all the recipients you entered. The alarms were mostly managed by the administrators themselves and, where appropriate, drew attention to the energy monitoring contractor. After configuring alarms, a lot of "redundant" alarms were long, which led to the set-up of alarms – changed to allowed consumption thresholds or alarm logic.

Monthly report

A report was sent to the RKAS on the monthly consumption. See0 Annex 2 – Sample of the course report. in Chapter 8 – An overview of the monthly report.

Quarter report

The main objective of the quarterly reports was to provide an overview of the consumption of the specific quarter, the problems encountered and the solutions and the work carried out. In the consumption data, the quarter of the project was compared to the quarter of the reference period (the previous quarter of the year, in the project the figures for the previous year were used as a quotation period) and highlighted changes and savings. As regards electricity and water consumption, a comparison of consumption data was carried out between the quarters of the project itself. An estimated overcharge was also included in the report at the request of the customer. Its purpose was to assess how much more could have been saved, in other words, how much of the excess consumption took place.

Presentation of quarterly reports and results

After the completion and transmission of each quarterly report, a presentation of the results took place. The main objective of the meetings was to discuss the problems and proposals described, and to find solutions to them or decide how to resolve them. If necessary, an additional person was agreed, who is to carry out what, or who must further address the specific problem. In addition, feedback was provided on past settings and changes.

Preparation and presentation of the final report

This report, which provides an overview of the results, workshops and recommendations for the future, was prepared during the project. The report also includes a presentation, but according to the situation (Covid-19 restrictions), the report will be presented later.

Description of test objects, technical interface, problems encountered

Võru State Gymnasium

General description of the building

Figure 1. Renovated part of Võru Gymnasium (source: https://lounaeestlane.ee/wp-content/uploads/2017/11/voru-gumaasium.jpg)

Heated area: 3321.7 m^2.

Year of construction or renovation of the building: 2015.

Available BMS system: Siemens Desigo.

Usage characteristics: A school building where other activities (hobby classes) can take place outside the study period.

Technical Interface with energy monitoring`s software

The BMS system uses the M-Bus protocol for data collection. In cooperation with the BMS Builder and the client, it was decided that the most optimal solution was the separation of the metering system from the BMS system and the installation of an independent central unit, the task of which was to transmit data through M-bus and data to the intermediate server through which the monitoring platform was transmitted. The reason for the separation of the systems from this object was that it was the fastest solution. The Central and intermediate server connections were made through the VPN software and the data transfer between the intermediate server and the monitoring platform through the HTTPS protocol.

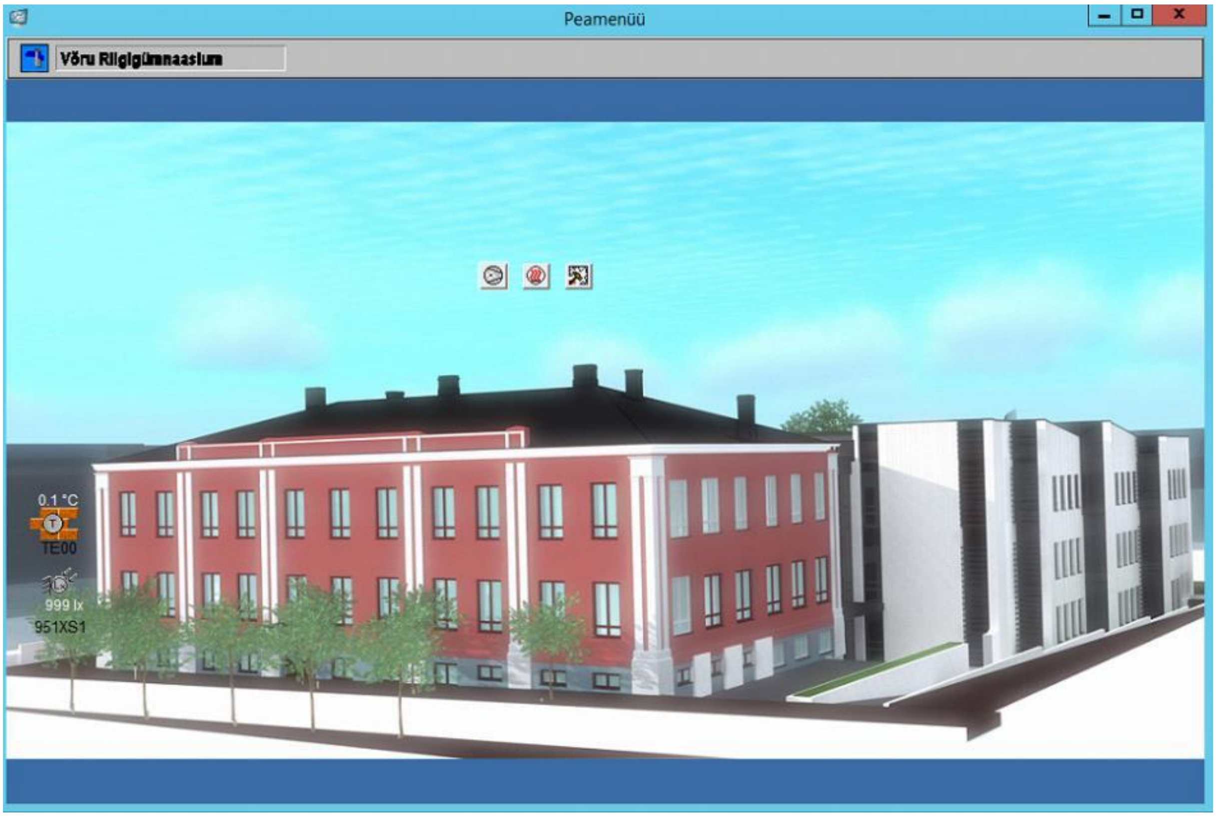


Figure 2. Building Automation Home Page

Issues discovered

System

- The building's main water meter is not connected to the BMS system, the data transfer had to be carried out manually, which was uncomfortable and did not allow for a real-time review of the building's aquifer. During the construction of the building, the water meter was interfaced with the system, but later the distributor switched off the meter and the new meter was not connected to the system.
- Due to a communication error, the technical staff reads the values manually, although the data reached the BMS system (unreasonable resource use).

BMS-System, Setup and construction

- The building automation has a lot of unpinned alarms.
- The person performing on-site maintenance is unable to receive operational information about alarms.
- The spacious client automation is built only in floor-heated rooms (mainly basement). In classrooms and other rooms there are manually configurable thermostats for radiators. In one room, different radiators could have set the settings to a minimum.
- The heating pump nodes are not connected to the machine automation.
- If the premises are overheated, the windows will be opened, but the thermostats of the radiators will not be set on minimum, and the radiators will therefore be asked to continue.

Figure 3. The windows are open due to overheating and the radiators are switched on

- Ventilation inlet temperatures are too high.
- Fuel systems are too high.
- The upper radiator temperature humiliation occurs only on weekends.
- The heating setting temperatures are too high.

- The visualization of ventilation equipment is not correct – the devices with plate heat exchanger have an exhaust ventilation fan and air intake filter shifts.
- The following information is missing from the SV304 of the ventilation aggregates, SV305 visualizations:
    - Temperature: Air intake (between the heat supply and after the heating coil), frost protection sensor etc;
    - Pressure: Air intake and extract filter;
    - Air flow rate in supply and exhaust pipe`s;
    - The instantaneous value of the heat recovery efficiency.
- In comparison with technical printouts for ventilation units, the heat recovery efficiency of devices (SV306, SV308) in practice is significantly lower:
    - SV306-PrintOut 69%, actual 53%
    - SV308-PrintOut 68%, actual 54%.

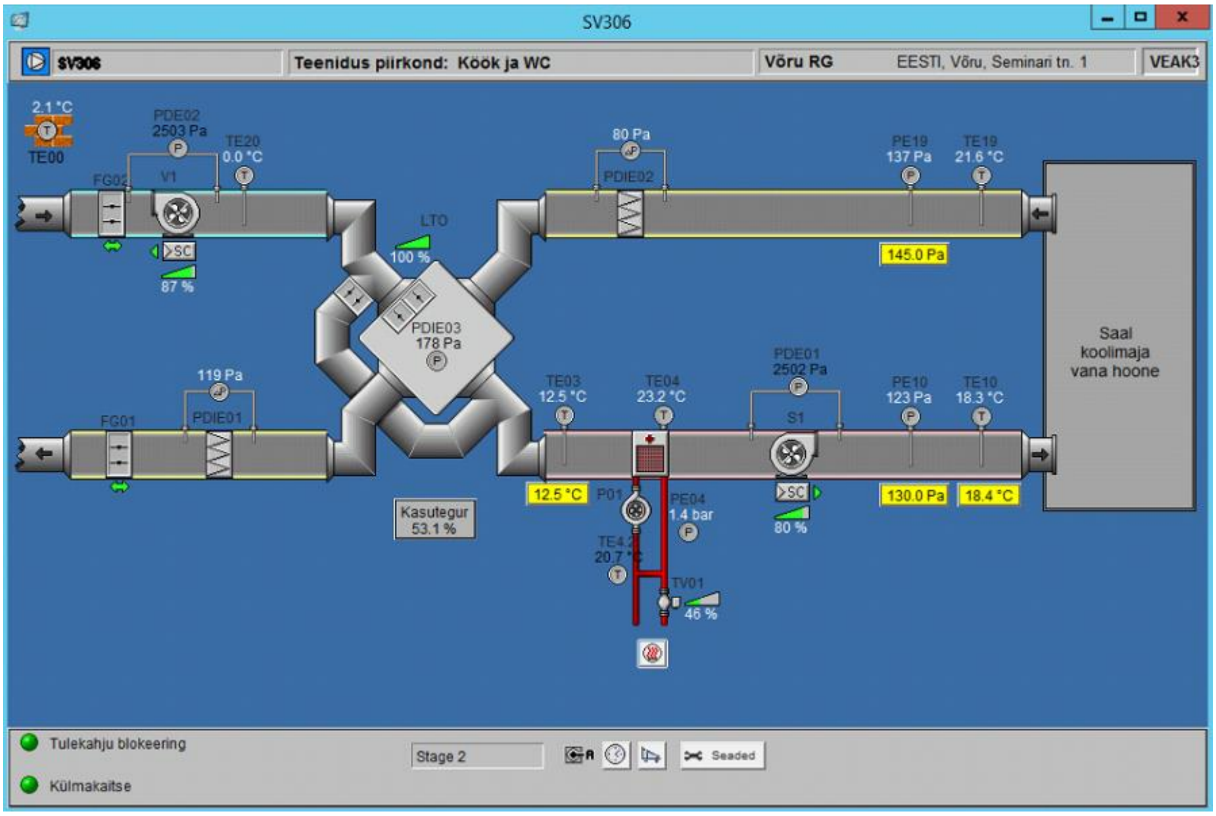


Figure 4. The heat return efficiency of the SV306 ventilation unit is considerably lower than expected

- The user does not know the exceptions to the working times of ventilation systems.
- The user does not have the opportunity to operationally turn on the ventilation system in exceptional circumstances for a specified period – the solution could be timer buttons.
- Air Curtain heat supply valve is open in a situation where it should be closed – the setting temperature is + 10 °C, the actual temperature + 26.8 °C.
- The domestic hot water circulation pump operates at 24/7.
- There are no demand control ventilation – e.g. assembly hall ventilation operates at one speed according to the time program (example from October).

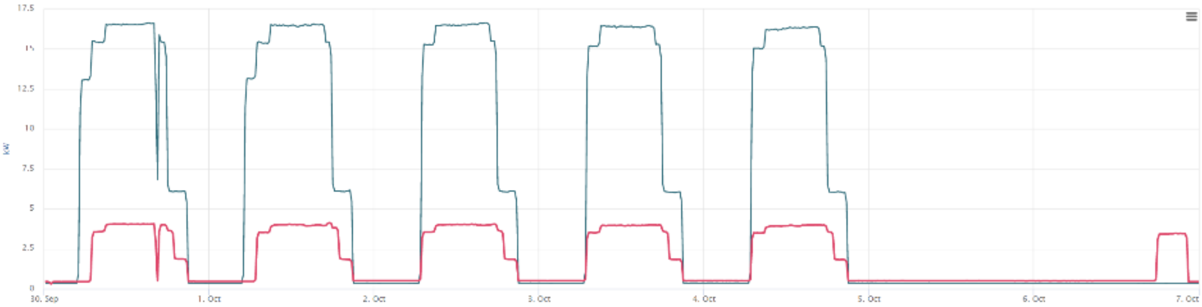


Fig. 5. Energy use of the Võru Gymnasium in October

- Ventilation equipment does not provide information on actual flow rates and therefore there is no overview of the actual flow rate of the systems and whether they correspond to the project and/or user's requests.
- The start of working time of the dining room ventilation system is too early.
- In the physics class above the kitchen (room no. 124), in the mornings the kitchen will come with smells and the teacher must ventilate the room (opening windows) to remove the smells.
- Overheating problems due to solar radiation.
- There is no night-time free cooling on the ventilation systems.
- Slow programs are not set up according to the actual use of the building – no exceptions.
- With the change of the main water meter, the meter connection was interrupted by the building automation and the consumption data must be collected manually.

Tartu Tamme Gymnasium

General description of the building

Figure 6. Source: https://tammegymnaasium.ee/wp-content/uploads/2017/12/2017_10_23-DJI_0003-nw-Tartu-Tamme-Gümnaasium_1680-e1537439597618.jpg, author Ragnar Vutt

Heated area: 7979.5 m^2.

Year of construction or renovation of the building: 2015.

Available BMS system: NIAGARA AX.

Usage characteristics: A school building where other activities (hobby classes) can take place outside the study period. Includes upper secondary school, part of adult upper secondary school and shooting range.

Technical Interface with energy monitoring software

The BMS system uses the M-Bus protocol for data collection. In cooperation with the BMS Builder and the client, it was decided that the most optimal solution was the software interface of the system administrator (who also built the system) and the contractor of the works. The data exchange between the system administrator and the executor of the works was encrypted through the client VPN and the contractor's intermediate server forward data through the HTTPS protocol to the energy monitoring platform.

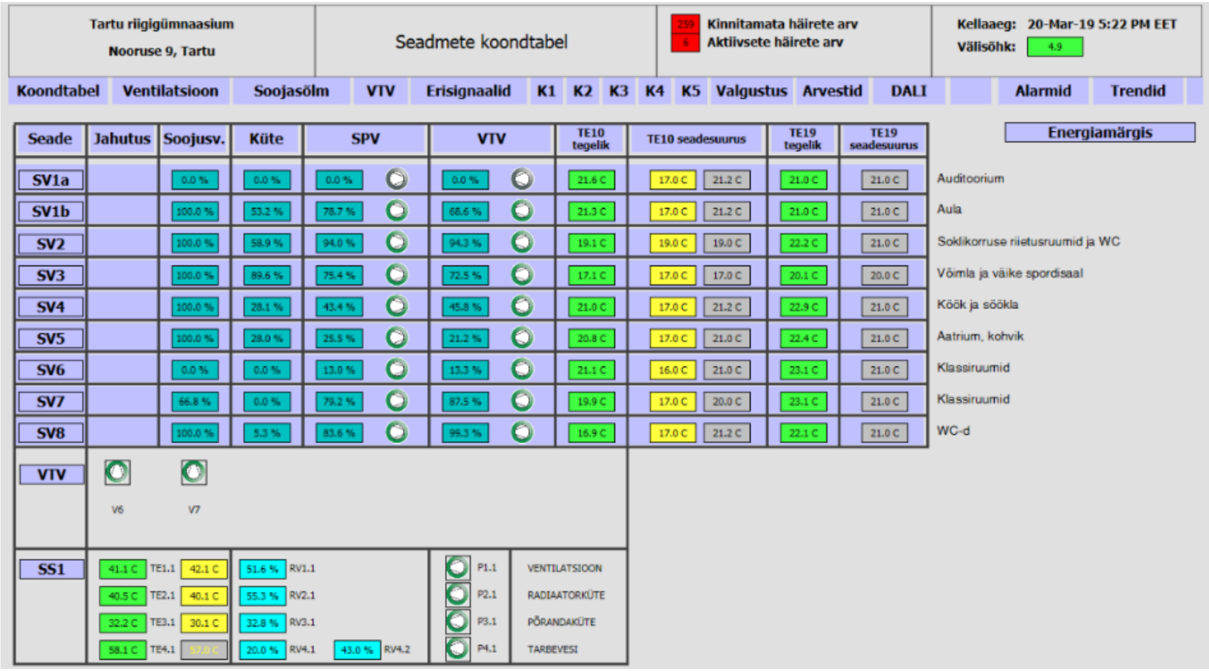


Figure 7. Building Automation System View

Issues discovered

System

- The shooting room water meters were not connected to the BMS although they it`s option.
- No heat meter for measuring the domestic hot water circuit.
- The main heat meter of the building is not connected to the BMS system, the data set had to be performed manually, which was uncomfortable and did not allow for real-time overview of the building's thermal facility. During the construction of the building, the heat meter was interfaced with the system, but later the heat distributor switched off the meter and the new meter was not connected to the system.
- Low quality of enforcement documentation.

BMS-System, Program`s and construction

- Domestic hot water set-point is too high (+ 57 ° C).
- The domestic hot water circulation pump operates at 24/7.
- The air temperature sensor in the heat circuits does not show the actual ambient air temperature because it is mounted close to the sunlight.

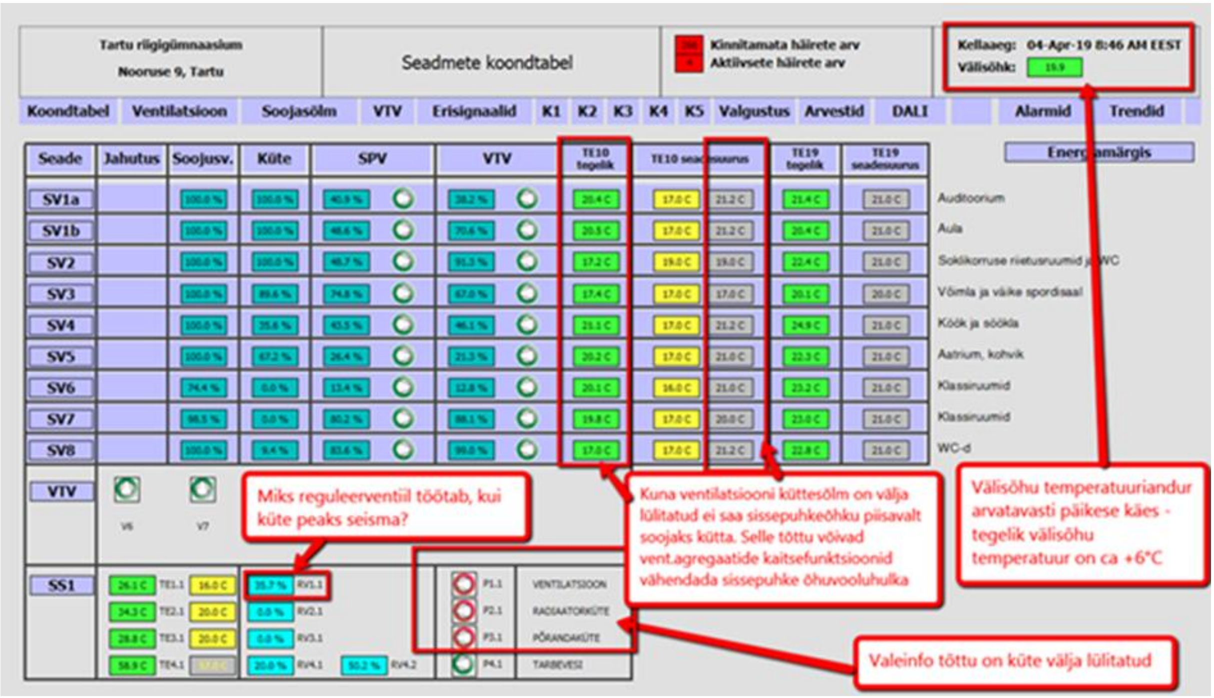


Figure 8. Impact of inappropriate placement of ambient air temperature sensor

- The blocking settings for heating systems in the ambient air temperature are not optimal.
- Ventilation heating control valve is open when it must be closed- block should apply in the ambient air temperature.
- The radiator heaters do not have a slow-down program, which can make the system stand for a summer break.
- Underfloor heating circulation pump are not connected to the building automation.
- The night-time free cooling function is not applied in ventilation controller.

- The temperature settings of the ventilation systems in the inlet air are constant - accompanied by excessive heat consumption and limiting the capacity of the ventilation systems to the free cooling.
- The airflow settings do not correspond to design airflows. The air flow rates are too small and it resulted poor air quality.
- The configurations of the building automation and the ventilation equipment are not in line-ventilation equipment works according to the slow program of both controllers, which causes anomalies.
- In the ventilation controls, the default setting is "low speed", which makes the equipment work all the time, although it should stop in the meantime.

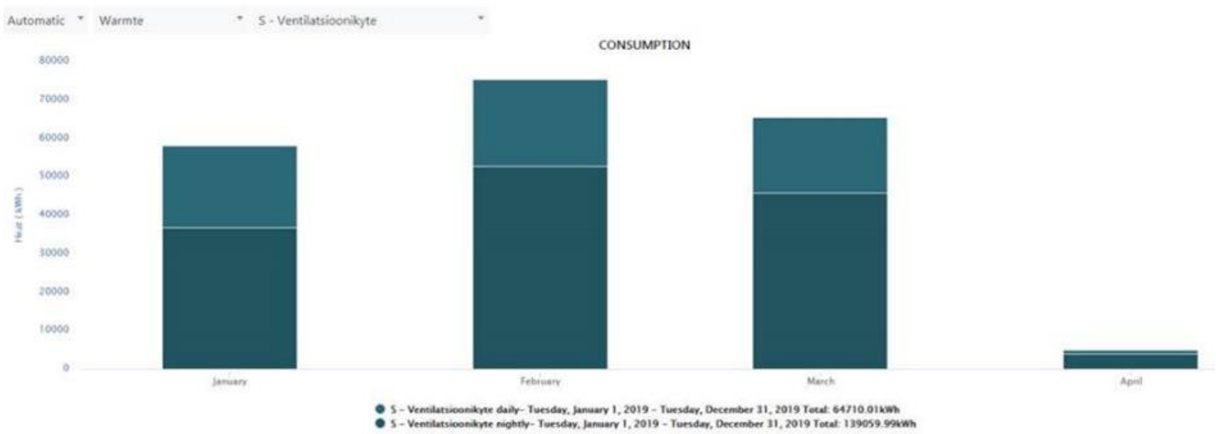


Figure 9. High energy consumption associated of ventilation systems

- The time-zone of the ventilation equipment controllers are incorrect.
- Time programs for ventilation systems in the building automatics do not correspond to the actual use and need.
- The visualization is not correct-the exhaust ventilators of the ventilation equipment are on the wrong spot.
- The air intake temperatures of the ventilation aggregates are not available in the visualization of the building automation system.

- There is no information about how the operation of exhaust ventilation V6 and V7 is controlled – constant pressure, constant speed or something else?
- The user does not have the possibility to turn on the ventilation systems quickly and operationally outside the working hours.
- There is no demand-controlled air change – the assembly hall, gym and auditorium ventilation units operate at a constant flow rate according to the time program.

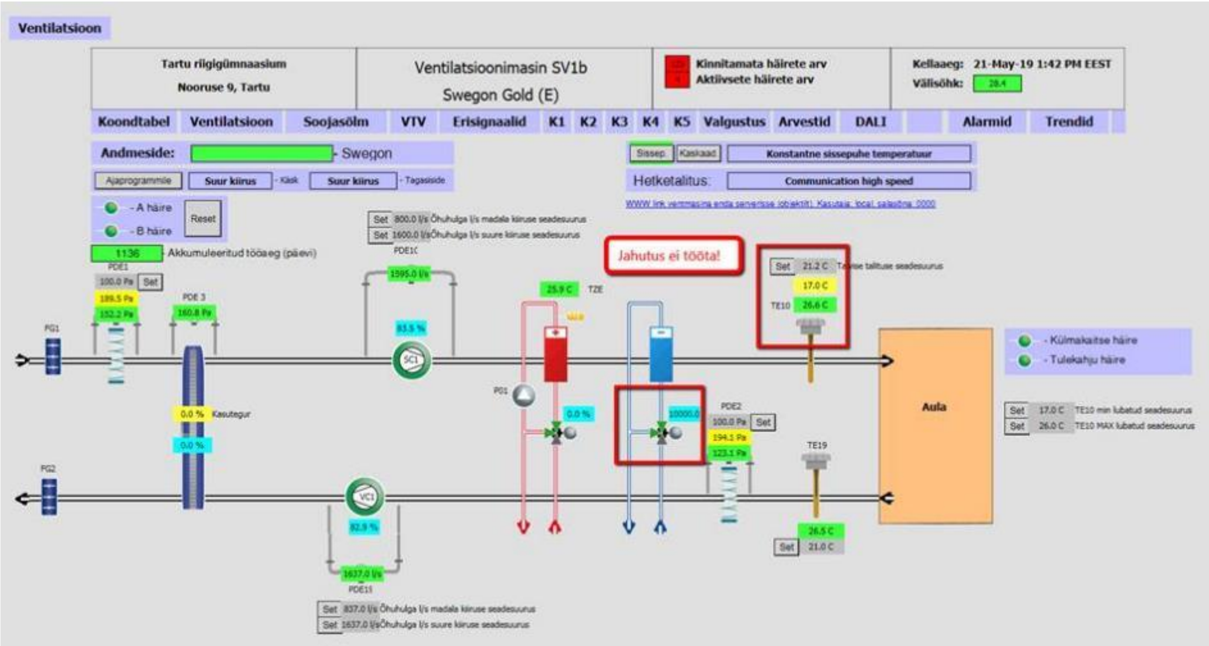


Figure 10. Ventilation device cooling is not operational

- The trends are missing air flow rates for ventilation equipment, which are critical parameters.
- Trend data in BMS is intermittent and too short.

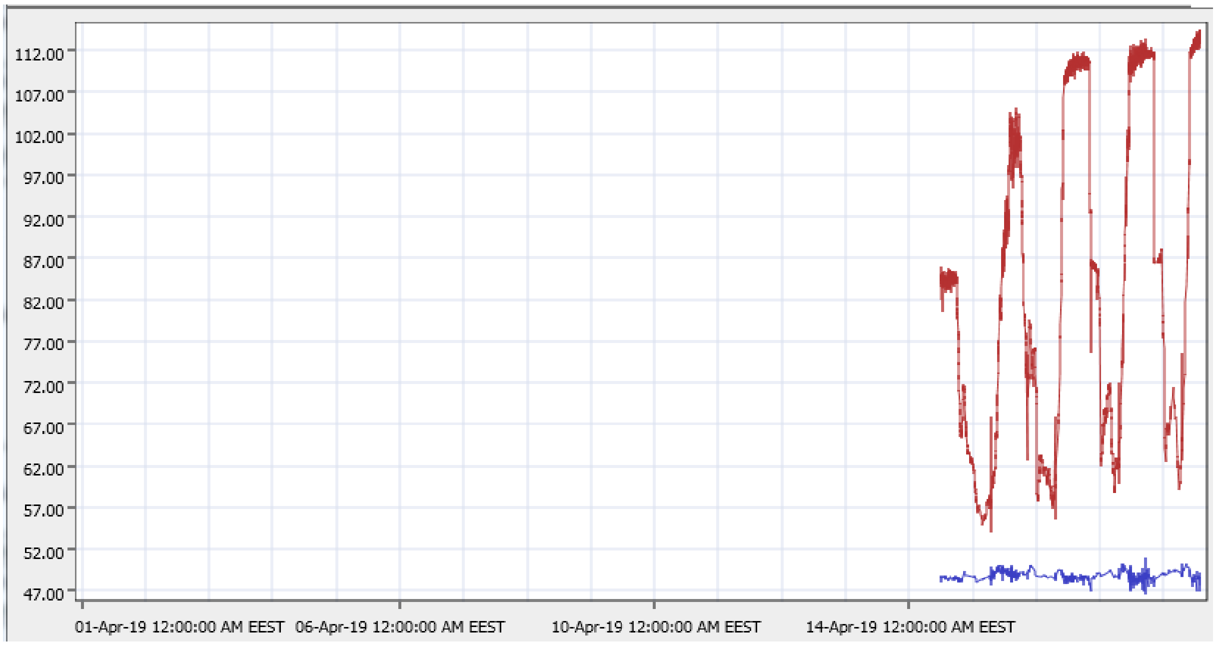


Figure 11. Trend history is too short

- Trend symbols in BMS are difficult to understand.
- The user manual of the building automation does not go into the visualizations of the actual building automation.
- It is not possible to view different data - a problem with building automation software when you sign in with a VPN connection using Internet Explorer.
- The room client management is not built on a whole heated surface.
- The heating settings of the room controllers are too high.
- Space controls have time-by-floor programs in the building automation, but there is no information about working logic the night and day-time service settings and how they can be changed.
- Overheating of the premises due to solar radiation.
- The building automation often has many unconfirmed and active interference.

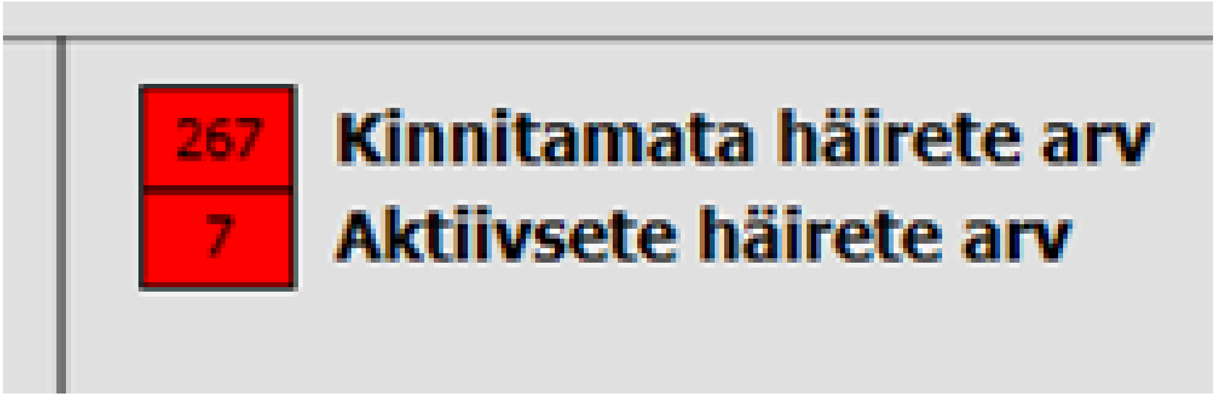


Figure 12. A lot of unconfirmed and active alarms

- Inadequate maintenance problems are not being aware, the problems are being slowly acted on, not used or the building automation is used.
- Slow programs are not set up according to the actual use of the building – weekly programs, exceptions.
- No heat recovery in systems S2, V2, V3.
- Shooting rooms ventilation systems are not connected with the building automation.
- Meters of hot and cold water on the shooting area are not connected to the BMS system, although they had a remote connection module.
- Confusion with consumption data-in connection with the exchange of water meters, the total consumption of submeters does not go together with the consumption of the main meter.
- With the switch of the main heat meter, the meter connection was interrupted by the building automation and the consumption data must be collected manually.

Tartu Rescue Centre

General description of the building

Figure 13. Source: Https://www.rescue.ee/et/asukohad/paastekeskused/louna-paastekeskus

Heated area: 4011 m^2.

Year of construction or renovation of the building: 2014.

Available BMS system: NIAGARA AX.

Usage characterization: 24 hours and 7 days a week used building.

Technical Interface with energy monitoring software

The BMS system uses the M-Bus and Modbus protocols to collect data. In cooperation with the BMS Builder and the client, it was decided that the most optimal solution was the software interface of the system administrator (who also built the system) and the contractor of the works. The data exchange between the system administrator and the works performed by the contractor was encrypted through the client VPN, and the information provided by the contractor's intermediate server was transmitted through the HTTPS protocol energy monitoring platform.

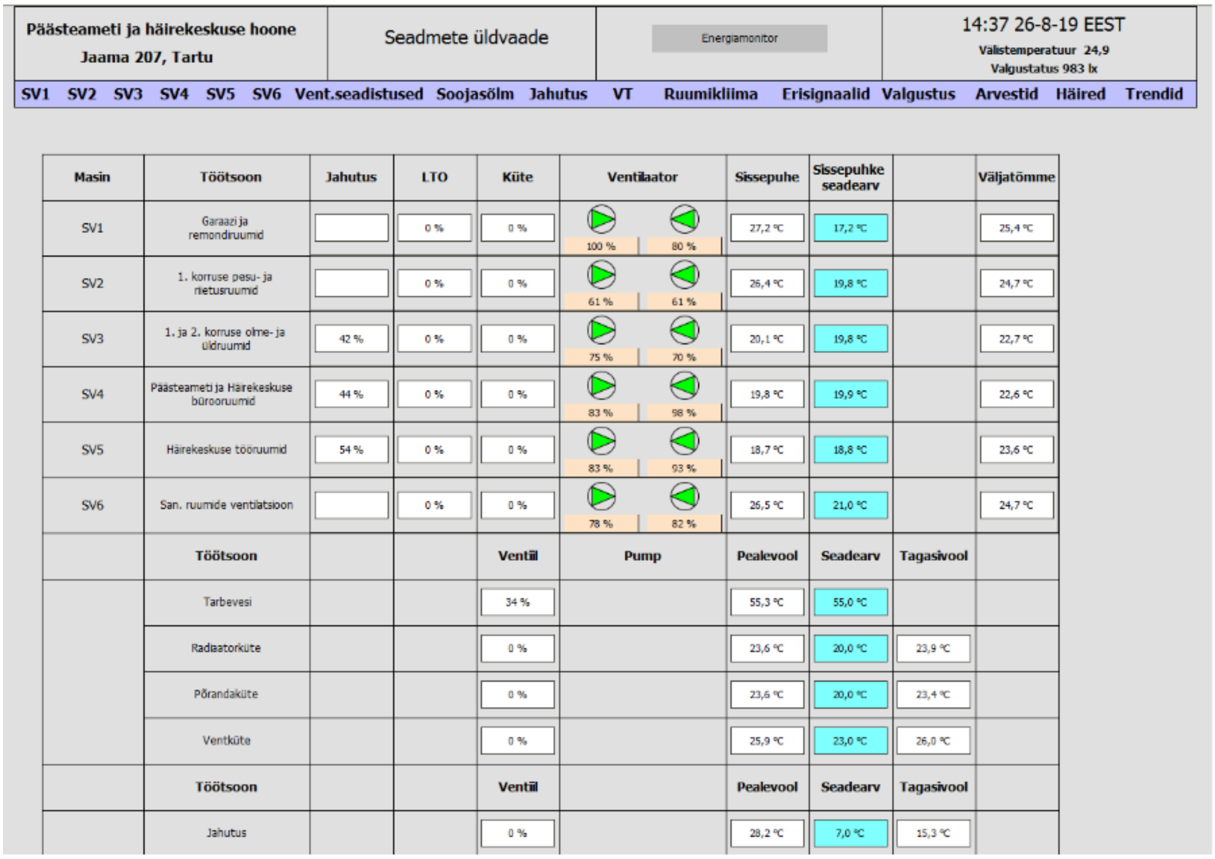


Figure 14. Building Automation System Summary View

Issues discovered

System

- No heat meter for measuring the domestic hot water circuit.
- The main heat meter of the building is not interfaced with the BMS system, the data set had to be performed manually, which was uncomfortable and did not allow for real-time overview of the building's thermal facility.
- Low quality of enforcement documentation.
- One water meter was mounted on the wrong circuit (so there were two meters for one circuit).
- Errors occurred with main electricity meters (lost data).

BMS-System, Program`s and construction

- The ventilation unit SV1 air intake temperature sensor shows approx. 6 K lower temperatures than other systems.
- Work-logic is missing in BMS visualization for generator room external air valves. It is not possible to understand how they work.
- Garage outside air valve shows 67% opening, although the control signal is 0%.
- Too small cooling-system accumulation tank. This causes the cold machine to turn on too often, which reduces the lifetime of the compressor and increases the electricity consumption
- Cooling system operates manually. Manual mode the system does not work optimally and consumes excess electricity.

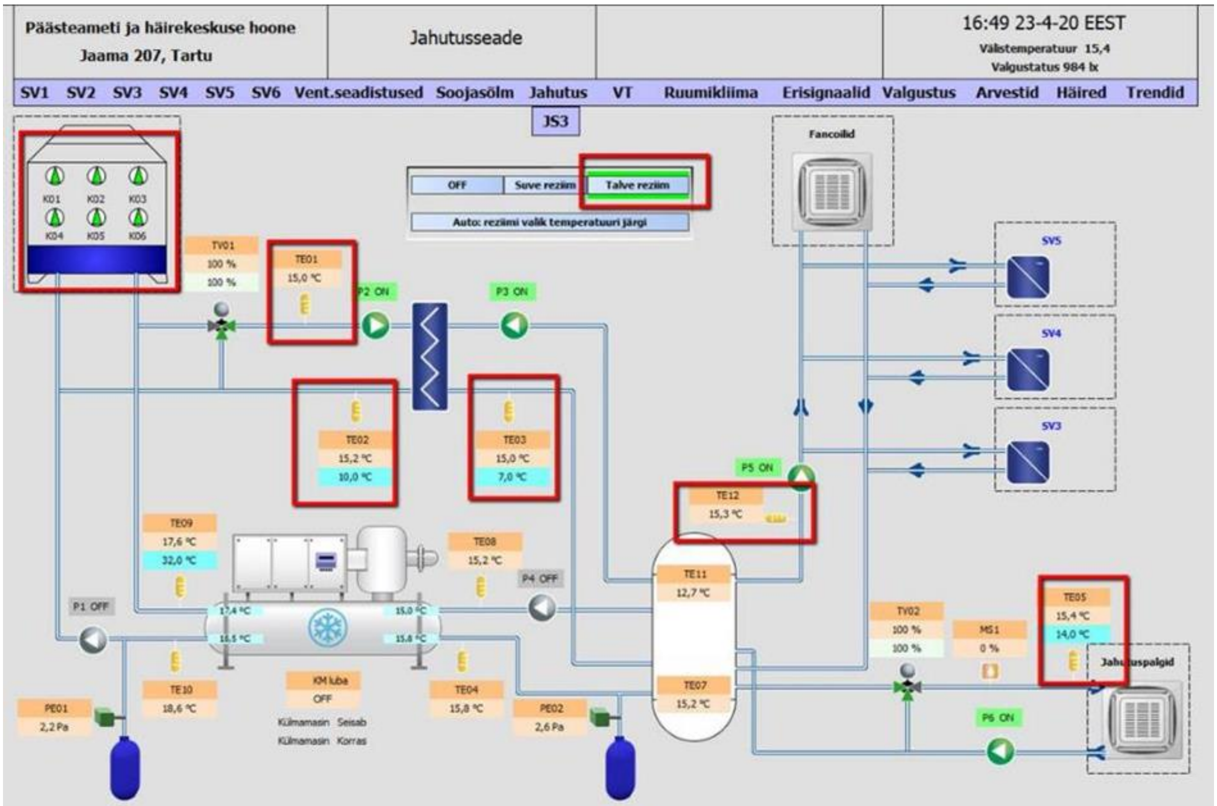


Figure 15. The cooling system operates with high energy consumption and very low efficiency.

- The temperatures of return pipe in cooling systems are missing from the BMS visualization.

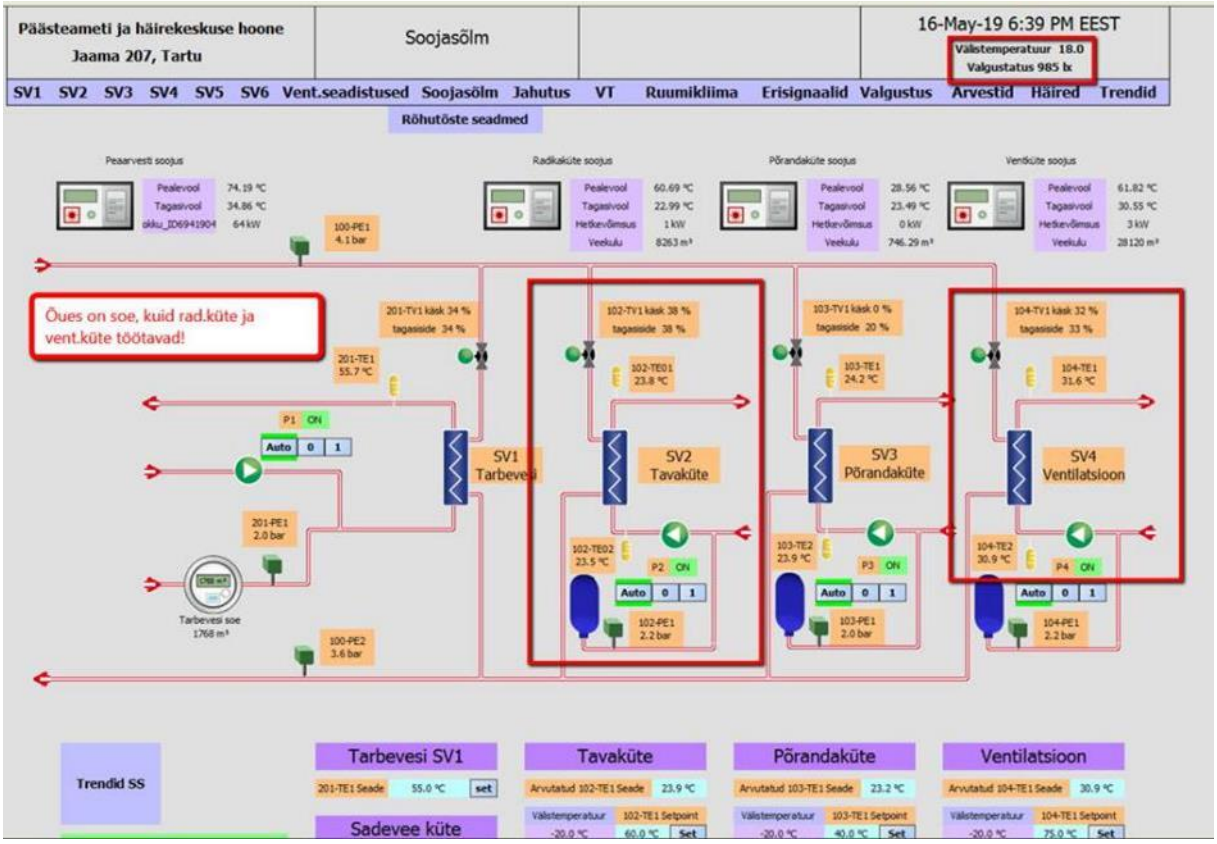
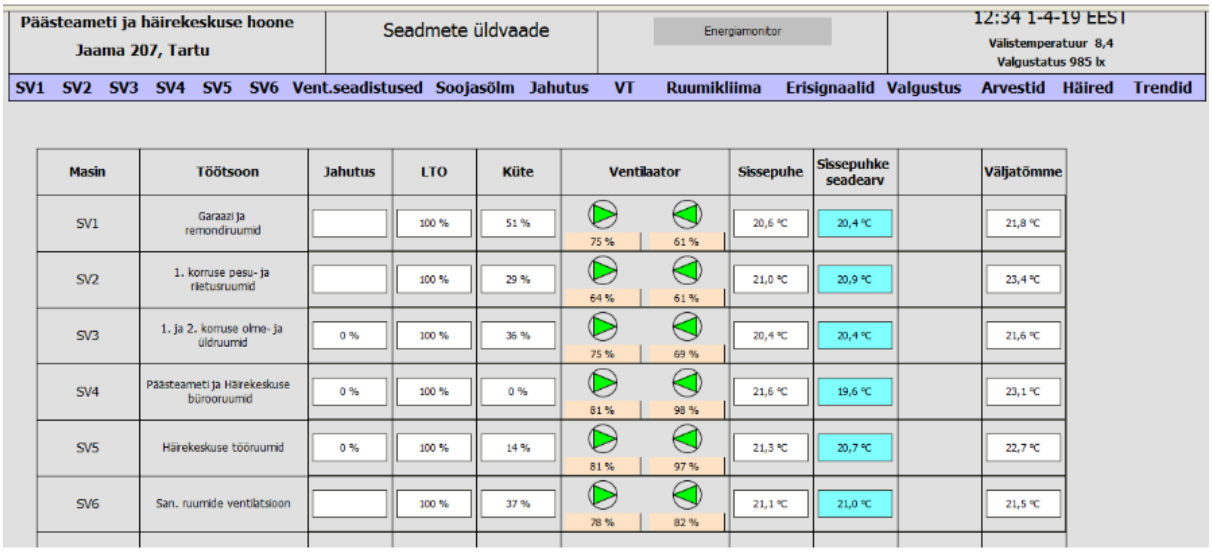


Figure 16. Radiator heating and ventilation heating circuits work in warm weather

- Ventilation heating is working in "auto" mode. It is not possible to understand what logic or number of settings the suspension has occurred.
- In BMS there is no efficiency % of ventilation equipment. The corresponding text exists, but the value is not displayed. According to the automatics, the efficiency value is shown when the ambient air temperature is below 8 ºC.
- The temperature sensors in the ventilation equipment show sometimes unlogical numbers. Therefore, it is not possible to finish understanding whether and where the problems are located. For example, 26 august at 14:45 is the SV4 outdoor air

temperature of + 22.6 °C and the supply air temperature of 28.1 °c and the heat supply does not work. 5.5 K The temperature rise cannot be due only to the fan.

- Air intake temperatures of ventilation equipment are approx. 5 K higher than the ambient temperature sensor reading (26.08, at 14:45). Indicates that the ambient air is warming up in addition to something, such as a dark wall or a roof that air is taken from.
- The cooling return function of the heat exchangers is not applied to the ventilation equipment.



Masin	Töötsoon	Jahutus	LTO	Küte	Ventilaator		Sissepuhe	Sissepuhke seadearv		Väljatõmme
SV1	Garaazi ja remondiruumid		100 %	51 %	75 %	61 %	20,6 °C	20,4 °C		21,8 °C
SV2	1. korruse pesu- ja riietusruumid		100 %	29 %	64 %	61 %	21,0 °C	20,9 °C		23,4 °C
SV3	1. ja 2. korruse olme- ja üldruumid	0 %	100 %	36 %	75 %	69 %	20,4 °C	20,4 °C		21,6 °C
SV4	Päästeameti ja Häirekeskuse bürooruumid	0 %	100 %	0 %	81 %	98 %	21,6 °C	19,6 °C		23,1 °C
SV5	Häirekeskuse tööruumid	0 %	100 %	14 %	81 %	97 %	21,3 °C	20,7 °C		22,7 °C
SV6	San. ruumide ventilatsioon		100 %	37 %	78 %	82 %	21,1 °C	21,0 °C		21,5 °C

Figure 17. Too high ventilation supply temperatures

- In the spring months, the free-cooling has worked inefficiently-with a large electricity consumption.
- The main heat meter is not connected to the building automation system.
- All ventilation systems operate at full speed around the timetable.

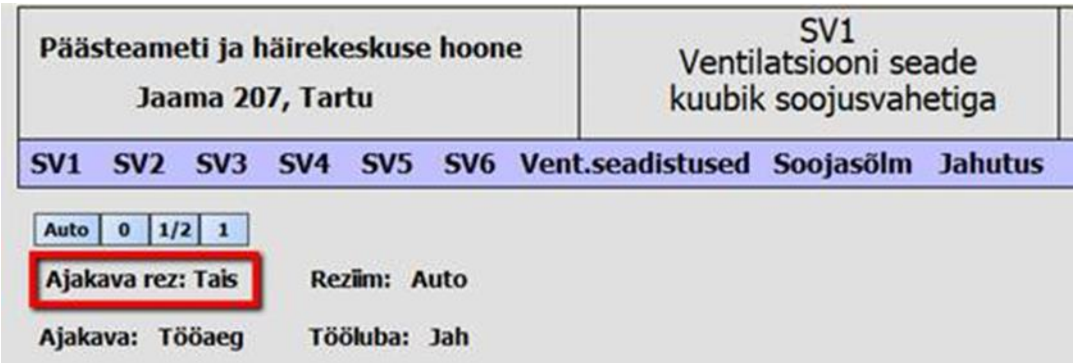


Figure 18. Ventilation Unit SV1 operates at full speed in manual mode

- The inlet temperature of the ventilation unit servicing the sanitary rooms is too high.
- CO_2 sensors in many rooms show the measurement results to 300 ppm or less. Such readings are not real because outdoor air CO2 level is approximately 350-450 ppm.
- The numbers of room-controllers are too high (23-25 °C).
- In winter mode, the settings of the cooling system are not logical - the primary side of the free cooling setting is higher than the secondary side setting.
- The cooling system works even then there is no need

Põlva State Gymnasium

General description of the building

Figure 19. Põlva State Gymnasium

Heated area: 2321.6 m^2.

Year of construction or renovation of the building: 2016.

Available BMS system: NIAGARA AX.

Usage characteristics: A school building where other activities (hobby classes) can take place outside the study.

Many technological solutions have been integrated into the building, such as external blinds, aiming at passively reducing the overheating of spaces; needs-based ventilation; rainwater collection, LED lighting and local power generation.

Technical Interface with energy monitoring software

The BMS system uses the M-Bus protocol for data collection. In cooperation with the BMS Builder and the client, it was decided that the most optimal solution was the software interface of the system administrator (who also built the system) and the contractor of the works. The data exchange between the system administrator and the works performed by the contractor was encrypted through the client VPN and the information provided by the contractor's intermediate server was transmitted through the HTTPS protocol into energy monitoring platform.

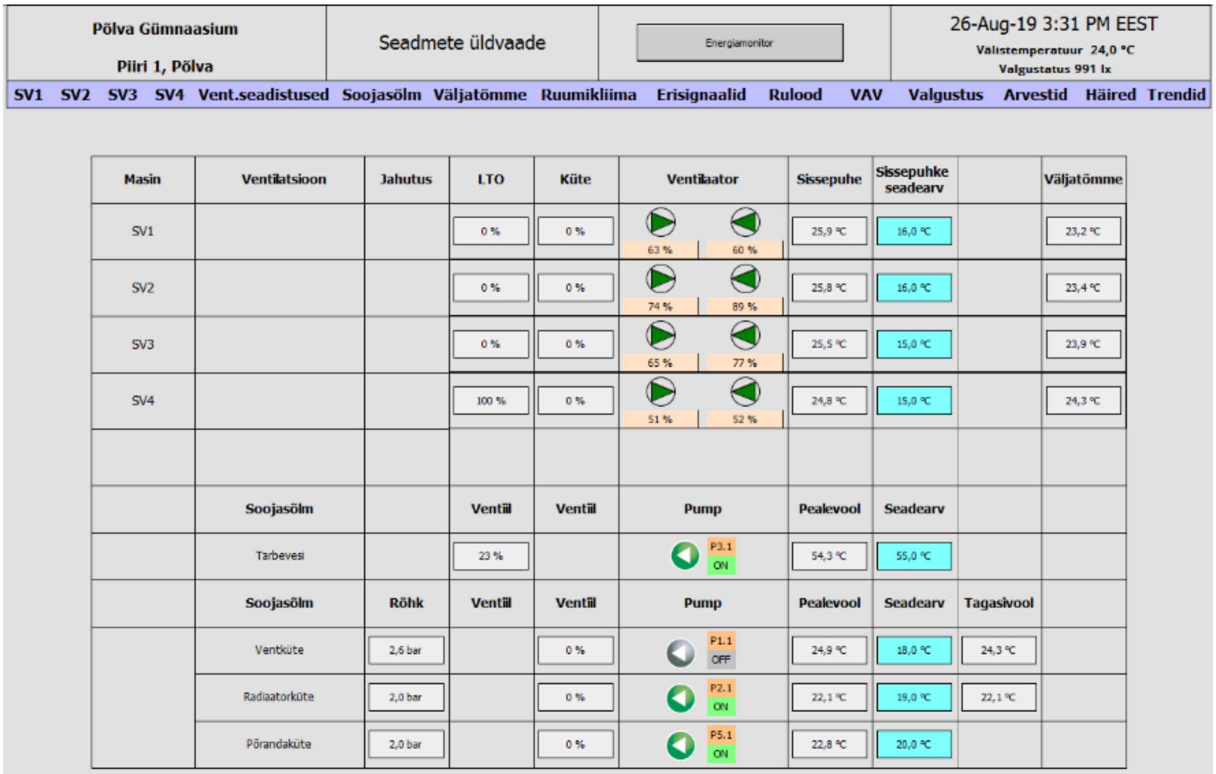


Figure 20. Building Automation Summary View

Issues discovered

System

- The meter installed to calculate the productivity of solar panels was not properly set up (the amount of energy consumed, not produced, was considered in the system).
- No heat meter for measuring the domestic hot water contour.
- Low quality of enforcement documentation.

BMS-System, setup and construction

- The electricity meter for PV panels was not properly set up. All electricity production information began to be received only in the autumn of 2019. There is no overview of the electricity energy sold to the network, it can be seen through the network analyzer.
- Unsuitable air diffusers in the classroom.

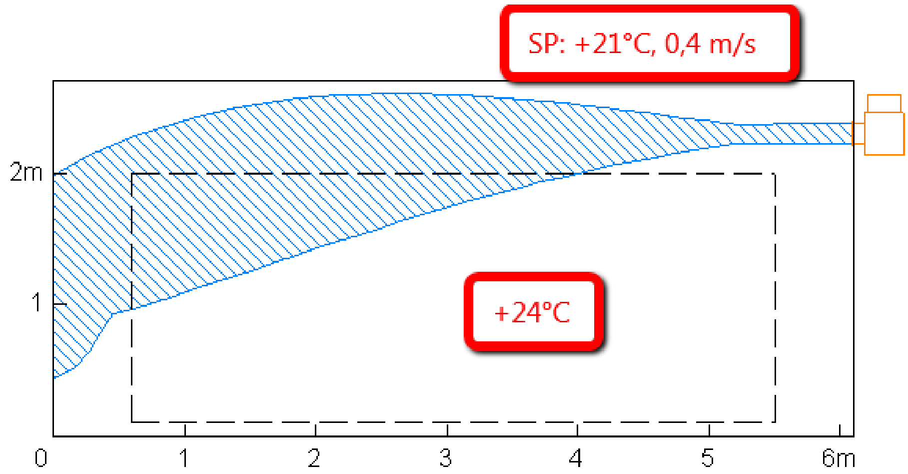


Figure 21. The Inlet to the entrance zone falls into the pupils-zone and the result is discomfort.

- Incorrect radiator position. In classrooms there are almost a wide range of windows that should be faced with radiators that generate the windows in the heating period in warm air as a "curtain", which reduces the window's low radiated temperature effect and heats up a cool air flow in front of the window. In practice, the radiators are mounted on the inner wall, which provide the necessary heating power in the room, but does not reduce the discomfort caused by the cold window.

Figure 22. Inappropriate placement of the radiator

- Overheating of the premises due to solar radiation. The outside Windows installed with automated blinds will mitigate the situation but will not solve the problem.
- Ventilation systems do not have passive night-time free cooling.
- The user does not have the option to operatively turn on ventilation systems in exceptional circumstances. The simplest solution would be timer buttons.
- The spacious client automation is not built in full – the heated surface is covered by CA 2/3.
- Slow programs are not set up according to the actual use of the building – weekly programs, exceptions. Heating also works in summer. Ventilation systems operate at night or in the weekend when no one is present in the building.

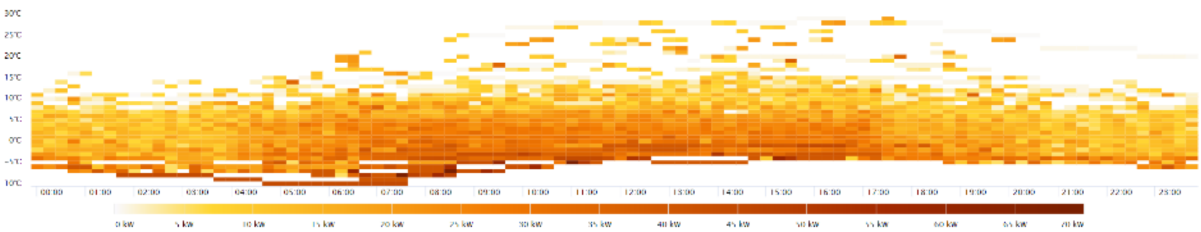


Figure 23. Heating capacity according to ambient temperature and time

- The ventilation systems were switched to the manual control, which resulted in them continuously working at one speed.

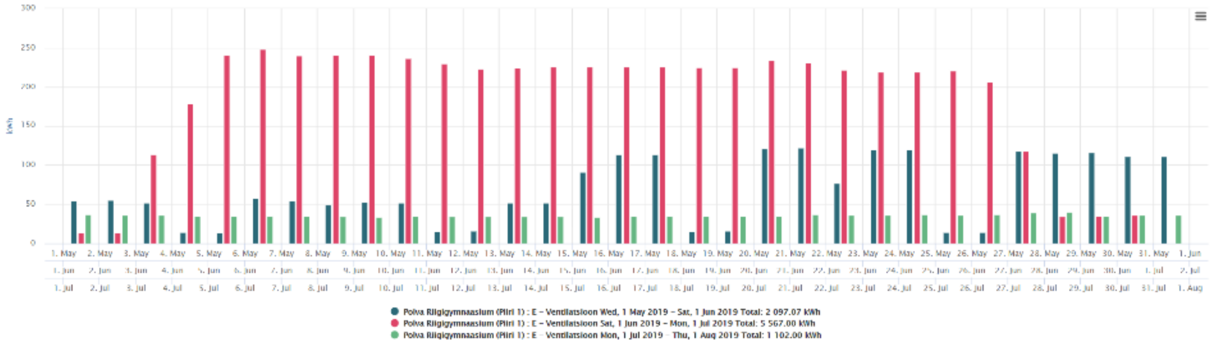


Figure 24. Electricity consumption of the ventilation system 01.05-01.08

- Too high heating setting temperatures in space controls and ventilation.
- In rooms with a spacious client automation, the heating setting temperatures and the permitted limits are too high.
- Working hours of room controllers/rest time setting is not optimal – the morning upstart starts too early.
- A blockage of the ventilation heating node occurs at an excessively high ambient temperature.

Lasnamäe 2 Office Building

General description of the building

Figure 25. Lasnamäe 2 office building (source: https://www.arihooned.ee/719-lasnamaee-2)

Heated area: 8928 m^2.

Year of construction or renovation of the building: 2009.

Available BMS system: Metasys.

Usage characteristics: office building.

Technical Interface with energy monitoring software

The BMS system was based on the Bacnet protocol and the records of data harvesting were made via M-Bus protocol and pulse concentrators. In cooperation with the BMS Builder and the client, it was decided that the most optimal solution was to connect the Central Unit of the work contractor to the BMS Bacnet network and through IP communication to inherit data directly from the BMS system. The Central unit was responsible for the data retrieval of the Bacnet protocol and the transmission of data to the intermediate server through which the data monitoring platform was transmitted. The central and intermediate server connections were made through the VPN software and the data transfer between the intermediate server and the monitoring platform through the HTTPS protocol.

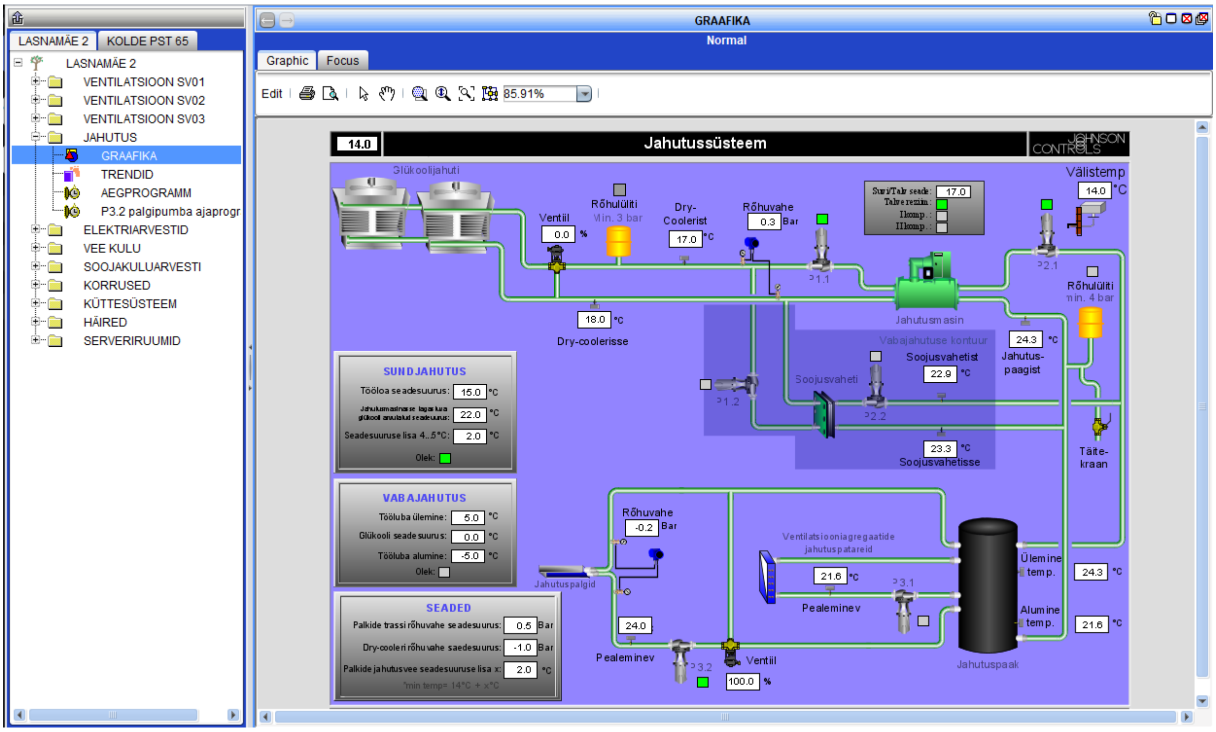


Figure 26. Building automation menu and the visualization of the cooling system

Issues discovered

System

- A remote reading module is installed on the main water meter, but it is not connected to the BMS system.
- Part of the water meters of the floor is installed in incorrect position where the "head" of the meter is pointing down. This installation is not permitted by the manufacturer. Some water meters are also installed in such a way that it is not physically possible to read them, or the information that is displayed on the system must be guided. It is therefore not possible to verify whether the indication in the system corresponds to a real indication.

- Floor water meters have been replaced a few years ago by new ones, but because the data transmission is done through impulses, the BMS readout does not count with the real physical meter, as the BMS also contains the impulses sent from the pre-installed meters (i.e. the current reading consists of the current meter and the sum of readings from the previous meter).
- The reading of one of the water-meters on the VI and X floors in the BMS system does not change (the system is not working properly or the error is made when installing).
- The humidification system does not have a separate water meter.
- The consumption of the ventilation unit submeter is unrealistically low (the system does not work correctly).
- Low quality of the enforcement documentation.

BMS-system, setup and construction

- According to the time program, the cooling system runs during certain periods also at night while the building is not in use.

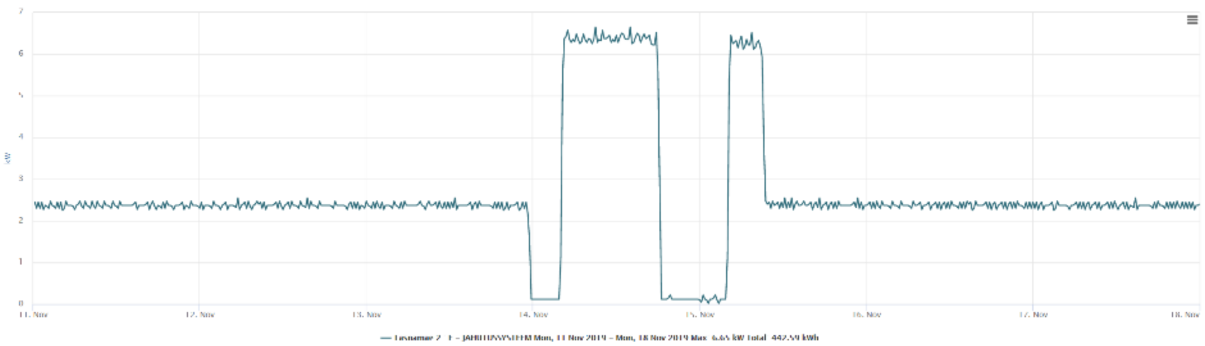


Figure 27. Electricity consumption of cooling system 11-18.11

- There are no exceptions to the slow programs for ventilation systems.
- There are no exceptions to the slow cooling systems.
- The setting size of the free cooling glycol is too low (+ 12 °c).
- No use of radiator heating is used to lower the temperature in the outside working hours.

- Fuel systems are sometimes too high.
- There shall be an uncovered area between the upper setting of the free-cooling work permit and the set-up of the forced cooling work permit, where neither are allowed and no cooling takes place.

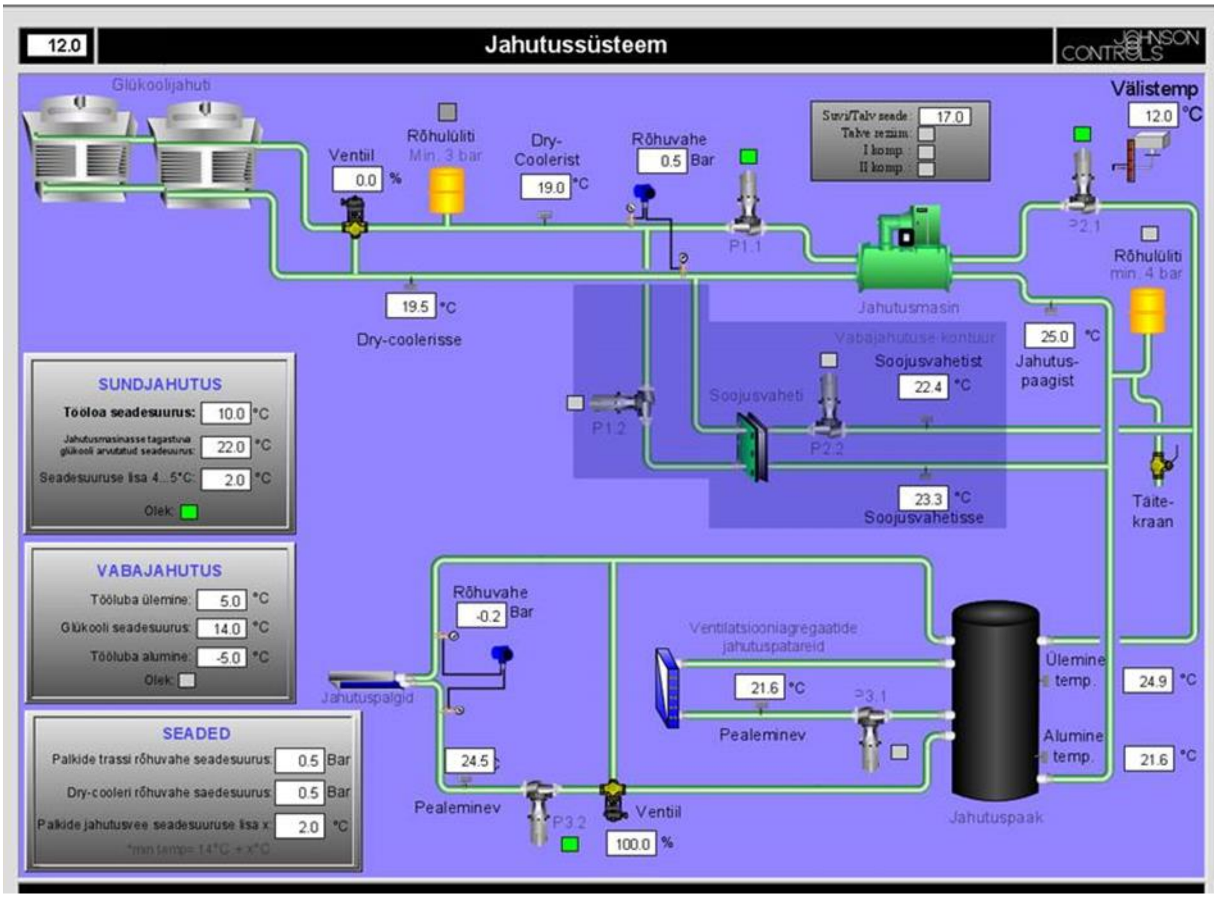


Figure 28. Due to an unsuitable setup, the cold machine is not working and the cold carrier is not cooled, but circulating pumps spend electricity

- The calculated device size of the glycol returned to the cooling machine is too low (2 K). This makes it necessary to move more air from the dry-cooler to cool the coolant and therefore to spend electricity to cool the returned glycol.
- Ventilation systems operate on half speed during the heating period 4.00-6.00.
- There is no information as to what logic the *dry*-cooler works.
- *Dry*-Coolers are not visualized.

- The temperature sensor in the lower part of the accumulation tank is not connected to the building automation. The visualizations indicate the temperature of the ventilation cooling flow.
- The cooling graph lacks temperature sensors for cooling logs and ventilation cooling back.
- The cooling graph does not present the frequency converters of the circulating pumps.
- There is no information about how to calculate the surface flow of cooling logs by component X.
- The pressure spacing of the cooling logs system is 0.5 bar, but the actual reading is 0.1 bar.
- *The Dry*-cooler pressure differential is on the cooling graph-1.0 bar, but the actual reading is 0.3 bar.
- There is no information as to the logic under which the upper and lower work permits of the cooling set forth in the quench graph are run, and the setpoint of the forced cooling work permit for the operation of the systems.
- There is no information on the calculation of the "calculated setting of the glycol in the cooling machine" shown on the cooling graph and what is meant by "annex to the device size".
- No information on the number or logic of the ventilating cooling pump P 3.1 is switched to the work.
- The circulating pump P 2.2 does not comply with automatic control and consumes electricity and heats the cooling system

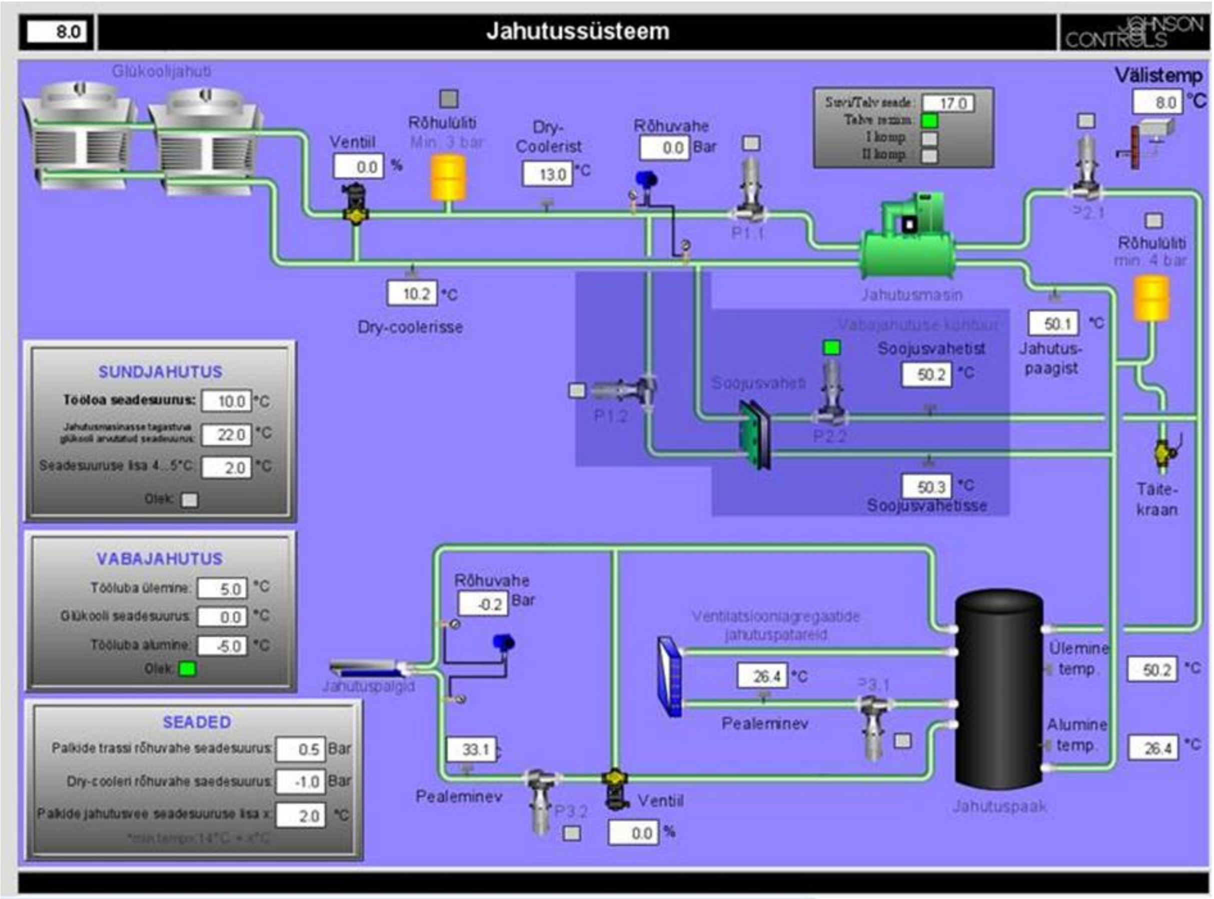


Figure 29. Circulating pump P 2.2 does not respond to automatic control

- There is no information about whether the cooling circulation pumps p 1.1 and P 2.1 are controlled by the cold machine and what is logic of operation of these pumps.
- The ambient temperature sensor of the heat node is + 20.9 °C and at the same time the exterior temperature sensor reading + 10°c.
- 1-6 and 8. floor space controllers are not shown in visualizations analogous to 7 and 9. floor. Therefore, there is no general overview and it takes a very long time to obtain information.
- There is no information about the size of the room-controllers dead-zone temperature.

- There is no information about the size of the space controls in the dead zone and the logic according to which the controller calculates the temperature for heating and cooling.
- The cafe smells move to the conference halls.
- No info how you can choose to change the time interval displayed in the building automation visualization.
- VAV and CAV valves are missing visualizations and there is no information about these statuses and logic.
- Too high inlet air temperature setting figures. In case of lower setting temperatures, users complain about the snap.
- Irrigation is accompanied by high energy consumption. Irrigation also works in the warmer period.

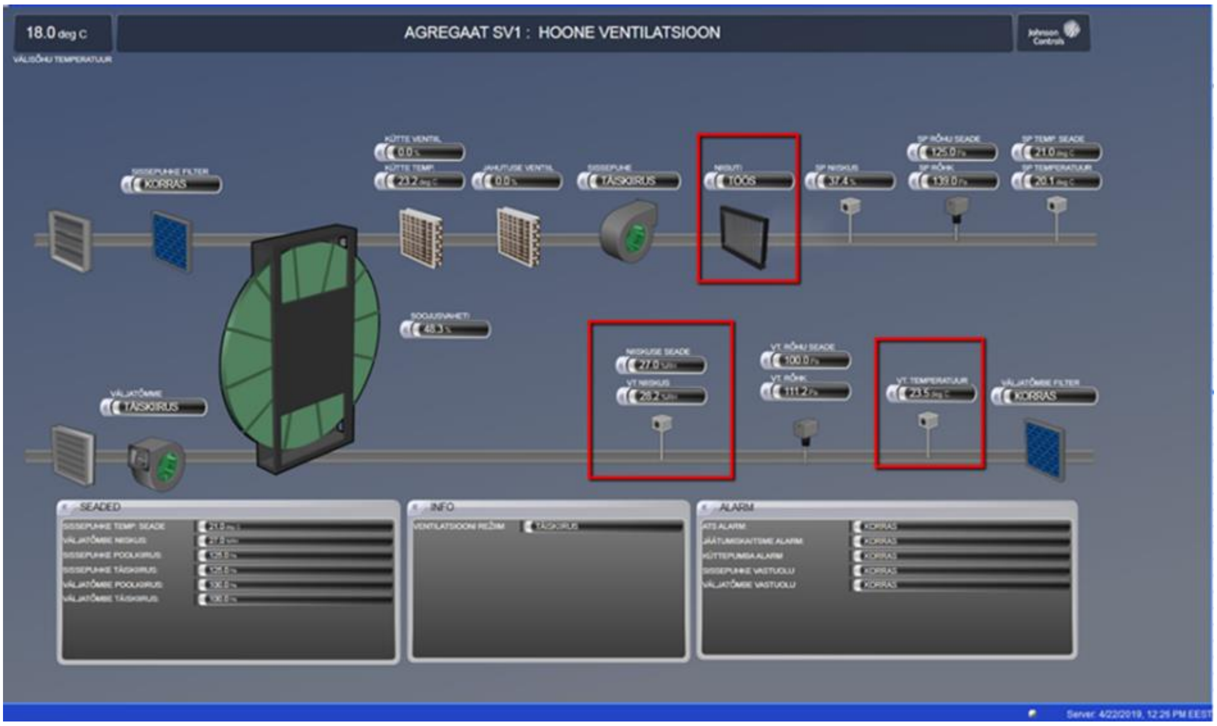


Figure 30. Humidifier also works in warm outdoor climate period while external air humidity level is suitable.

- Server room in floor 4. Setpoint temperature is too low. In the case of a higher setting temperature, the relative air humidity is too high.
- Server room in floor 4 actual temperature is significantly lower than cooling setpoint.

Results achieved

Due to the fact that there were shortcomings in the enforcement documentation of the objects, the systems were not properly set up and structural errors were made, it was possible to start with system optimization significantly later than planned, since the before mentioned errors had to be clarified and corrected in the case of energy use, but which could be diagnosed due to energy and BMS monitoring. This shows how important it is for the contracting authorities to have thorough control over the execution of the building and the inspection and acceptance of the work of the systems, since the subsequent diagnosis and repair of errors are considerably more time-consuming and costly.

Below are the terms used for describing results and comparing consumption (i.e. reference period) and the period of the project.

- The reference period is 12 months immediately preceding the project: 01.03.2018-28.02.2019. Consumes up to 3 years prior to the project have been the same for buildings that have been in use for a long time. New and newly renovated buildings have fluctuated widely in consumption in the first years. As a result, only the last 12 months were taken for the reference period.
- The period of the project in which monitoring took place is 12 months following the reference period: 01.03.2019-29.02.2020.

Total objects

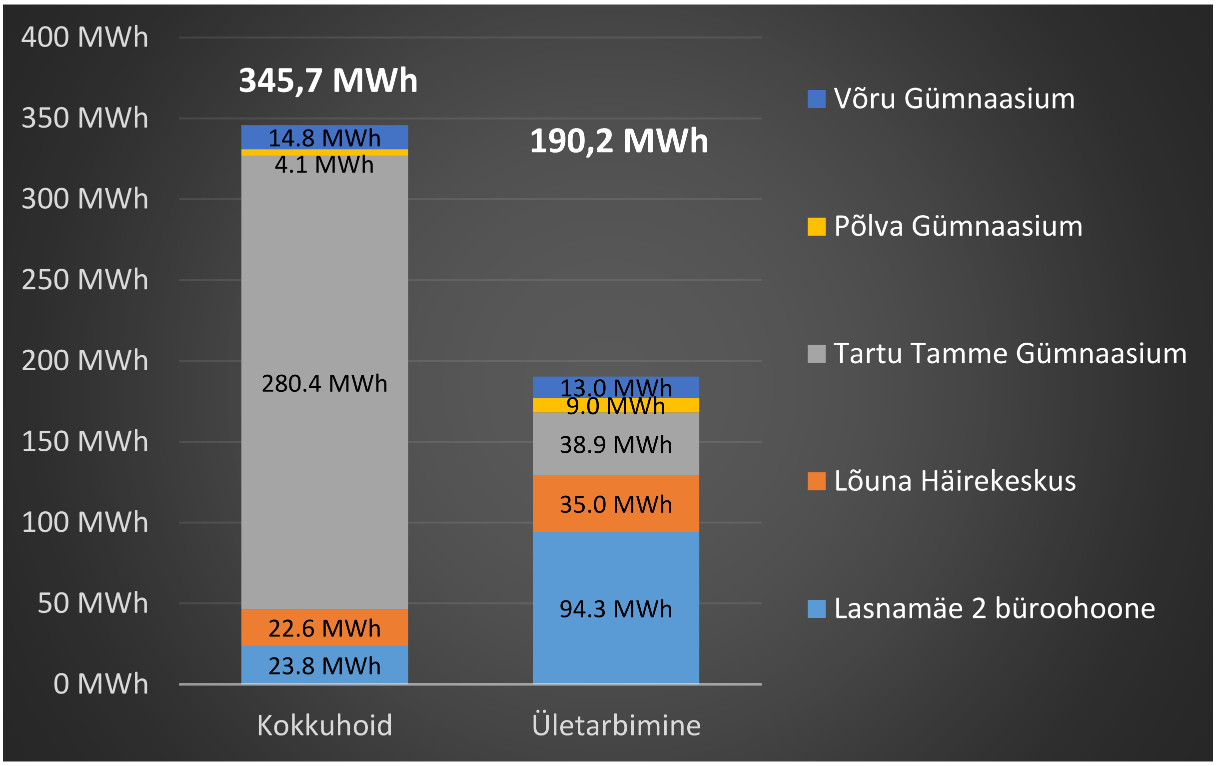


Figure 31. The energy saving and estimated overconsumption (consumption that could still be achieved) during the period of the project. Consumption data is reduced to normal year.

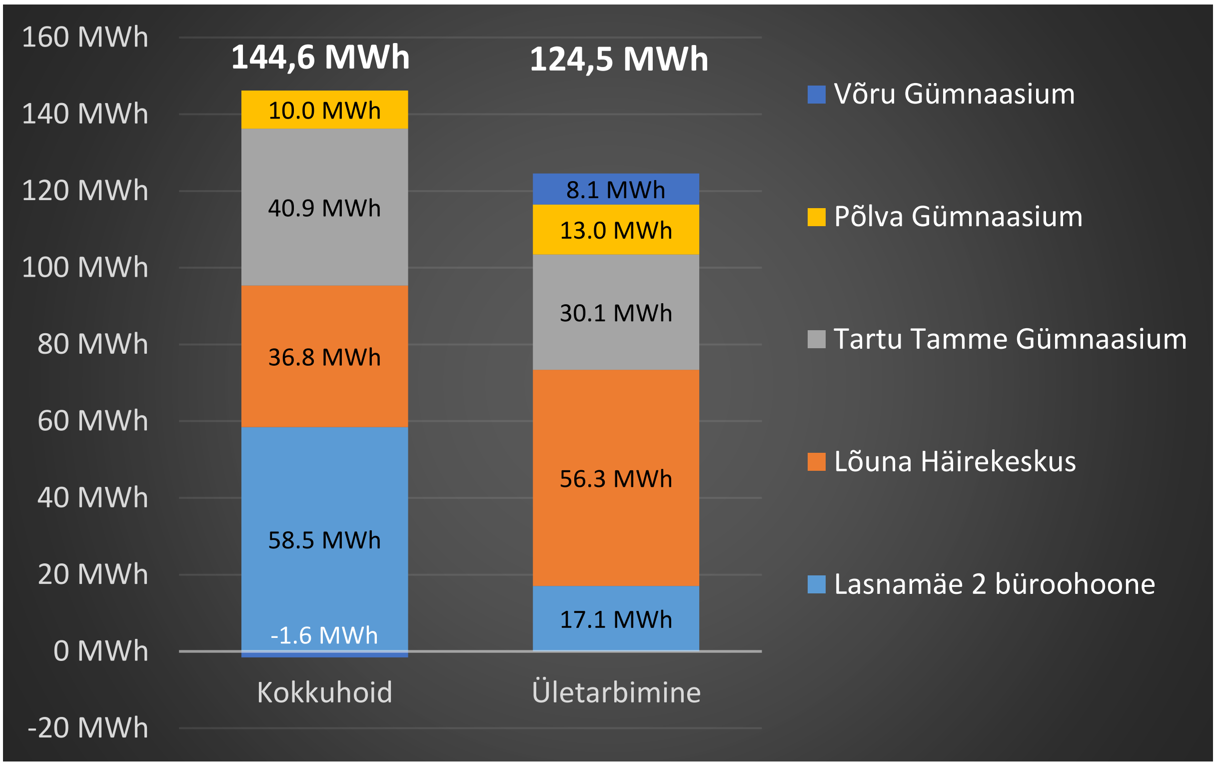


Figure 32. Saving of electricity achieved during the project period and estimated overconsumption (consumption that could still be savings)

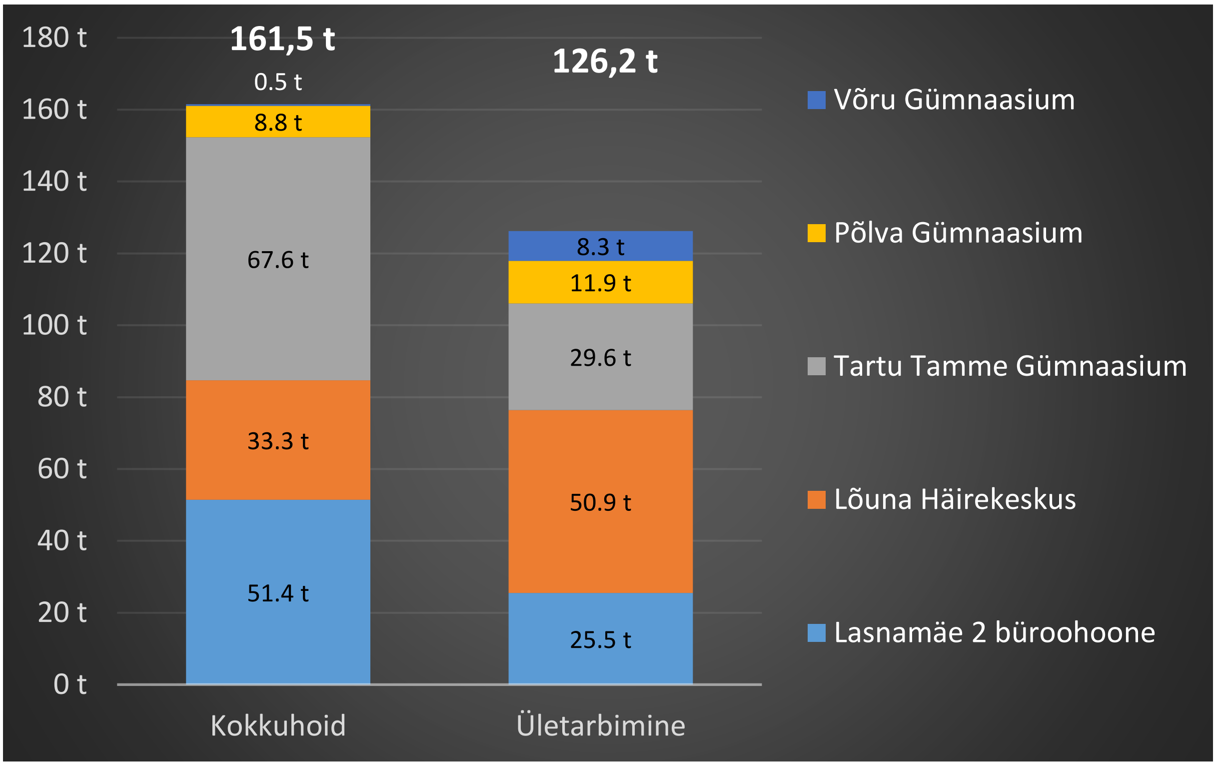


Figure 33. Reduction of greenhouse gas emissions from energy savings during the project period and estimated amount of total consumption emissions, CO2 equivalent

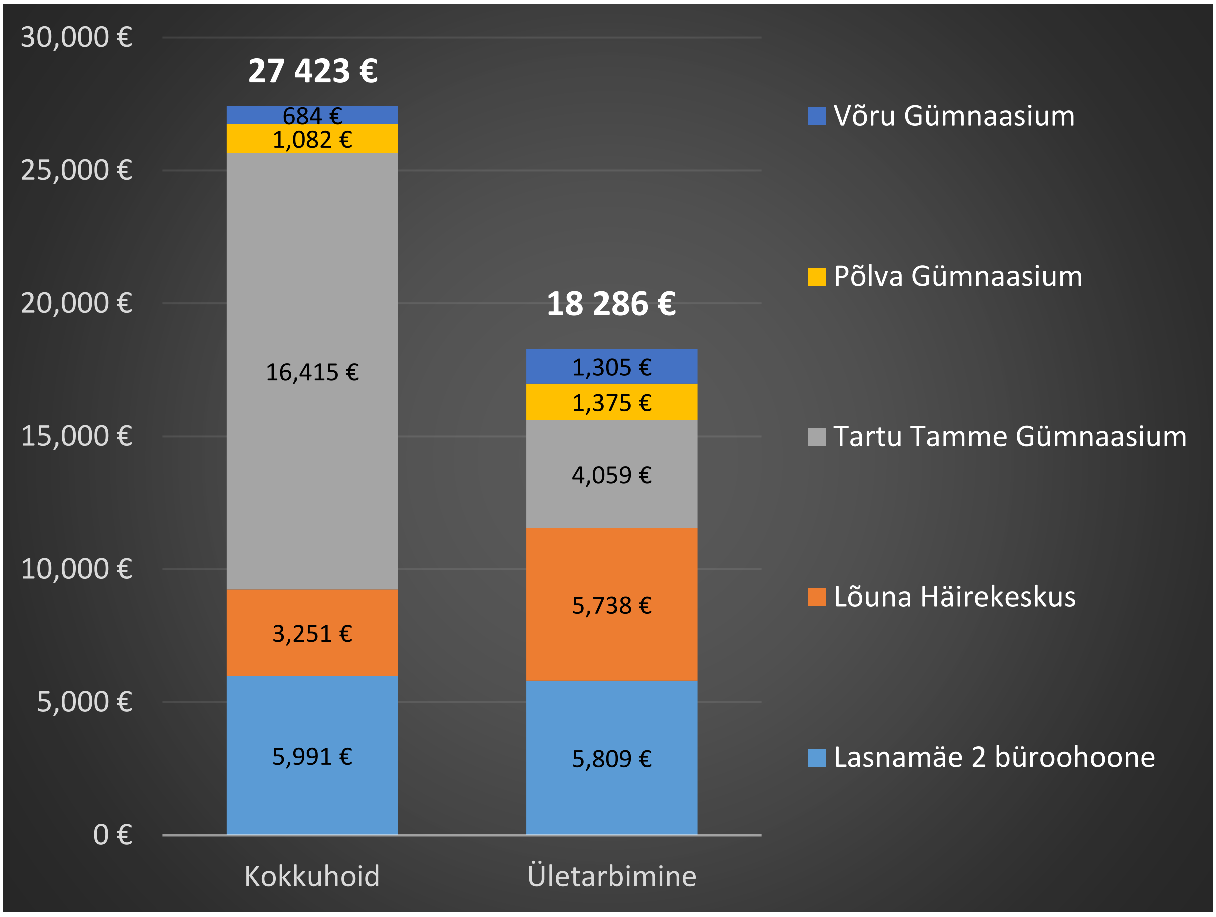


Figure 34. The financial savings achieved during the project period and estimated cost of overconsumption

Table 1. Energy consumption during the reference period and during the project period

Building			Lasnamäe 2 Office Building	Southern Alarm Center	Tartu Tamme Gymnasium	Põlva Gymnasium	Võru Gymnasium	**Total**
Heated area			8928.0 m^2	4011.0 m^2	7979.5 m^2	2321.6 m^2	3321.7 m^2	**26561.8 m^2**
Consumption of heat *	Reference period	MWh/A	700.8	384.2	1030.5	126.1	362.8	**2604.4**
	Project period		677.0	361.6	750.2	122.0	345.1	**2255.8**
	Change		-23.8	-22.6	-280.4	-4.1	-17.7	**-348.6**
Electricity consumption	Reference period	MWh/A	723.1	595.1	397.8	70.4	185.6	**1972.1**
	Project period		664.6	558.3	356.9	60.4	187.2	**1827.4**
	Change		-58.5	-36.8	-40.9	-10.0	1.6	**-144.6**
Total energy consumption	Reference period	MWh/A	1423.9	979.3	1428.4	196.4	548.5	**4576.5**
	Project period		1341.6	919.8	1107.1	182.4	532.3	**4083.2**
	Change		-82.3	-59.5	-321.3	-14.1	-16.1	**-493.3**

* Thermal energy reduced to normal year

Table 2. Specific energy consumption during the reference period and during the project period

Building			Lasnamäe 2 Office Building	Southern Alarm Center	Tartu Tamme Gymnasium	Põlva Gymnasium**	Võru Gymnasium	**Total**
Heated area			8928.0 m²	4011.0 m²	7979.5 m²	2321.6 m²	3321.7 m²	**26561.8 m²**
Differentuseof heat*	Reference period	kWh/(m² a)	78.5	95.8	129.1	54.3	109.2	**467.0**
	Project period		75.8	90.1	94.0	52.5	103.9	**416.4**
	Change		-2.7	-5.6	-35.1	-1.8	-5.3	**-50.5**
Differentusage of electricity	Reference period	kWh/(m² a)	81.0	148.4	49.9	30.3	55.9	**365.4**
	Project period		74.4	139.2	44.7	26.0	56.4	**340.7**
	Change		-6.6	-9.2	-5.1	-4.3	0.5	**-24.7**
Total Energyuse	Reference period	kWh/(m² a)	159.5	244.1	179.0	84.6	165.1	**832.4**
	Project period		150.3	229.3	138.7	78.6	160.3	**757.1**
	Change		-9.2	-14.8	-40.3	-6.1	-4.9	**-75.2**

Nb! The table shows the low and high consumption in each row with colors. Green – low consumption or good result; red – high consumption, or bad result. The remaining tones will remain on the tab. Each line must be viewed separately.

* Thermal energy is reduced to the normal year.

* * The electricity consumption of the Põlva secondary school does not include the electricity produced and consumed by the on the spot PV panels, so that the specific energy agency in Põlva Gymnasium is somewhat lower.

Võru State Gymnasium

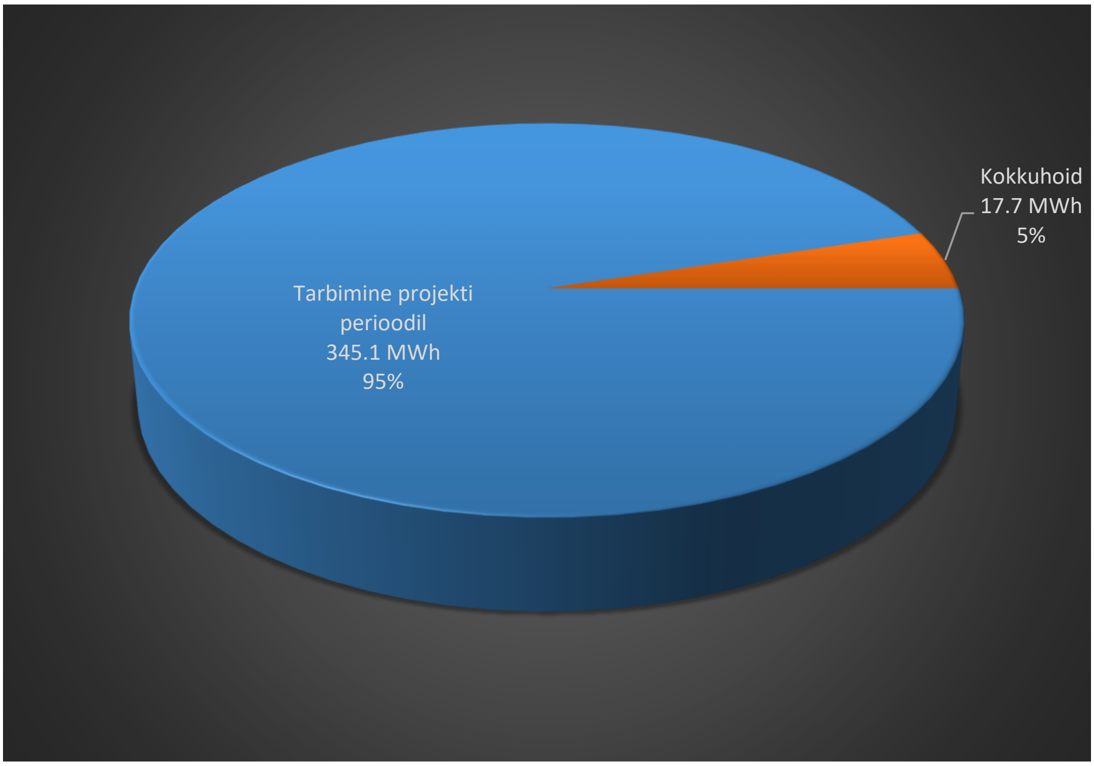


Figure 35. Heat consumption (blue) and achieved savings (orange)

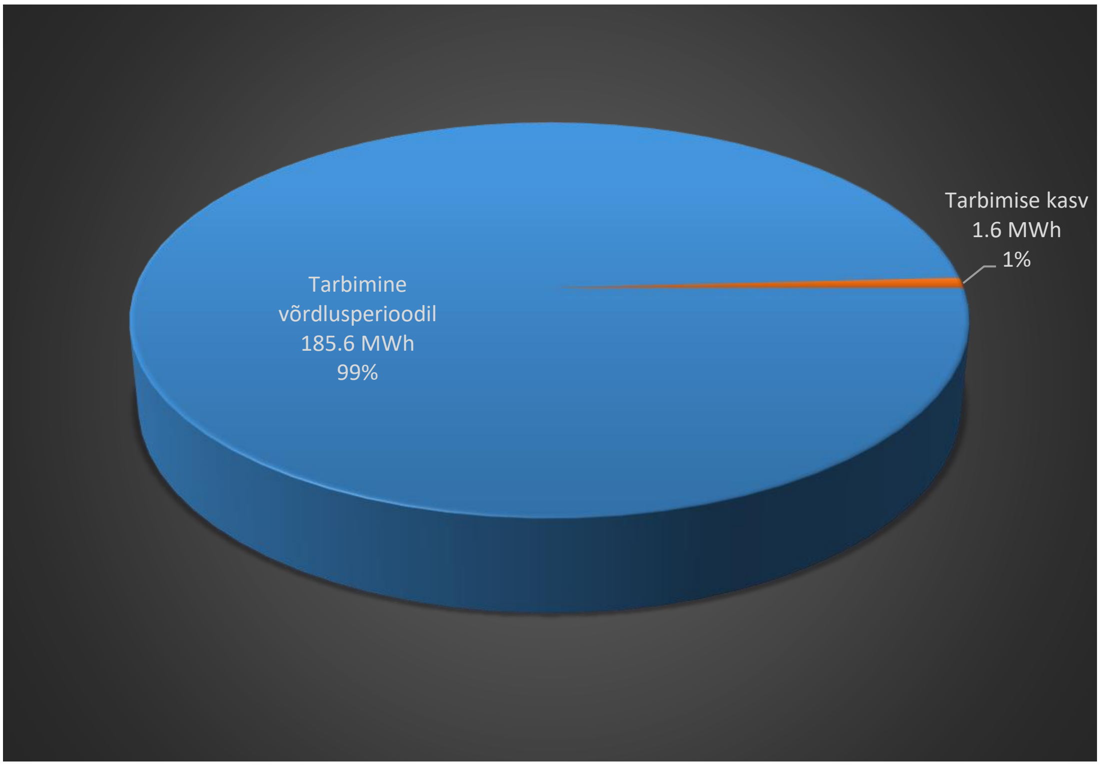


Figure 36. Electricity consumption (blue) and achieved savings (orange)

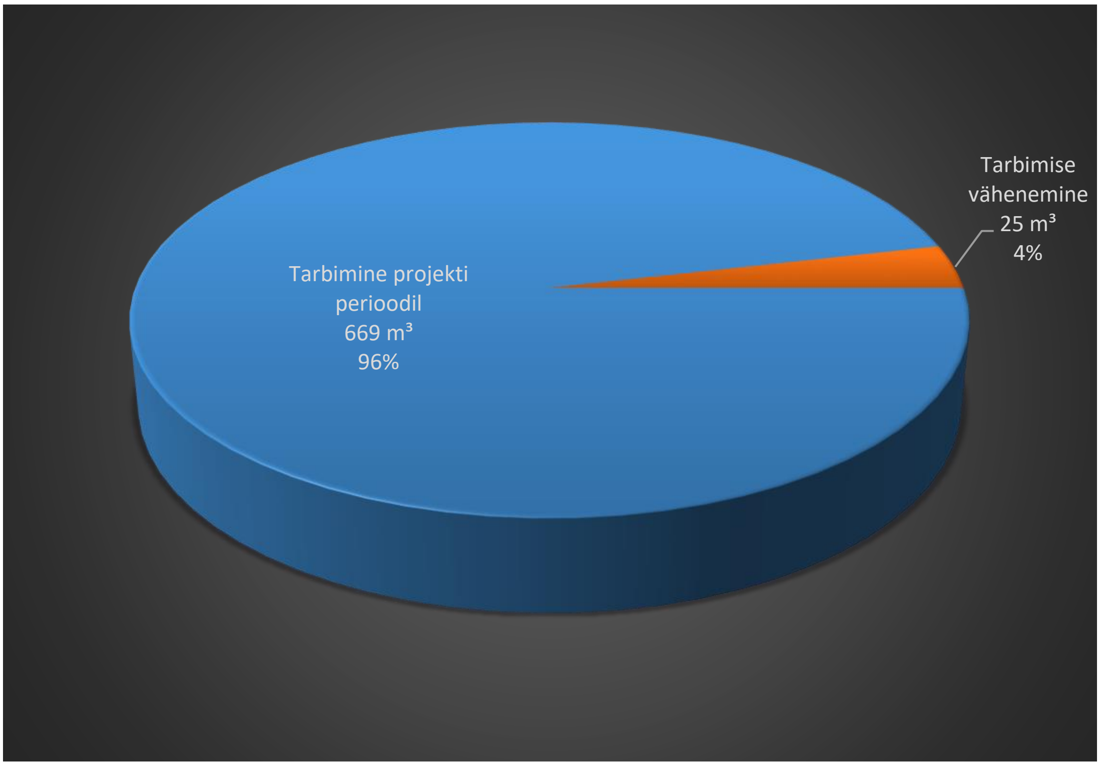


Figure 37. Water usage (blue) and achieved savings (orange)

Specifies:

- Most of the building's spacious client (heating) management is automatized.
- Many different events outside the normal lifetime.

Table 3. Issues detected and resolved on the object and settings performed

Jrk. Nr.	Problem/Theme	Solution/Action	Status	Effects
1	In classrooms, the thermostatics of radiators sometimes have very different setting numbers. In one room maybe settings min and max.	Inform the user: Harmonise radiator thermostats setting in space (recommended maximum set number is 3)	Carried out	Small
2	If the rooms are going to be hot, the windows are being opened, but the radiators keep heating at the same time.	Inform the user: During opengening the windows, the thermostats of radiators must be rotated to the minimum	Carried out	Average
3	In the physics class above the kitchen (124), there are smells of kitchen in the morning and the teacher needs to vent the space by opening the windows	Change the operating speed and working time of the SV303 system serving the physics class. Currently running the system Mon-Fri: 6.00-7.00 Half-speed. Proposal Mon-Fri: 6.00-7.00 Full speed	Carried out	Small
4	Ventilation aggregates have too high temperatures	Lowering the temperatures	Carried out	Average
5	Fuel systems are too high	Lowering the temperatures	Carried out	Small
6	The starting time of the ventilation system is too early in the working days	Correct time Programs	Carried out	Average
7	The person performing on-site maintenance is unable to receive operational information about alarms	Add corresponding contacts to the alarm notification list in the building automation	Technical staff informed	Average
8	The building automation has a lot of unfastened alarms.	The alarms must be responsive and confirmed when they are dealt with	Technical staff informed	Small

9	The building automation has a lot of alarms since the beginning of the year (mostly related to ventilation systems).	Identify the cause of the alarms and if they can be avoided in the future, perform the necessary actions	Technical staff informed	Small
10	The user of the building does not know the exceptions to the working times of ventilation systems.	To make a user training	Carried out	Average
11	Air Curtain Barrier 1 valve is open in situations where the temperature of the device is + 10 °c and the actual temperature + 26.8 °c	Find out what is the cause of the valve open and eliminate the problem	Carried out	Small
12	The upper radiator heating temperature is lower than 2, 5K only on weekends (Sat and Sun) between 7:00-24:00	Lower the radiator heating temperature to 5K as follows: Mon 0:00-04:00 Mon-Fri 19.00-06:00; SAT-SUN 0:00-24:00	Carried out	Small

Tartu Tamme Gymnasium

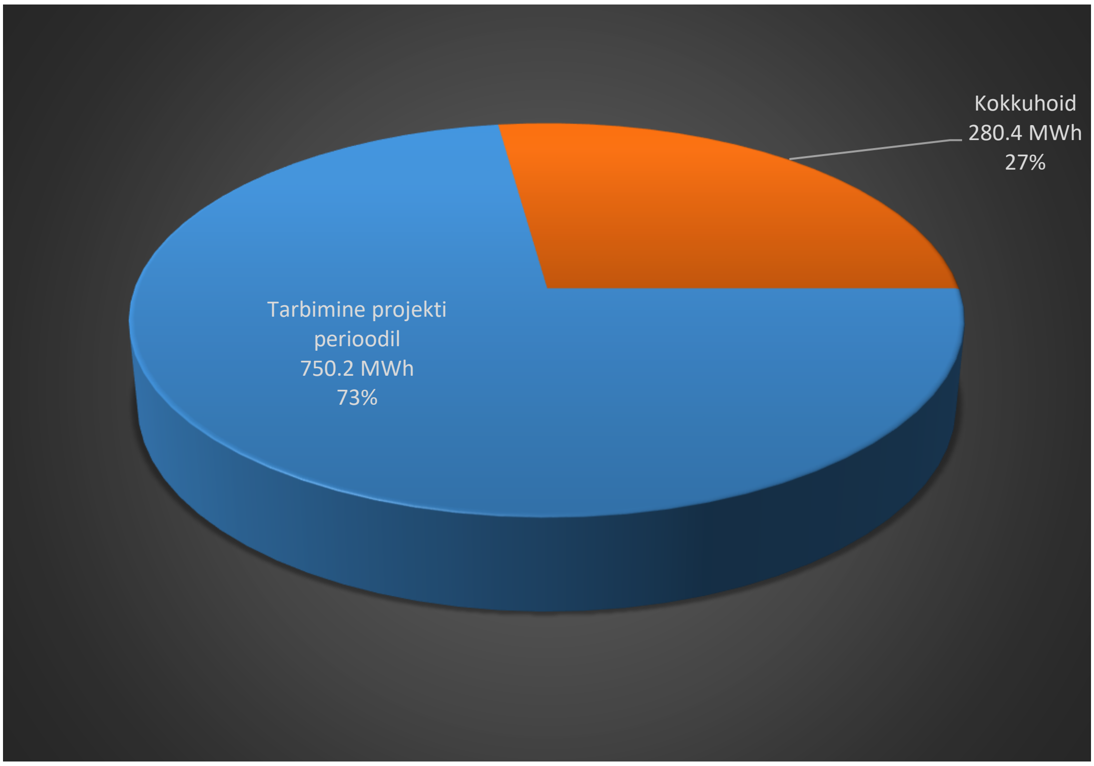


Figure 38. Heat consumption (blue) and achieved savings (orange)

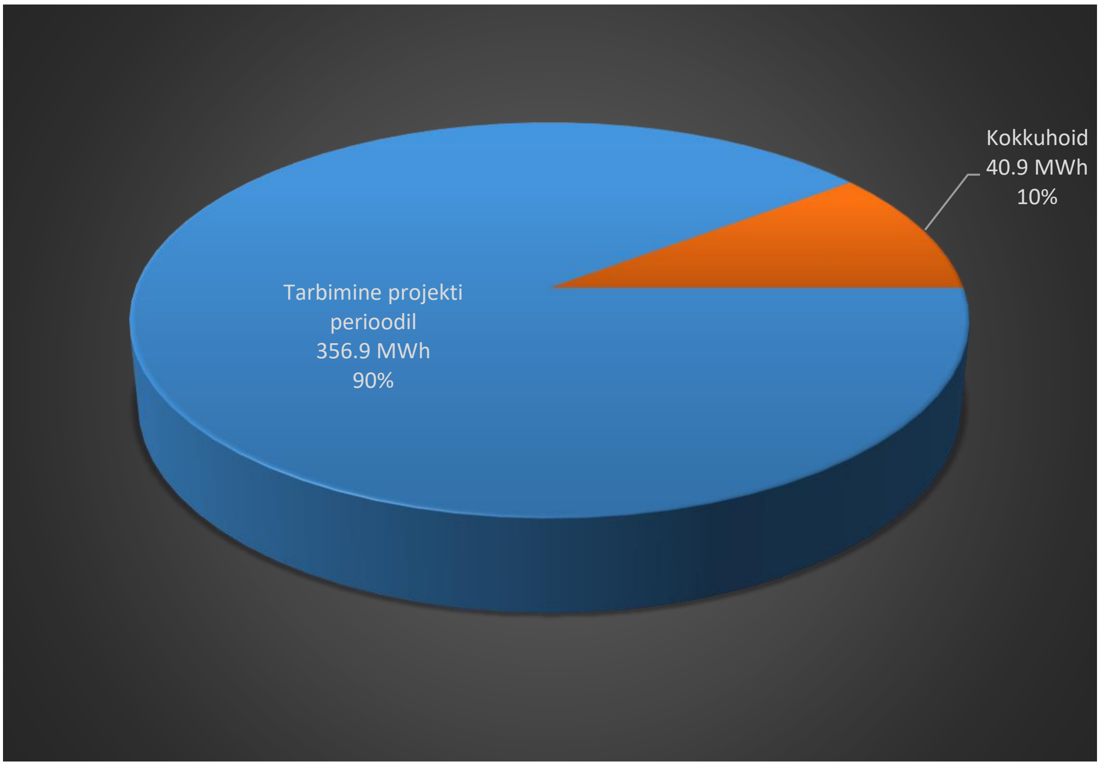


Figure 39. Electricity consumption (blue) and achieved savings (orange)

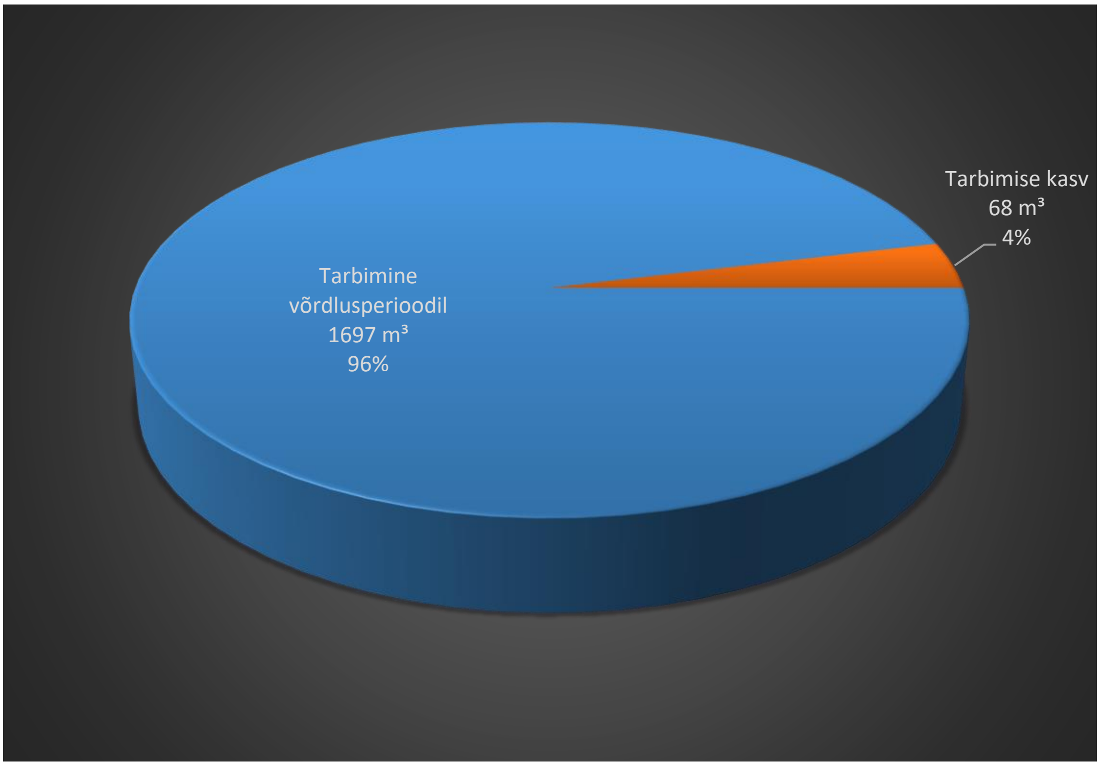


Figure 40. Water usage (blue) and achieved savings (orange)

Specifies:

- Ventilation systems were working 24/7 during the reference period.

Table 4. Issues detected and resolved on the object and settings performed

Jrk. Nr.	Problem/Theme	Solution/Action	Status	Effects
1	Domestic hot water setting is too high + 57 °c. Causes excessive energy consumption.	If there is no justification for a higher than normal number, lower the + 55 º C.	Carried out	Small
2	Non-optimal setting figures in the Heat node. Causes excessive energy consumption or indoor climate problems.	Adjust the heat substation setpoints as follows. Assumption is the correct installation of the heat pump air temperature sensor and the correct indication. P 1.1 Starting set-point: + 15 °c P 2.1 Starting set-point: + 15 °c P 3.1 Starting set-point: + 20 °c	Carried out	Average
3	The rooms heat up over the sun due to the free heat.	Implement the night-time free cooling function on the ventilation system	Carried out	Great
4	The temperature setting of the inlet air is constant. Causes excessive heat consumption. Limits the free cooling capability of ventilation systems.	Apply air temperature control to the ventilation equipment according to the exhaust	Carried out	Average
5	The airflow settings do not correspond to the production in the project. The air flow rates are too small and, as a result, the internal air quality is poorer.	Adjusting the Airflow setting numbers	Carried out	Great

6	Ventilation equipment is operated by the device's own controller and the schedule of the building automation. Excessive energy consumption and a misunderstanding of why and when the device is working.	Control only the building Automation program and delete the corresponding settings from the Ventilating controllers.	Carried out	Average
7	In the ventilation controls, the default setting is "Low speed", which makes the equipment work all the time, although it should not. Excessive energy consumption.	Change the corresponding setting on the "Normal stop" controls in the ventilation equipment.	Carried out	Great
8	The hours of the ventilation equipment controllers are incorrect	Adjust times	Carried out	Small
9	Time programs for ventilation systems in the building automatics do not correspond to the actual use and need.	Correct slow programs	Carried out	Great
10	Room-controllers set-points are too high. There is a risk that the heating system will work against the ventilation free cooling.	Numbers of room controllers lowered to + 22 ° C	Carried out	Average
11	The visualizations have exhaust ventilation fans on the wrong position-should be after the heat recovery but were before it.	Correct the visualization.	Carried out	Small
12	There are no equipment airflow trends that are critical parameters. Trendline abbreviations are difficult to understand (which is what)	Complement trends and visualizations. The necessary information about data points can be received from the Modbus registry of ventilation equipment.	Carried out	Small
13	Trend data is fragmented	Identify the cause and make the necessary corrections to ensure that trends data continue to	Exercising	Small

14	The ambient temperature sensor in the heat node does not show the actual ambient air temperature. It is believed to remain in the sun and, as a result, can show a higher temperature of 15K	Identify the reason for the wrong readings and make the necessary corrections so that the system reaches the correct temperature value.	Installed a new sensor that stays in less sunlight. The maintenance man will continue to monitor whether the sensor is suitable for the spot – by temperature. The longer the days, the more the sun could influence the sensor.	Great
15	Ventilation-heating control valve in the heat supply was opened when the circulation pump was standing due to the high ambient air temperature. If the pump stops due to high ambient air temperatures, the adjustment valve must be closed.	Check on the spot whether the ventilation-heating control valve closes when the circulation pump stops due to high ambient air temperatures. If not close, identify the cause of the problem and eliminate it.	The maintainer says the valve closes. When looking at the building automatics, the valve closes. Problem solved.	Average
16	It is not possible to view different data from the building automation log when using IE as a VPN connection: floor heating, radiator heating, exhaust ventilation V6 and V7 time program, alarms etc. This information is only seen by logging in via the RKAS server.	Identify and eliminate the cause (s) of the problem.	The presumed cause is the need to update the Java software on the on-premises computer. If in fact there is also a reason for this, then a maintenance man should continuously monitor the need for renewal. Currently, the issue does not occur. Monitoring.	Great
17	Space controls have time-increments in building automation, but there is no information about working logic-what happens if the night service is implemented instead of the daily service, and where the management-related settings can be changed at the site?	Provide the relevant information.	Carried out	Average

18	The building automation often has many unconfirmed and active interference. Why is no one dealing with the problems encountered?	Communicate with the people you need to respond with sufficient speed and that they are confirmed in the building automation.	Carried out	Average
19	There are no air intake temperatures of ventilation units in the visualization of building automation. As the overall ambient temperature is affected by the sun, the temperatures of the air intake should be displayed to know the actual situation in the ventilation equipment.	Complement visualizations.	Carried out	Average
20	The user is not able to turn on the ventilation systems quickly and operationally in the outside working hours. Everything needs to be done through the building automation	Install timer buttons (1-6 hours) on the necessary systems for the user in the appropriate place	The job has been partially added to the repair jobs budget. Exercising.	Average
21	Assembly hall's ventilation works at one speed by slow program	Install and connect CO2 and presence sensors. Visualize the sensors ' readings/statuses in BMS. The productivity of a specific aggregate is changed according to the readings and status. Productivity management by CO2 and cooling needs	Exercising	Great
22	Auditorium ventilation works at one speed by time program	Install and connect CO2 and presence sensors. Visualize the sensors ' readings/statuses in BMS. The productivity of a specific aggregate is changed according to the readings and status.	Exercising	Great
23	The gym ventilation operates at one speed according to the time program.	Install and connect CO2 and presence sensors. Visualize the sensors ' readings/statuses in BMS. The productivity of a specific aggregate is changed according to the readings	Exercising	Great

		and status. Protect the sensors against physical injuries. The same system also operates a smaller gym. This means that one CO2 sensor must also be installed there. In addition, it would be worthwhile to think about VAV valves because one system serves two spaces.		
24	The room client management is only partially connected to the building automation	Build a modern room client management that is connected to the building Automation (actuators, window sensors, space controllers, etc.)	The room client management of the auditorium is planned to connect to the building automation. Not performed elsewhere	Average
25	The radiator heaters do not have a slow program, which can stop the system during the summer break. If the building is not used in summer, it is not necessary to spend heat energy to ensure the indoor climate.	If it is not necessary to perform on-site maintenance work in order to stop or restart the radiator heating system for a longer period of time, add a time program to control the operation of the radiator heating system in the building automation.	Heating is switched off from the heat exchanger in summer.	Average
26	There are no temperature sensors for the return of water in the heat node with ventilator, floor heating, and warm consumption. This is because of the lack of information about whether the system's upstream temperature or the operating mode of the circulating pump is optimal.	Add missing temperature sensors. If circulation pumps are connected directly to the building machine, then most systems can reach these temperatures. In addition, much more information about the work of pumps, such as: flow, pressure, current power, electricity consumed, etc.	Exercising	Small
27	When looking at remote administration, the heating valves serving classrooms (SV6 and SV7) are disconnected if not supposed to be. Excessive heat consumption.	Check the actual status of the valves and actuals on the spot and identify the cause of the problem.	Unknown	Average

28	The cooling of the assembly hall ventilation unit does not work.	Identify the cause and fix the problem.	The reason was the refrigerant leak. The maintenance man should continue to monitor the technical condition of the devices.	Average
29	During the warmer period, the rooms will overheat due to free-heating and there is no necessary resource to cool.	To install passive or active solar eclipse solutions. Install refrigeration equipment for ventilation.	No cooling devices are installed. Only solar eclipse solutions are used. Exercising	Great

Tartu Rescue Centre

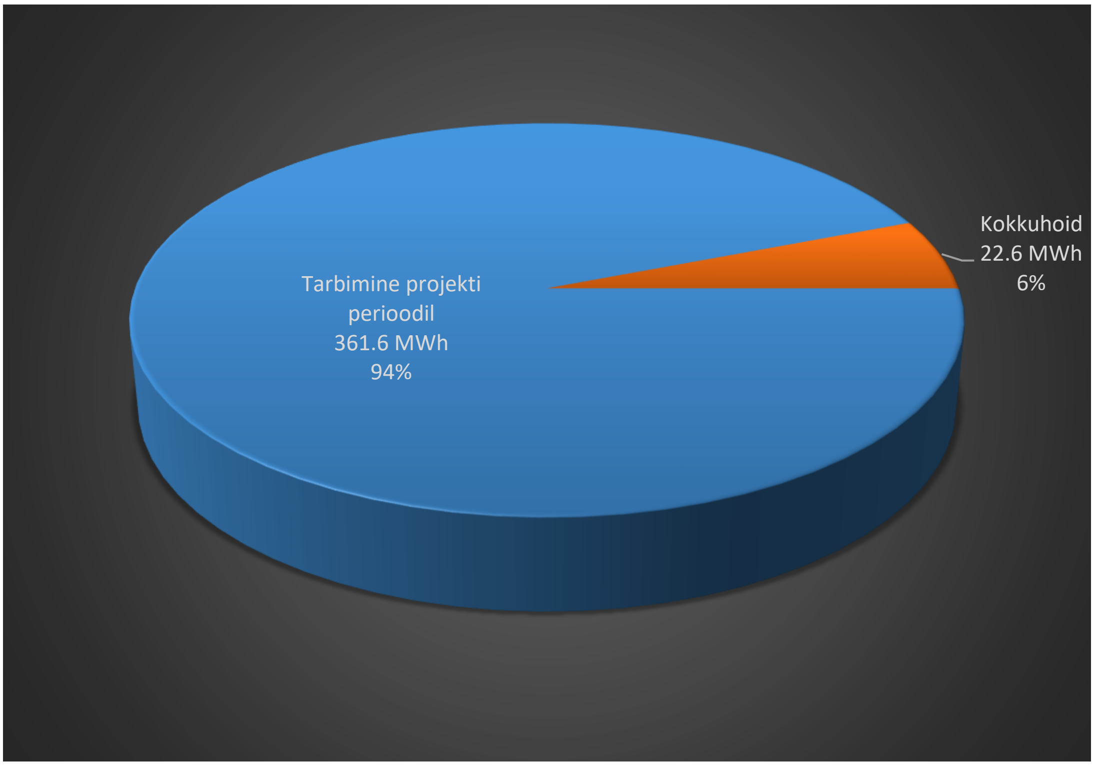


Figure 41. Heat consumption (blue) and achieved savings (orange)

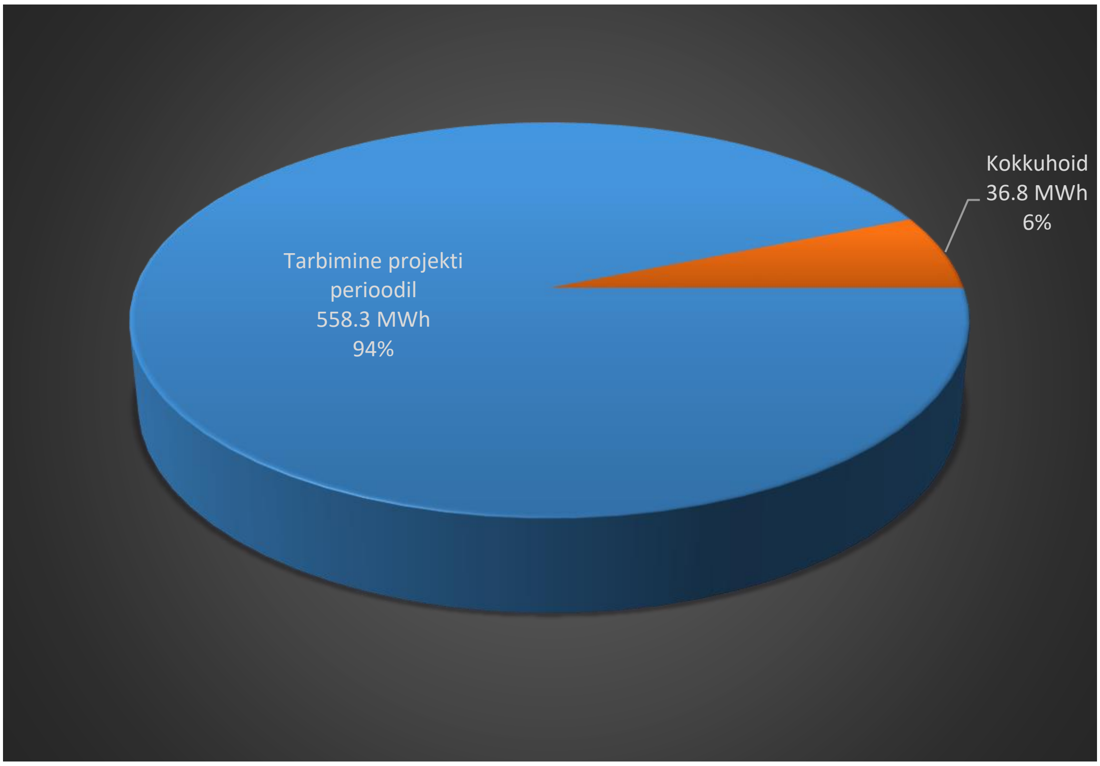


Figure 42. Electricity consumption (blue) and achieved savings (orange)

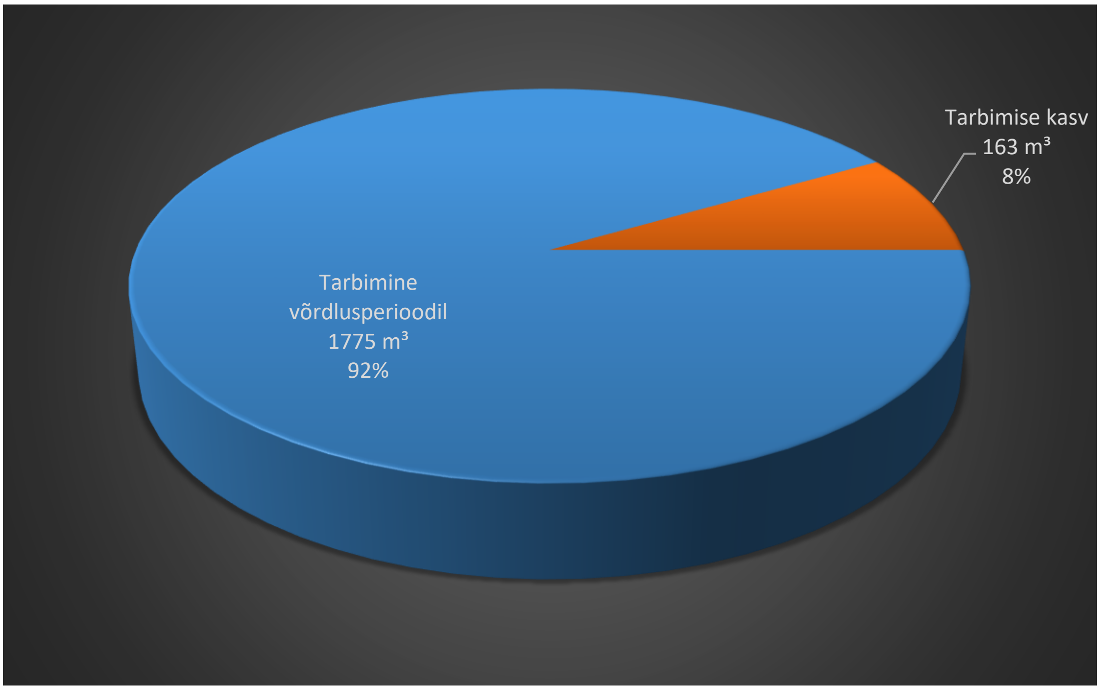


Figure 43. Water usage (blue) and achieved savings (orange)

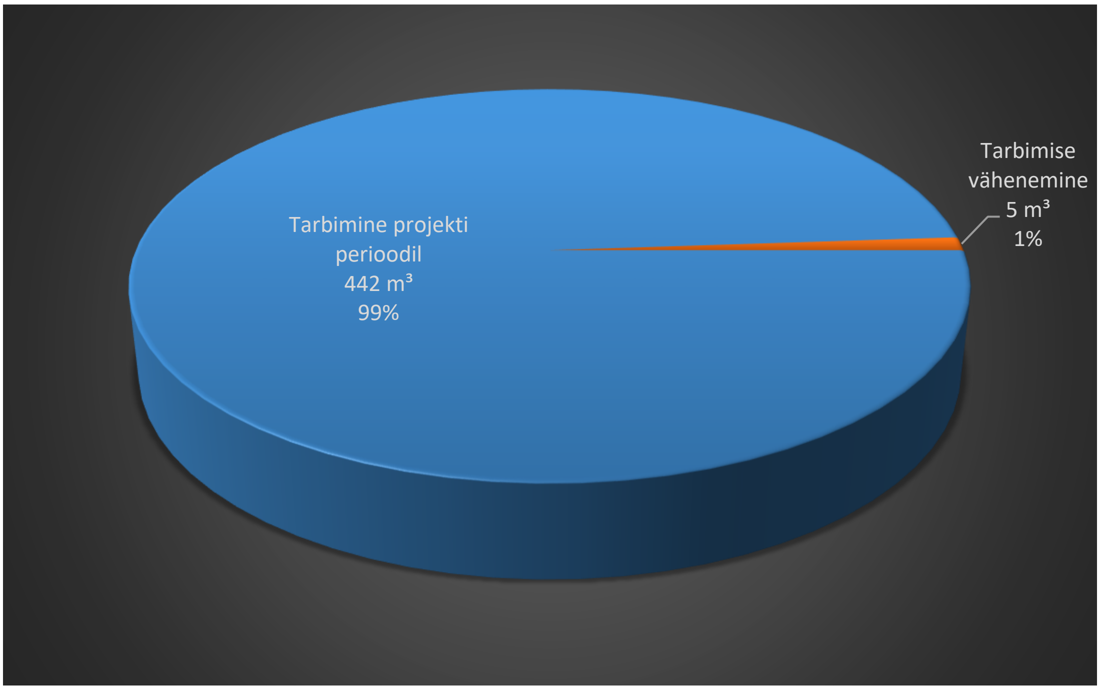


Figure 44. Fire department water usage (blue) and achieved savings (orange)

Specifies:

- The building's 24-hour usage.
- High water consumption.
- Lots of different meters.

Table 5. Issues detected and resolved on the object and settings performed

Government No	Problem/Theme	Solution/Action	Status	Effects
1	The ventilation unit SV1 the air intake temperature sensor indicates a temperature of approx. 6K lower than that of other ventilation aggregates for the air intake temperature sensors and ambient temperature sensor	Switch off the sensor	Carried out	Small
2	Description of the generator R146 for external air valves is missing in the BMS visualization. It is not possible to understand what and how the work of the outdoor valves leads.	Upgrade Visualizations	Carried out	Small
3	The feedback of the emergency garage outside air valves shows 67%, although the control signal is 0%.	Identify the cause of the problem and eliminate it	Performed – The valves were physically restricted	Average
4	There is no interlock in the heating units of the radiator heating and ventilation heat units. Heating systems also work in the event of a warm outdoor climate, which is accompanied by excessive energy consumption.	Complement the control (and visualization) of the heat node in BMS with a rule that in the case of a flat ambient temperature (setting) turns off the corresponding heating system in the heat node. Each system must have its own setting number	Carried out	Average
5	In BMS there is no information and settings for the control of pre-heating of ventilation aggregates. It is not possible to analyze whether the pre-heating is used optimally.	Upgrade visualizations	The use of pre-heating is related to icing/frost-if the pressure loss on the heat rear rises above the setting, the pre-heating is applied for melting purposes.	Average

			The visualizations add the preset pressure difference to the numbers. Carried out	
6	Ventilation heating is suspended in the heat-knotted "auto" mode. It is not possible to understand what logic or number of settings the suspension has occurred.	Submit relevant information	Carried out. The pumps had not responded to management and needed a reboot.	Small
7	In BMS there is no efficiency % of ventilation equipment. The corresponding text exists, but the value is not displayed. According to the automatics, the efficiency value is shown when the ambient air temperature is below 8 º C.	Disable the limitation	Carried out	Small
8	Changing the temperature of the cooling logs, depending on the dew point. It is not possible to understand where the air parameters are measured and how the dew point is calculated.	Add corresponding information to the cooling part of the BMS	The temperature of the dew point is calculated by the humidity sensors of the ventilation aggregates. Based on the worst reading. Carried out.	Average
9	BMS has been written that the lowering of the temperature of the cooling logs is performed by the dew point device size. In practice, increasing the temperature should occur. There is no relevant information in the trends and it is not possible to check how the logic actually works	Provide relevant information about how logic works in practice and correct the text in BMS.	The lower flow temperature reduction is used when there are no problems in the building and no condensate of cooling logs occurs. The temperature of the dew point is retrieved in the visualizations. Carried out.	Average
10	The cooling return function of the heat exchangers is not applied to the ventilation equipment.	Complement the use logic of ventilation equipment with the appropriate function.	Carried out	Average
11	Supply temperature for garage AHU was too high	Lower the supply temperature settings between 16 °-22 °c	Carried out	Great

12	All ventilation systems operate at full speed 24 hours a day	Set up a minimum of operating hours of ventilation equipment servicing the offices and garages as needed.	Carried out	Great
13	The figures for the space controllers are too high (+ 23 °... + 25 °c)	Temperatures + 23 °c or lower.	Carried out	Average

Põlva State Gymnasium

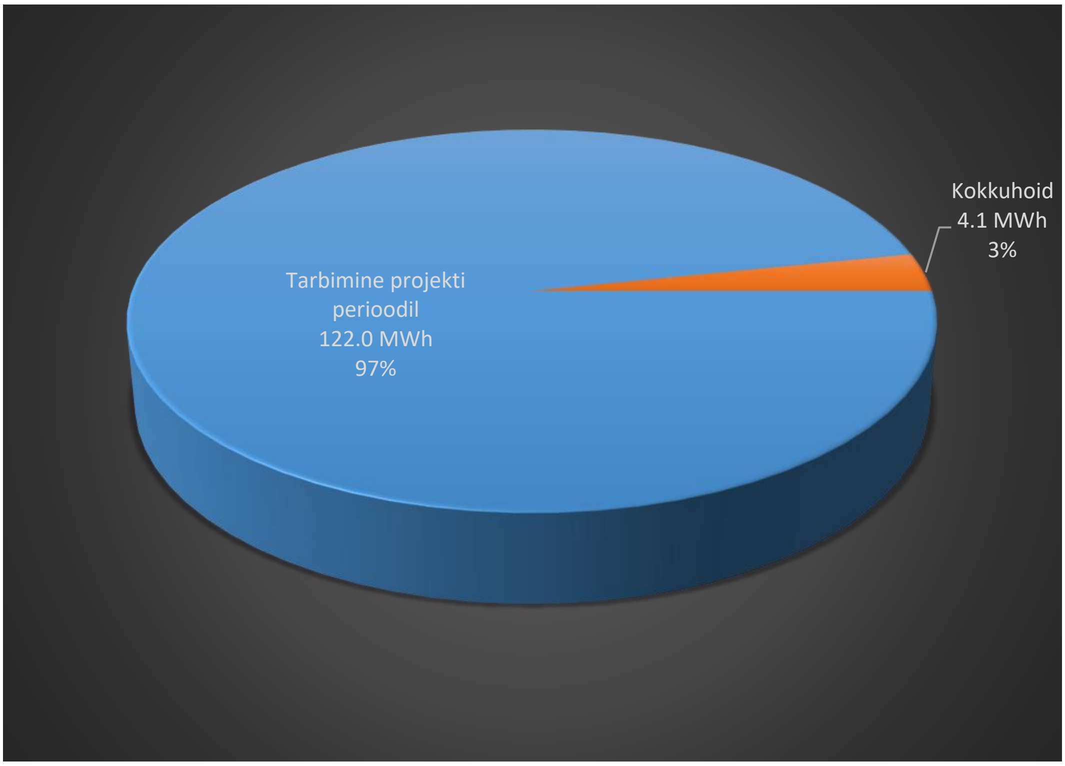


Figure 45. Heat consumption (blue) and achieved savings (orange)

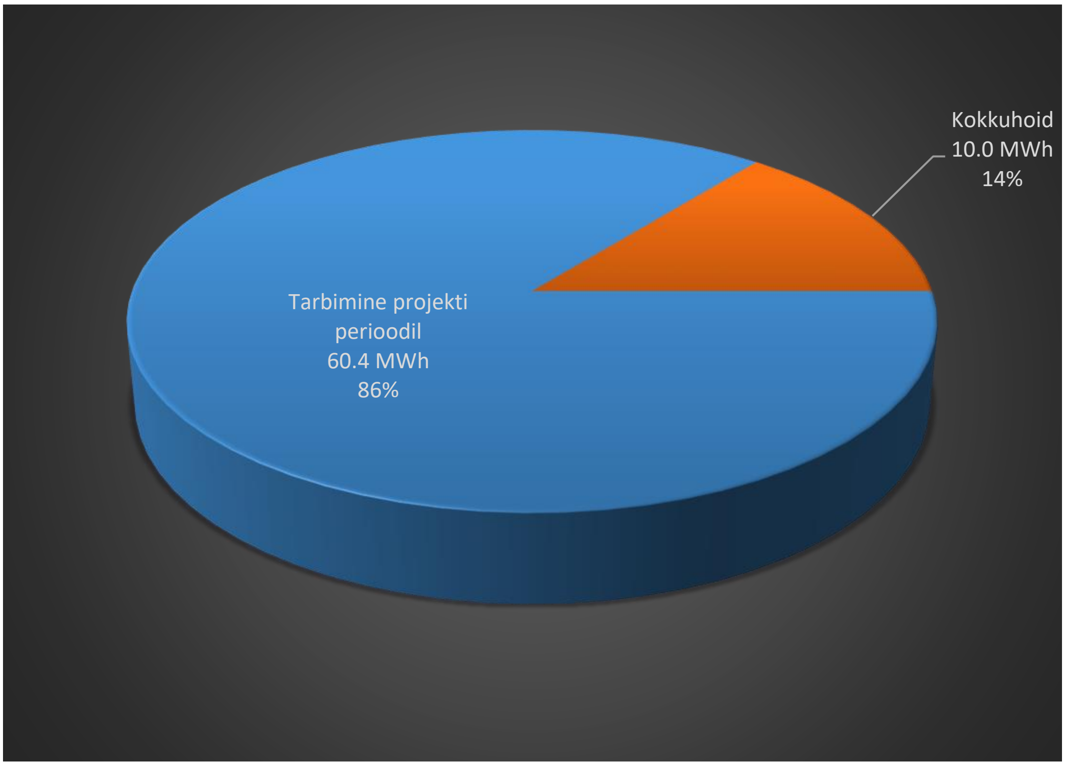


Figure 46. Electricity consumption (blue) and achieved savings (orange)

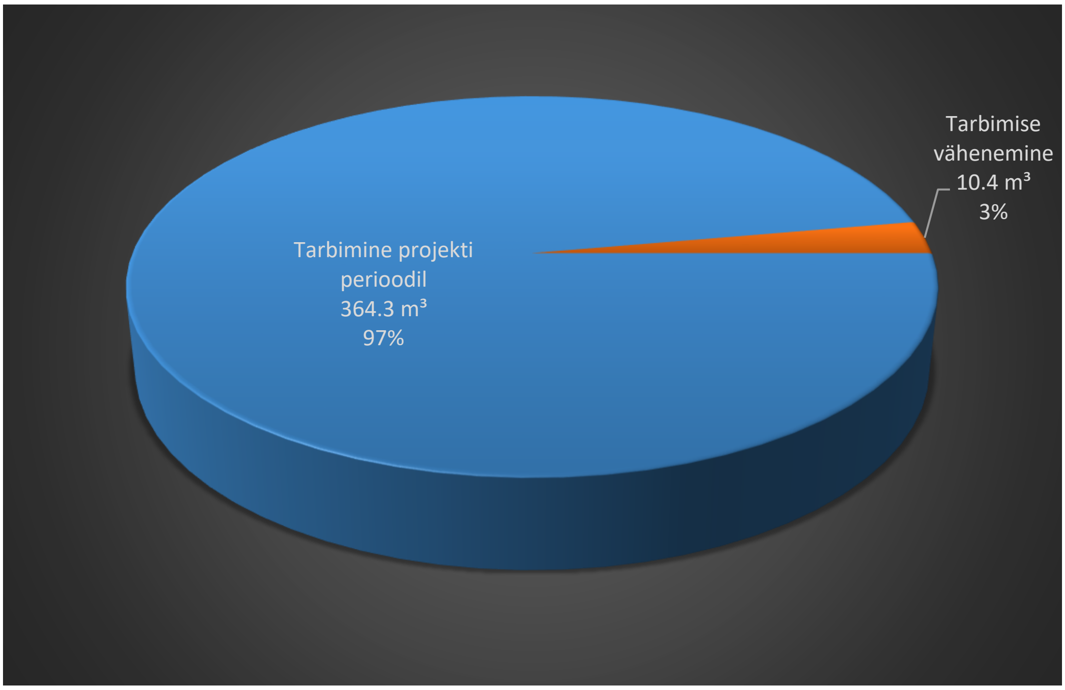


Figure 47. Water usage (blue) and achieved savings (orange)

Specifies:

- PV panels are on the roof of the building and the total electricity output and the electricity consumed in the building in the reference period and during the project period are unknown.
- The precipitation is collected, which is mainly used as a rinse water for toilets.

Table 6. Issues detected and Resolved on The object and settings performed

Government No	Problem/Theme	Solution/Action	Status	Effects
1	The "maximal temperature of the space controllers" is too high (+ 25 °c). Excessive energy consumption when no one is in the building.	Lower set + 22 °c	Carried out	Great
2	The "Maximum user setting size" of space controllers is too high (+ 25 °c). Causes excessive energy consumption.	Lower setting + 24 ° C	Carried out	Average
3	The start of the working time of the room controllers is too early (Mon: 0.00, Tue-Fri: 4.00). In view of the maximum permissible sizes of room controllers, excessive energy consumption is caused.	Change the working time of room controllers-Mon: 3.00, Tue-Thu: 5.00	Carried out	Great
4	In the Heat node, the displacement of the radiator heating temperature is too large (7 °c) and the duration of the shift time is too long (120min). In view of the maximum permissible sizes of room controllers, excessive energy consumption is caused.	Change the setting invoice to the following-offset: 5 °c, Shift duration: 60 min	Carried out	Average
5	The temperatures of the inlet ventilation systems are too high (+ 22 º C). There is a risk of rooms overheating if free heat from the sun is added to the rooms. Causes excessive energy consumption.	Lowering the temperature of the inlet air to at least + 19 ° C or lower	Carried out	Great
6	Stopping the heating of the ventilation is at an excessively high ambient temperature (+ 20 °c). Causes excessive energy consumption.	In the settings of the heating node, the setting number of "venting shutdown when TE00 >" + 15 ° C	Carried out	Average
7	The starting time of the ventilation equipment is too early	Change the working time of ventilation aggregates for later	Executed and reverse	Great
8	Ventilation equipment operating in manual 24/7-Different time moments	Switch to Auto-control	Executed and reverse	Great

Lasnamäe 2 Office Building

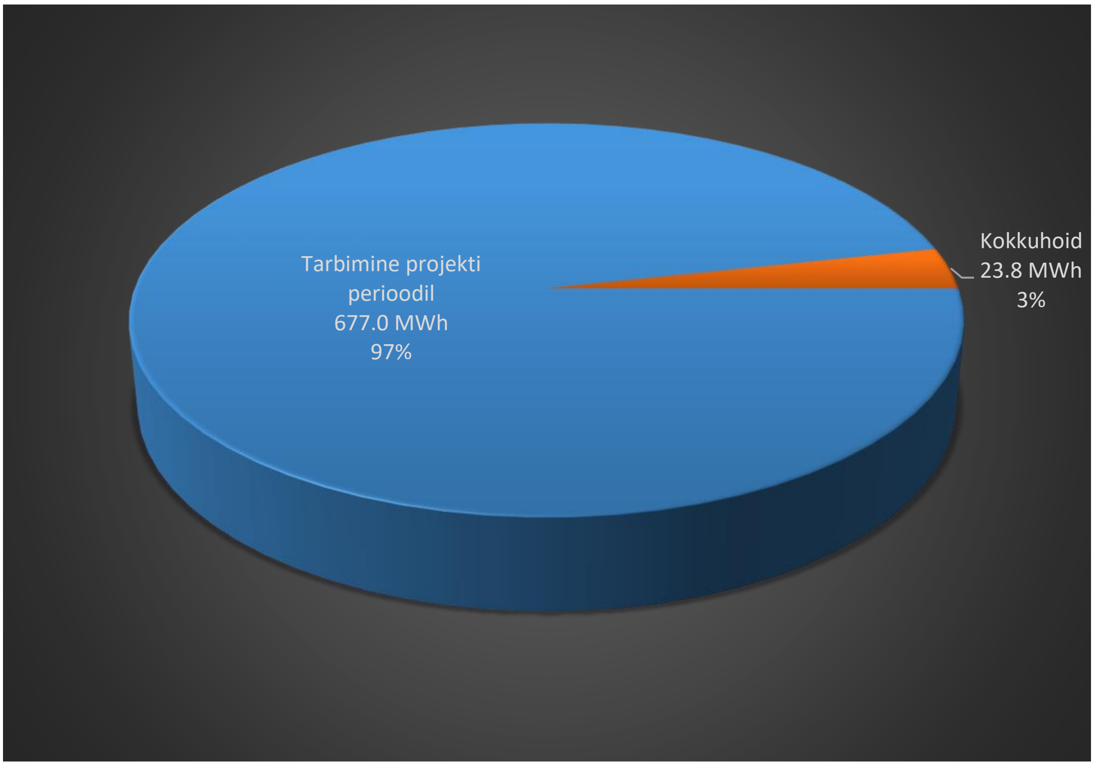


Figure 48. Heat consumption (blue) and achieved savings (orange)

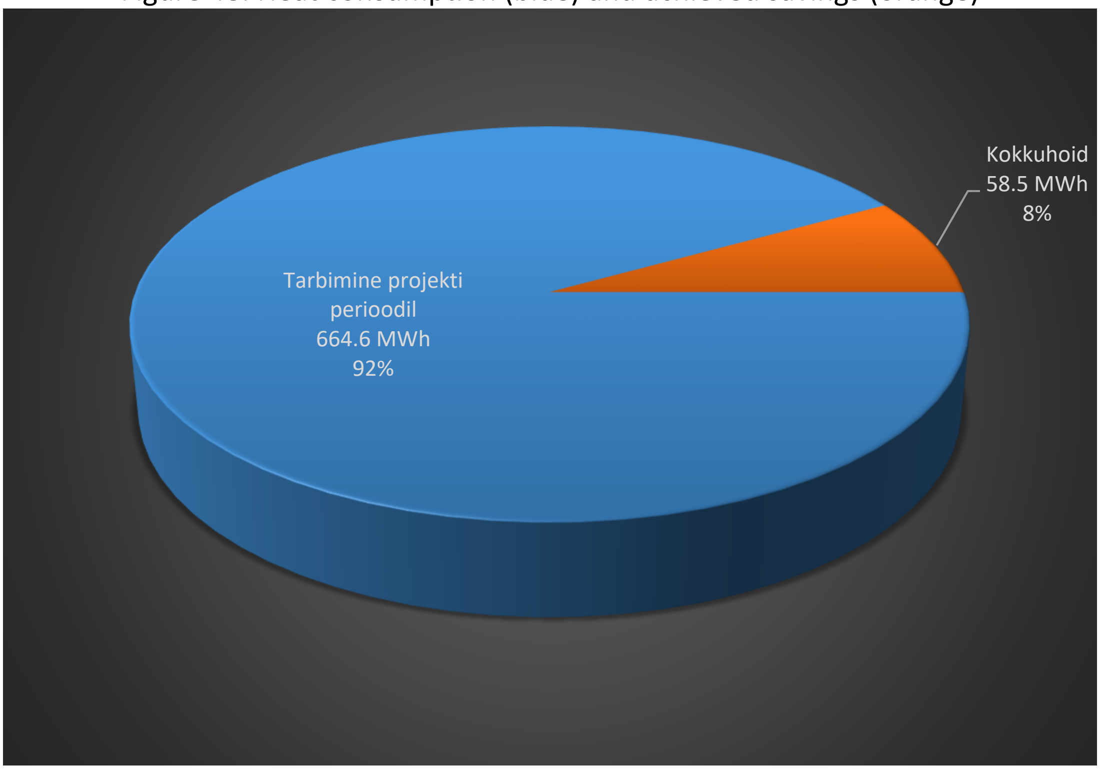


Figure 49. Electricity consumption (blue) and achieved savings (orange)

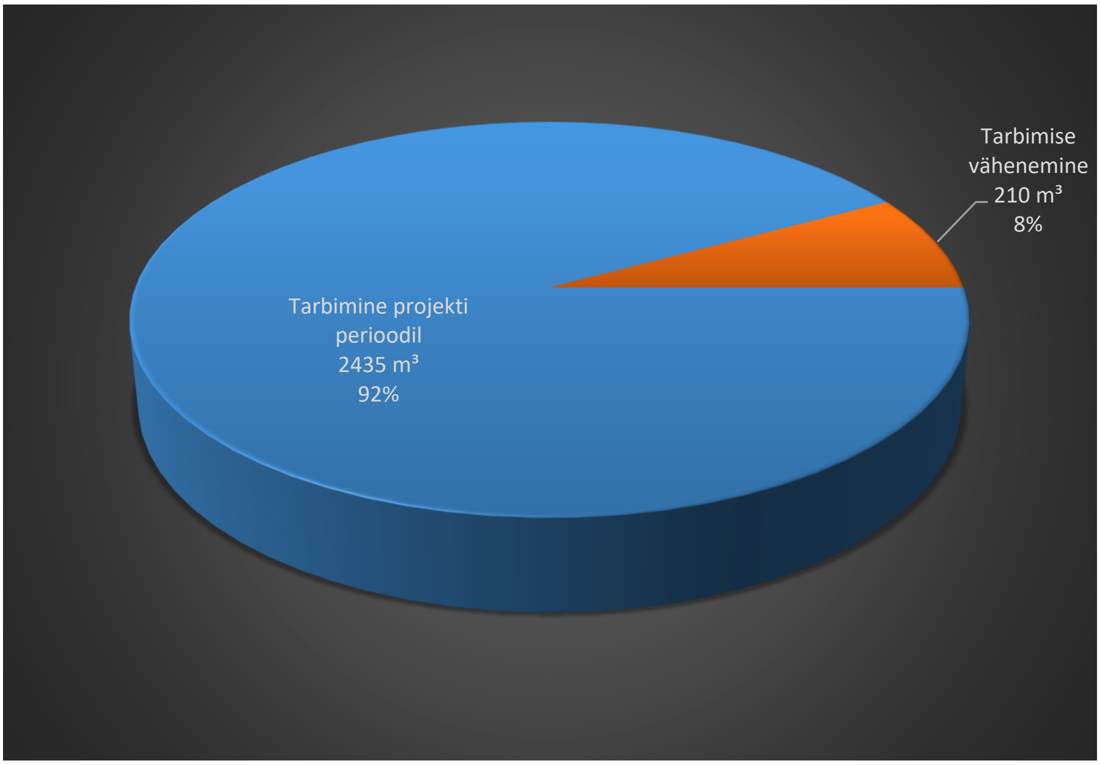


Figure 50. Water usage (blue) and achieved savings (orange)

Specifies:

- Many different meters.
- There are many shortcomings in the metering system.

Table 7. Issues detected and resolved on the object and settings performed

Government No	Problem/Theme	Solution/Action	Status	Effects
1	According to the time program, the cooling system runs at night when ventilation systems were stopped	Without working with ventilation systems, rooms cannot be cooled. The time programmes for cooling systems are corrected as follows: Working hours Mon-Fri 5.00-19.00	The cold station working hours have been changed, but the cooling log circulation pump is continuously running.	Great
2	The setting size of the free cooling glycol is too low (+ 12 °c).	Increase the setting number to + 14 °c	Carried out	Average
3	No use of radiator heating is used to lower the temperature in the outside working hours.	Activate the radiator heating surface flow	Carried out. Temperature control 5K	Average
4	Fuel systems are too high	Adjust the setting invoice	Carried out	Average
5	The sensor in the ambient air temperature of the heat node is not hidden from the sun? The current reading is + 20.9 °c and at the same time the exterior temperature sensor reading + 10 °c	Lift the sensor to a suitable place where it is not directly affected by the solar radiation.	The sensor in the sun is not. Probably had some other influence. No further pursuit.	Small
6	Display on floor 1-6 and 8 room controllers in the information plan, analogous to 7. and 9th Floor	Each room controller needs to be looked at separately now, it requires a lot of time. Room controller information plans provide a quick overview of the space clients on this floor and the work of the respective systems. As far as possible, show all room controllers information in the plan.	Carried out	Average

7	The setting number of the air conditioners on the 4th floor server compartment is too low. Causes excessive energy consumption. The setting number could not be raised earlier because the relative humidity turned too high in the room.	In case the existing solution does not work, a separate drying device should be installed, or existing refrigeration equipment should be replaced with the drying function.	After installing the "moisture suction" The problem is not high relative humidity. The setting temperature was increased to + 20 º C.	Average

Conclusions and recommendations

Wider deployment of energy monitoring Systems in public buildings

The introduction of the energy monitoring system in public buildings is in the perspective of the results of the project, and energy savings can be achieved, but the monitoring alone does not bring savings – this also requires an active response and action. This can be done by an autonomous program or a person with experience. The main issues that need to be solved (through thinking) when introducing the energy monitoring system are.

- How the existing building automation system has been built and the metering system comprising the meters attached to it.
- Which is the facility automation platform in use and the software it is compatible with, and how complex is the Integration of the energy monitoring system and measurement system.
- When detailed information from an existing measurement system can be collected and whether it is sufficient, or it would be necessary to install additional meters/change the meter information collection settings (for example, the interval of data collection).
- Is it possible to use (extract) data from prior periods in order to create a reference period for comparing consumption?
- Which software to deploy and the required functionality.
- The energy consumption of the building and the resulting savings potential.
- What are the building personnel – what their competence is and what part of the person can do, what should the program do?

What can be joined to the system

The interface of energy monitoring with other systems depends mainly on the software used, the existing system and the one who performs the interface.

It is theoretically possible to interface most of the systems that can be accessed from the network, but the main issue is the reasonability of carrying out a technical solution.

When used as an example of the software and systems used in this project, the following data were collected in the energy monitoring system.

- Through the Estfeed platform, electricity hourly consumption was collected from main meters (i.e. in buildings electricity headings).

  Note: The project was not required to interface with software interfaces and was proposed by the contractor (for testing and comfort purposes). Unfortunately, the environments were not sufficiently reliable for the project, with the result that electricity consumption data should continue to be forwarded manually (in case there was no duplicate main meter installed).

- Through the Estfeed platform, it is also possible to collect gas waste data in the future, and no collection of heat consumption data is excluded.
- External temperatures and degree days data were gathered through the databases of the Web environment in the Energy monitoring software.
- Through the BMS system, a dataset of all the meters that were federated with the automation systems was collected in the energy monitoring software (through the sub-server).

Since the dataset was collected prior to the energy monitoring Software Intermediate Server, the amount of data that is collected by the intermediate server (and through the data sources) is not restricted and can also be transmitted to other systems, such as SCADA systems, several parallel EMS environments, or management software, if necessary.

In conclusion the connection itself, the number of interfaces is dependent on the skills of the contractor, the technical solution used and the existing systems, and are not specifically limited.

Main challenges

- Duplicate main meters must be used to ensure the system and the autonomy of the data.
- It is important that the system collect data at sufficient intervals (for example, 15 minutes) and store them in an archive. The system must allow for the export of data to carry out integration or transition to other systems.

- The BMS used must allow interlocking with third party software. For example, transfer data to the HTTPS protocol using the Ecoscada software (which was used under this project).
- Energy use must be measured by parts of the building and by any larger or more specific technical utility system (e.g., ventilation unit, cooling device, heat oil, consumption, kitchen, sauna, swimming pool, part of an area). According to the rule of thumb, at least one meter must be installed for each €5000 year of expenditure.
- Energy savings are a low priority for most parties.
- The energy price is too low.
- The customer and the maintenance staff have lack of motivation for energy saving.
- The client requires settings that entail unreasonable energy consumption.
- The maintenance man has not implemented several simple optimizations that will achieve the highest savings – precise setting of time programs with exceptions, setting temperatures.
- Several features are missing or not set up or are not optimally configured.
- Inadequate maintenance – many unconfirmed alarms, systems are running in manual or high energy mode.
- The buildings do not have a digital service diary where all necessary activities are recorded. There is a situation where no one knows who, when, and what changed.
- It is too long for the settings to be performed, and the necessary operations are often not done.
- Automation control logic is unclear and there are no correct instructions for use.
- The equipment is not controlled.
- There are inconsistencies in the automation control logic.

Answers to questions asked by the Client

Is Energy monitoring (additional application) financially viable?
If you use the finished solution/service together with the building automation monitoring, this solution is undoubtedly cost-effective. In particular, in chapters 3.7 of profitability, the 0 Profitability of energy monitoring and 0Monitoring energy usage as a service .

What are the benefits of a building user, building owner, manager and maintainer from an additional service/app?

Building User

- Optimising money and energy consumption.
- Improving indoor climate.
- Better functioning systems.
- Smaller footprint of the environment – fewer greenhouse gas emissions.
- Improving the energy label to comply with the established requirements.

Owner of the building

- Overview of technical building systems and related issues.
- Ideas and conceptual solutions for renovations.
- New ideas to consider when designing and building new buildings.
- Smaller footprint of the environment – fewer greenhouse gas emissions.
- Additional supervision of maintenance etc.

RKAS Building Manager

- Overview of technical building systems and related issues.

Maintenance man

- Add a tool to identify problems and improve the quality of care services.

Is it possible to interface different automation controllers with the system?
Yes, interfacing with EMS software on different systems is not limited, provided that the automatic controller and the EMS software used allows it. More specifically, the interfaces described in chapters 1.4 and the 0.

Cooperation between the monitoring platform and the automatic system – what is reasonable and what is not?
This issue has been dealt with in chapter 3.5.

Benefits and feasibility in public buildings?
Public buildings with firmly developed use templates are a very good candidate for monitoring and management implementation to achieve energy savings. More specifically, the topic is described in Chapter 3.1.

To what extent does artificial intelligence contribute to achieving results?
In parallel to this project, a test project was carried out on the Lubja 4 building, where the focus was precisely the application of automatic control by the machine using artificial intelligence. The project was very successful, but it should be borne in mind that there were very large differences between the two projects, so they could not be compared to one-on-one.

- This project was not provided to the contractor, all the changes were performed by the managers and the technical maintenance agents. In the parallel project the autopilot was essentially free to make changes.
- When this project was dealt with by 5 buildings, the Lubja 4 project focused, specifically on a single building.
- Lubja 4 building is more modern than this project, data points are there by repeating more, and the autopilot communicated directly with THE BMS system. This project used a separate EMS-environment, which collected only meter data.
- Artificial intelligence can process considerably more data points in parallel if it is capable of any operator. However, artificial intelligence puts certain limitations on this programmer, and artificial intelligence may not always find such mistakes, which are due to the cascading effect or that arise from very unusual circumstances, such as structural mistakes.

As a result, the following conclusions could be drawn in a general manner.

- Artificial intelligence is a very important helper and certainly helps to achieve even better results, with no linear benefits for data points. The more data points the building has (sensors, controlled devices, etc.), the greater the benefits are artificial intelligence, capable of parallel processing significantly more information than a person.

- Artificial intelligence sets certain limitations for this programmer/fixer. The optimal solution is to combine artificial intelligence with a competent operator, who will solve the problems of artificial intelligence in trouble. However, artificial intelligence can also be of great help by informing an unfavorable situation or a malfunction, but a more profound diagnosis of the problem may often require an operator's experience and perception of the situation on the ground.

Symbiosis of the monitoring system and automatic systems

Depending on the solution used, the building system and the energy monitoring system often use software designed with different objectives. While some of the functionality may overlap, the rule of thumb is that the BMS (*Building Management system*, *Building automation system*) is designed to manage and control the buildings, and that there is no or little emphasis on the energetic profile of the building. The EMS (*Energy Management system*), on the other hand, has been designed specifically for analyzing energy consumption, detecting anomalies and optimizing energy use, or has built-in tools for optimizing energy consumption, but depending on the software, there may not be a direct interface to the BMS, i.e. there is no control and no change option.

In addition, the question is whether the monitoring of energy consumption and optimization is carried out by the same staff who will be carrying out technical monitoring of the building. Therefore, the interaction between EMS and BMS depends on the specific source conditions, but the following may be excluded as genera.

- Since EMS and BMS are mostly of different orientation, where EMS is mainly used for the monitoring of energy consumption, and for the control and monitoring of HVAC building systems, it would be expedient to keep them apart for most of the software provided, because they are likely to have separate systems for their specific functionality, analytical capacities and algorithms.
- The separation of EMS and BMS allows for more convenient sharing of tasks between the various parties, for example, BMS monitoring can be carried out by the maintainer and EMS monitoring building manager or a corresponding specialist. If one of the

parties carries out both functions, there will be a danger place where, for example, the maintainer is aware of certain problems, but because there is no external control function, it does not address the problem, because it does not consider it to be reasonable or does not wish to deal with it easily.

- However , in some cases it is recommended that the work of BMS and EMS be linked, for example, if the EMS being used is capable of running directly through the BMS (using, for example, machine learning) or BMS and EMS are in close connection with each other and thus allow for more enhanced data exchange than can be achieved through the introduction of a third-party EMS.

Potential security risks

Unauthorized access to BMS may result in catastrophic consequences that may be caused by negligence, ignorance, or maleness. In a more lenient case, changing the settings may result in inconvenience for the building users or an increase in energy consumption. In the worst case, the equipment or building may be harmed. As a result, significant attention should be given to access to the BMS to prevent unauthorized access.

The main risk for EMS (if not directly related to BMS, i.e. not its own management functionality) is data leakage to unwanted parties. The data can be exploited, for example, to find the main uses of the building, analyze the energy creation profile of buildings and find weaknesses in the exploitation of the building or the design of the crime.

As a result, it is recommended to always apply the following measures.

- The use of systems is allowed only for authorized users using authentication.
- Data exchange between environments and/or computers should operate in encrypted form.
- If possible, use VPN software (*virtual private network*).
- Use HTTPS protocol in web environments.

Profitability of energy monitoring

The profitability of the energy monitoring service depends very much on the precise content of the service. Only monitoring energy consumption in a separate way, significant energy saving does not give, but opens the opportunity to identify anomalies in building consumption and diagnose sources of problems.

To achieve energy savings, automatic systems must also be monitored in parallel. Rather, the main work of building automation and energy monitoring are the means to identify anomalies and evaluate the results achieved.

In the context of this project, financial savings were achieved at CA 27.4 K € and the potential for another 18.2 k € was estimated. The total cost of the project was 60 k € and this annual cost, in case of a constant purchase of the service, is approx. 20 k €. Considering only the real savings achieved and if the service will continue to be used, the cost of monitoring will need to be over 5 years. If the potential savings or overruns are also considered, the payoff period will be less than 2 years.

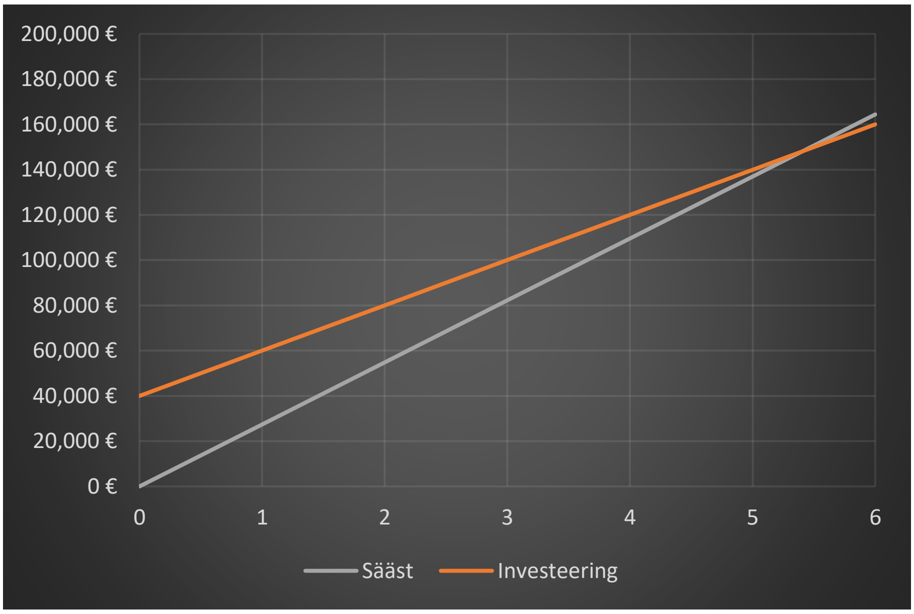


Figure 51. The payoff period, considering only real savings (grey) and investment (orange)

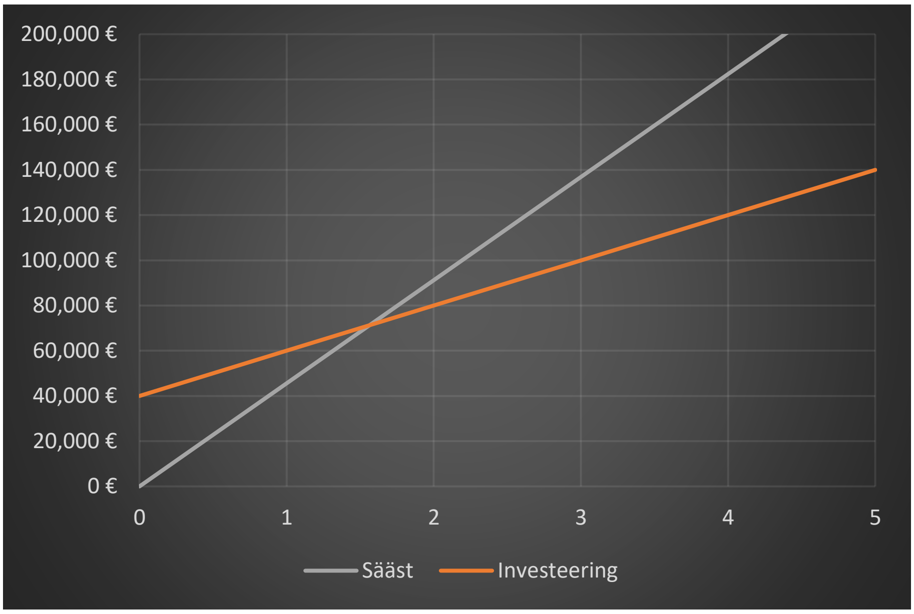


Figure 52. Potential savings in the light of the solution payoff time

The above information is summarized on all five buildings. In practice, savings and profitability numbers fluctuate very much depending on the building. Generalization, it can be said that the payoff time is definitely longer for small objects and shorter on large objects. The prerequisite is that the buildings are properly designed and constructed and the systems (above all automation) work in a way that is designed to do so.

EFFECT4Buildings is a pilot project and was also involved in the development of the system and service. As a result, the initial investment was considerably more expensive than it would be in the process of preparing the solution, since all the interdependencies had been carried out first. In addition, it must also be considered that, over time, when fine-tuning has been made to technical systems, running costs will be reduced to some extent as the work is reduced.

Monitoring energy usage as a service

Within the project

The EFFECT4Buildings project highlighted some issues that resulted in no maximum effect achieved. To derive the maximum benefit from this service, it is necessary to give more liberal hands to the contractor. A long command circuit will be a situation where different parties have to coordinate and comment on each decision. This ultimately results in a series of meaningful proposals due to time and communication problems. Particularly negatively affect the motivation of the various parties to tighten energy savings.

State Real Estate Ltd managers and building end users are not, or will soon be, HVAC, specialists in field systems. Therefore, decisions to implement management logic must give the service provider the discretion to do so and not to burden the administrators and the users of the building with technical nuances. In the extreme case, maintenance man should be included in the decision. For the final result, the Energy monitoring service provider will consult directly with the user of the building to find out, which final result is desired in relation to the indoor climate. On this basis, the service provider makes best discretion changes to the settings to achieve optimum energy consumption. In addition to rights, there is a need to precisely agree on responsibilities and an action plan in principle to solve problems. Contracts must precisely specify the obligations, rights and necessary coordination rules.

The electronic service book, where all parties can enter records of changes made in the building automation and utility systems, will also be useful.

The most important thing about the service is that the service provider is competent and motivated and can provide quality service. EFFECT4Buildings project repeatedly highlighted the inability or willingness of the maintenance man to solve the problems. In addition, managers and maintenance providers often lacked the motivation to work for the energy savings. As an exception, the State Real Estate Ltd manager of the Tamme Gymnasium, who clearly wished to achieve energy savings in the building and the improvement of the indoor climate, should be highlighted. All related parties must have the motivation to work. For example, there could be some percentage of the money saved.

How could the monitoring be a service?
Theoretical object:

- Assumption:
  - Object size 3000-8000 m².
  - The existence of building automation.
  - A remotely readable meter in the building 10-20.
  - Rights and powers to change the settings of the monitoring Supervisor.
- Cost of the theoretical sample object.
  - Initial investment For EMS 2000-4000 €.
  - Monthly monitoring for approx. 10 hours (500 €).
- Profitability.
  - Savings are achieved throughout the theoretical overconsumption.

- Estimated payoff time 1-2 years.

Customer and user Feedback

State Real Estate AS in cooperation With DeltaE in the test of energy monitoring, its impact and usefulness in a 12-month period in five different buildings. The testing was done using the Ecoscada software and The Technical Staff of DeltaE who regularly watched the building automation system remotely. This chapter is written based on feedback from four users (all from the State Real Estate Ltd) (Mikk Maivel, Rauno Laiv, Gert Rahnel and Madis Kaljuvee).

Software EcoScada:

How often you used the EcoScada program?

Depending on the job specificity of the property manager, the role of the state real estate business manager is primarily to be a project manager and to deal with customer interactions, which is why there is a lack of time for additional energy use software. However, it allows easily, conveniently, and automatically to use the monthly reports to get an overview of the different customers energy usage and thus allows to conveniently redirect invoices to the subtenants. According to the Ecoscada the full functionality of the program was not used.

How you comment Ecoscada alarms - are they useful and justified and helped to control the energy usage of the building?

Sometimes, however, there were too many false notifications, and the interference limits were required to be validated. At the end of the monitoring period, the alert thresholds were in place and the energy change notifications were justified. There were problems with the division of roles, so the alarms remained too informative. When thinking about the future, it will be better to think about the alert response. Abnormalities and changes were not detected.

Was the program's visualizations understandable and helpful in obtaining a quick overview of the energy efficiency of the building and energy consumption?

The visualization was generally understandable, but it would have required somewhat more continuous use and more in-depth training.

Can you see soon the EcoScada program on your desktop?

The addition of any new program may not always simplify work. EcoSCADA is a specialized program and tool for the company's energy efficiency specialist or analyst, who monitors the energy consumption of buildings. The administrator is not able to use program on a daily basis – but automatic notifications and reports, that direct the schedule of energy consumption directly, will undoubtedly help and allow for a faster and more accurate data analysis.

Do you consider that the program allows you to measure the efficiency of the energy saving project?

To measure the efficiency and impact of energy efficiency, the program is suitable. The program can be set up with the desired reports and alert notifications, which automatically send the desired insights.

DeltaE Energy Monitoring:

Was DeltaE on energy monitoring helpful? Please describe what and how this helped to do your work better?

Energy monitoring i.e. the continuous monitoring of the energy use and utility systems of the building, was helpful. Sometimes it caused confusion and extra work for the maintenance man. For the building user it is helpful and helps to improve the indoor climate and reduce energy use. However, during the test period, there were problems with a long so-called "command chain", where the monitoring contractor provided problems to the administrator, and often the maintenance man disagreed with the problems, and the small changes often required a very unreasonably long time. The monitoring also clarified several problems that previously had no one pointed out (e.g. wrong selection of air hubs, etc.).

Has the customer satisfaction in the energy use of the building and internal climate increased based on the monitoring period?

Difficult to say. Surely a lot of problems solved or at least we got to know the problem existed. Customer satisfaction and energy savings are often contradictory, but many indoor climate problems were solved with the activities and the aim was to make the building more optimal for the user. Rather, the user was neutral. To achieve a better result, the end-user of the building must be interested and contribute.

Are the problems and proposals identified by DeltaE adequate and are you considering the implementation of these proposals?

Several suggestions will be planned in next year. The quick changes were made immediately. In many cases, the organization of procurement and the time of bureaucracy require that the work could not be carried out during the monitoring period, but we plan to realize reasonable recommendations.

Were the problem descriptions transmitted by DeltaE understandable and contributed to the planning of energy efficiency projects/repair work?

In general, the problem descriptions were clearly formulated with the professional. In the future, it would be reasonable that the proposal should already be detailed in the tender Technical Specification, which would greatly simplify the work of the administrator.

Feedback- General Energy monitoring test period:

Do you and how often do you follow the submeters and their consumption?

The submeters are rather monitored daily. If the indication of the sub-meter is required for monthly fee, the minimum consumption shall be monitored monthly, otherwise only, if there is doubt about the inefficient operation of the systems.

What was more useful – Ecosacada software or The DeltaE expert's?

Rather, the recommendations and suggestions of DeltaE were more useful than following the EcoScada.

Were the quarterly reports forwarded by DeltaE understandable and with sufficient detail?

In overall the quality of quarter reports were good, although the efficiency was low, as the information came with a large delay. In a future it will be a good idea to make work meetings more intensively and develop appropriate automatic reports, that provide a better overview. It is wise to discuss the improvement proposals in working meetings.

Summary

The current document is a summary of a sub-project conducted as a part of EFFECT4buildings. During this project, the metering systems of 5 buildings were added to an EMS-software (*Energy Management System*). Through the EMS and BMS (*Building Management System*), monitoring of energy usage of the buildings was conducted and solutions to decrease energy usage were offered.

The buildings that participated in the project were new (or renovated) and each had a BMS. The systems that were included in the project were Niagara AX, Siemens Desigo and Metasys. The EMS-software that was used is Ecoscada.

For a period of one year, the data was collected, which was followed by putting together this end-report. Additionally, reports were made periodically (1 month and each quarter). The project had a lot to teach, but there were some of obstacles which prevented maximizing energy savings. For example, there were issues in the BMS, constructional issues, communication problems and passive attitude.

DeltaE acquired an active role as an "energy manager" because savings cannot come from simply monitoring, but from changes and action. As a result of cooperation between the parties, using the EMS and BMS systems and applying solutions, the following savings were achieved, during the period of the project (compared to the reference period, which was 1 year before the project started).

- Heating Energy saved for 5 objects: 345.7 MWh, potential for additional savings is 190.2 MWh.
- Electrical Energy saved for 5 objects: 144.6 MWh, potential for additional savings is 124.5 MWh.
- Water consumption also decreased, but since no significant methods were applied, the savings are not calculated here.
- During the project, 161.5 tCO_2eq and 27 423 € were saved.

The payoff for the project, if it were to continue with the energy manager, would be around 6 years. If all the savings potential was realized, the payoff time would have been 2 years. If the project ends here and there will be no additional costs (for energy management service), the payoff time is also 2 years. Taking this into account, we can conclude that combining EMS-software with energy management service, the service is very profitable and useful.

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Annex 1- requirements for new and renovating buildings

Structural

- Ventilating air intake, which remain in the hands of direct sunlight and the surrounding surfaces heat up significantly the air intake air, measures must be taken to reduce the impact of solar radiation during the cooling period. For example, coating the surrounding surfaces with light coating material.
- The cooling and heating accumulation tanks must be dimensioned in such a way as to prevent too close the on-and-off switch of the cold machine or the heat pump. This means that the volume of the piping cannot normally be considered. It should be noted that the scale of the piping cannot be considered when designing, since the storage capacity of the piping manifests itself only in a situation where the system operates at a stable capacity.
- It is necessary to use the best practice in designing and constructing the most spacious solutions, to avoid later indoor climate problems. For example, heaters and cooling equipment must be positioned in such a way as to ensure that the best possible operational (sensory) temperature is also available to the people nearby for external surfaces and windows, it is necessary to effectively use air distributors interfering with the air and laminar air distributors, with minimal risk of pulling.
- A very big problem is the overheating of the rooms, often accompanied by a light hash. To avoid these problems, it is necessary to design and construct suitable solutions that block most of the direct radiation (light and heat). The solution must match the exterior of the building and must not completely block visual contact with the external environment. Overheating is a problem in all buildings without cooling, and partly also in cooling buildings.

Automation and control

Visualization

- All required and required sensor readings must be displayed.
- All setting numbers that are controlled by the building automation must be displayed. This means an invoice that does not relate to the internal logic of the factory automation of any device. Because the setting bill can be very much, you need to pick out those that are directly related to the energy use. For example, pre-heating and after heating of ventilation, air exchange rate or flow rate, lowering the temperature of the operating time for room controllers, etc.
- The control signal and feedback of actuating engines and other equipment must be on the same scale. This means, for example, that there must be no situation where the control signal is between 0-10 V and the feedback is 2-10 V.
- To make the system easy to understand for the user of the building automation, you must add the logic explanatory records if necessary. Different solutions have been considered.
- If any settings are made elsewhere than in the building automation (e.g. from the control of the ventilation unit itself), then this information must be included in the visualization.
- The visualization of equipment and systems must be carried out correctly according to technical prints, performance drawings and other requirements.

Management

- If a system is managed from the building automatics and the device's own controller, it must be very specific to delimit where something can and must be done.
- The air exchange in the building/section must be balanced. To this end, an appropriate section must be added where:
- Displays the air flow rates of all ventilation systems,
- Calculate the total air flowrates,

- Displays the balance/imbalance,
- Alarm is sent if a greater deviation occurs,
- The air flow rates of the ventilation systems shall be automatically corrected.
- Efficient production and sustainable use of cold energy. The refrigerant must always be measured with the electricity consumed and the cold energy produced and the simultaneously calculated efficiency factor. In the indication of the efficiency factor, the alarm shall be given or the switching between the free-cooling and forced cooling is performed.
- It is necessary to create simple solutions for the user of the building outside the normal use time. For example, timer buttons that turn on and maintain a specific ventilation system or part of a ventilator for a given time.
- Features designed to ensure indoor climate and optimize energy consumption must be implemented.
- Night free cooling with ventilation system.
- Cooling return for ventilation equipment.
- Control of the temperature of the ventilation system inlet air to the exhaust air temperature or any analogous function which considers the changes in internal or external climates.
- Nudging the usage time from external settings. For example, air flow rates of ventilation systems, room temperatures.
- The suspension of domestic hot water circulation for an external period of use.
- The need for a room client.
- VAV/DCV-valves or air distributors for rooms where the operational load changes in a large range (meeting rooms, classes, gyms, etc.).
- The intake temperature optimization depending on the rooms need.
- Pressure optimization in systems with variable airflow.
- Spacious client management by presence.

- Management of HVAC systems by actual use of the building – presence sensors, surveillance system, time programs, etc.
- Control of illumination by place of presence and enlightenment.
- The configuration of HVAC systems must be carried out in the course of monitoring, so that in the rooms where people are present, most of the valves from heating and cooling equipment are partially open at all times. In this case, the room will be heated or removed from the space evenly. In a situation where the state of the valves often changes between closed or partially open states, oscillations occur in the room climate, which causes discomfort to the user (draft, operating temperature).
- For the use of the spacious client heating and cooling valves, smooth-handling solutions must be used: 0-10 V voltage signal or, in most cases, PWM signals.
- To maintain the temperature of the rooms as stable as possible, the temperature management hysteresis must be minimized, such as +/-0.5 K.
- It is necessary to automate the entire building's space – all heaters and cooling equipment of all rooms.
- The space controllers, thermostats and temperature sensors must be installed in such a way that they are "open" to the air, but at the same time are not affected by other factors (direct sunlight, injection air, cooling device, heater, etc.).

Sensors

- Sensors that measure the external environment must be installed in such a way that they only measure the intended purpose and are not influenced by other factors. A very common error is the installation of external air temperature sensors so that they are affected by solar radiation.
- Sensors in ventilation and air ducts shall measure the average airflow parameter. Therefore, the automation of factory-mounted automatics, which has been tested and the problems resolved, should be preferable. In the case of a hash solution, all

requirements must be observed for the installation of the sensor – long enough straight channel sections and so on. If necessary, sensors or solutions that give an averted reading – temperature, pressure, etc. must be used.

- In large spaces (rooms, gyms, etc.), the parameters (temperature, air quality) must be used to measure at least two sensors located at a different point in the space.
- All liquid heat carrier subsystems must be fitted with the temperature sensors for backflow in addition to the surface. For example: radiator heating, cooling logs, domestic hot water circulation.

Remote Reading System

Meters that collect and store data in the measuring system should be designed in the building. Although the meters required for the metering system may vary depending on the type of building, the nodes can be presented, which should always be measured irrespective of the type of building (assuming that such hubs are built into the building).

Electricity meters should be installed on the power input(s) of the building and meters or network analyzers should be used which allow other parameters, such as tension, current, reactive energy parameters, etc., to be included in addition to the consumption of electricity. In addition, electricity consumption should be measured in different technical systems, including the ventilation system (s) (if there are several, then, separately for each system), cooling system (s) (if there are several, separate from each system), heat substation (s) (if there are multiple, each system separately) and other technical systems (e.g. elevator (s), pumps, lighting (if solved with separate shields or shields) , etc.). In addition, it would be advisable to measure separately the electricity consumption of different parts of the building, for example, by story labels or by building parts. In addition, it is appropriate to measure the special nature of the building parts with energy consumption, such as kitchen/dining room, sauna (s), etc. When choosing meters, it is always advisable to use a factory-metering meter, which also has other functionality in addition to accounting for energy consumption (e.g. measurement of other electrical parameters).

- Lighting.
    - Interior lighting.
    - Exterior lighting.
    - Special lighting.
- Specialised equipment/consumption/consumers.

  - Lifts, escalators, etc.
  - UPS.
  - Servers.
  - Pumps.
  - Sauna.
  - Kitchen/dining room.
- Utility Systems.
  - Heater, etc.
  - The cooling system
  - Ventilation equipment – Use device-based records for very large equipment.
  - Other room client devices.
- Parts of buildings.
- The building's power input (s).

Heat meters should be installed separately for each heating circuit and a duplicate main meter should be installed in addition to allow verification of the energy consumption measured by the distributor and the Submeters. Since the main meter is mostly owned by a heating distributor, the duplexing meter helps to prevent a situation where it is not possible to collect information from the main account. It is always advisable to use ultrasonic meters with a factory calibration when choosing meters.

- Input.
- Radiator Heating.
- Ventilation heating.
- Hot water.
- Floor heating.
- Special systems – drying, swimming pool, etc.
- Disposal of residual heat-cooling, wastewater, etc.

Water meters should be installed across contours, parts and/or HVAC systems. In addition, similarly to heat, it is feasible to install a duplicate main water meter which has a control function and is not dependent on the distributor's willingness to cooperate. It is always advisable to use ultrasonic meters with a factory calibration when choosing meters.

- Cold water.
- Hot water.
- Kitchen cold water.
- Kitchen with warm water.
- Technological water.
- Water to ensure indoor climate (irrigation, cooling).
- All resources – urban water network, drainage, water well; When different water resources are used, virtual meters must also be created, indicating the total water consumption.
- In case the system supports and the consumption of significant amounts of water through these meters is recommended, it is also advisable to measure the intake in parts of the downstream system, the flushing water of the toilets, the watering water, the fill of the heating system.

The measurement of water consumption must be reasonably constructed. As the distribution of water consumption depends very much on the use of the building and the structure of the HVAC system as a whole, it is necessary to assess the water meters separately for each building, which is reasonable and what is not. It is most important to observe that all "special" and larger system components are measured.

- Virtual meters of utility equipment. Information to be "pulled" into the building automatics. Many modern indoor climate proofing devices (heat pump, ventilation unit, cold machine, circulation pump, etc.) are the meters built into the factory (virtual or physical). These meters are not calibrated and have a certain inaccuracy, but certainly give a significantly better overview of consumption.
- The entire metering system depends very much on the use of the building and the distribution of the consumption. Consumption data by building is required for larger buildings or buildings occupied by different institutions.

- The structure(s) of the measurement system must be made.
- For a multi-resource energy system, alarms and/or switching logic must be created by efficiency factor or price. For example, the refrigerant must always have measured electricity consumed and the cold energy produced and the simultaneous calculated efficiency factor. In the indication of the efficiency factor, the alarm shall be given or the switching between the free-cooling and forced cooling is performed.

Training and informing the user of the building

- Clarification of the parameters and settings that affect mainly the operation of the internal climate and HVAC systems. This is a ongoing process and one-off action is not enough!
- Ecological Footprint – Install an energy monitor in the building, which also shows the quantity of CO_2 emissions generated by the consumption of a particular building.
- If the system allows, calculate and display changes in consumption in the period of time X. The calculation must be comparable and true, which considers the degree days, special situations, etc.
- Compare the consumption of different buildings and share this information with the users of the buildings.

Annex 2 – Sample of the course report

Status of your current energy usage

2019 December

www.ecoscada.com

Tartu Tamme Gymnaasium (Nooruse 9)

Nooruse

50411 Tartu

Surface (m^2): 8104

Opening hours

Monday	8:00 - 20:30
Tuesday	8:00 - 20:30
Wednesday	8:00 - 22:00
Thursday	8:00 - 22:00
Friday	8:00 - 16:15
Saturday	closed
Sunday	closed

Dear Customer,

In this document we present a number of indicators and graphs on energy consumption in the last month.

Energy Overview

	Energy Consumption	Energy Costs	CO2-emission	Cumulative*
Electricity	31,566 kWh	€ 3,157	14,520 kg	-6%
Heating	78,506 kWh	€ 3,925	19,627 kg	-36%
Water	155 m³	€ 387	0 kg	NaN
Total		**€ 7,469**	**34,147 kg**	

* Savings compared to the previous year in %

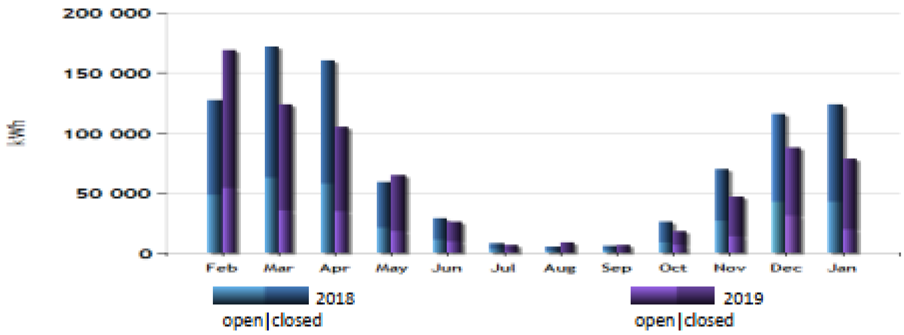
If you want more information about this report, please contact us.

We have done our utmost to ensure that the information reported to you are correct. If you do notice that the data is not correct in the attached document, please contact i.LECO Sp. z o.o. via the contact details below. No rights can be granted to the information in this report.

i.LECO Sp. z o.o., ul. Marii Curie-Sklodowskiej 48/8, 50-369 Wrocław, Poland
Phone: +48 (71) 79 49 565, info@ileco.energy

Heating consumption (not normalized): December 2019

Yearly Heating Consumption:

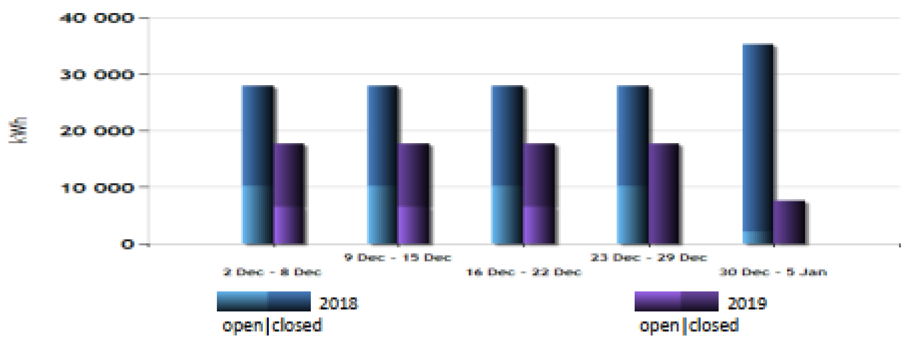


More information…

Last Year

- Heating consumption compared to heating consumption during the same month last year has changed **-36 %**

Heating consumption during the previous week and the same period last year:



More information…

ecoSCADA

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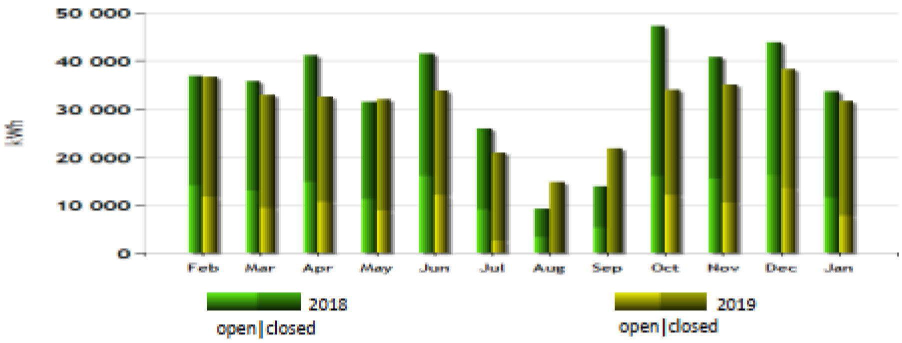
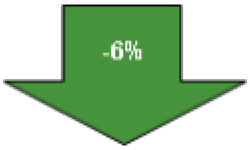
Electricity consumption: December 2019

Yearly Electricity Consumption:



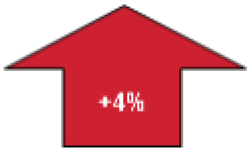
More information...

Consumption compared to last year



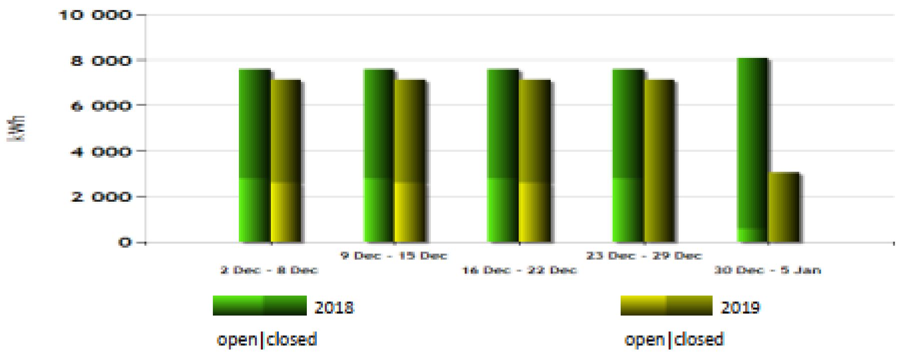
- Electricity consumption has changed -6 % compared to the electricity consumption last year during the same month

Since 1 January



- Electricity consumption compared to the average electricity consumption from January 1 this year has changed 4 %

Electricity consumption:



More information...

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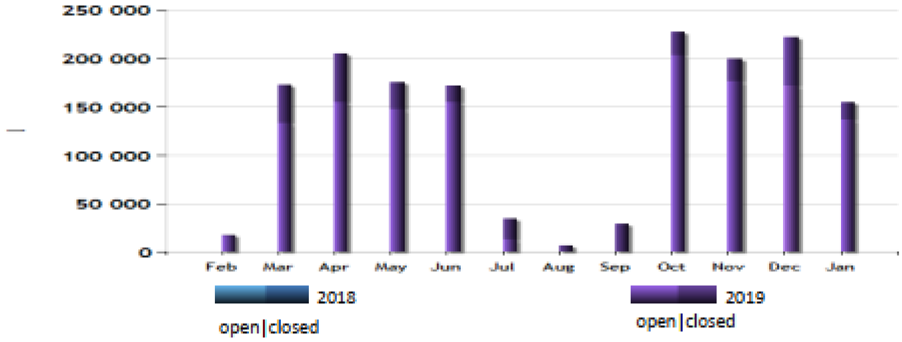
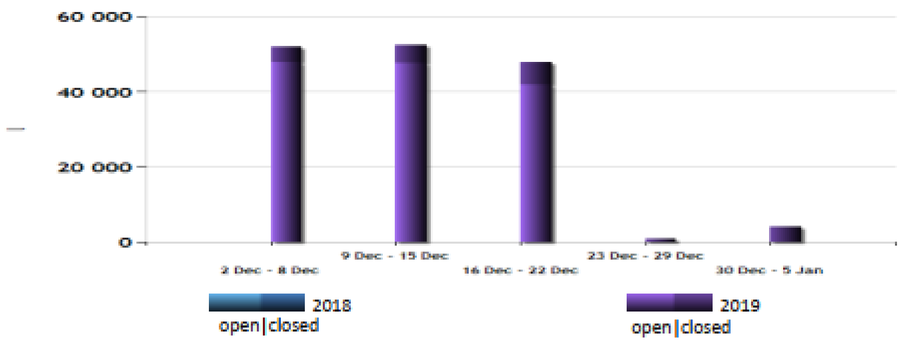
Water consumption: December 2019

Water Consumption:



More information...

Water Consumption:



More information...

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Submeters from 01/12/2019 till 31/12/2019

Medium	Name	Data %	Consumption	Unit
Electricity active (kWh)	E - JK lasketiir	100	1433	kWh
	E - JK14	100	5696	kWh
	E - JK31 kokku	100	2856	kWh
	E - JKV1	100	5305	kWh
	E - JKV2	100	4975	kWh
	E - Peatarbimine (arve)	100	31566	kWh
Warmte	S - P6randakyte	100	2423	kWh
	S - Peatarbimine (arve)	100	78506	kWh
	S - Radiaatorkyte	100	44370	kWh
	S - Ventilatsioonikyte	100	27265	kWh
Water (m3)	KV - K66k	100	25	m³
	KV - Peaarvesti	100	155	m³
	KV - Peatarbimine	100	155	m³
	KV - Taiskasvanute Gymnaasium	100	17	m³
	KV - Tamme Gymnaasium	100	140	m³
	SV - K66k	100	29	m³
	SV - Koristaja	100	0	m³
	SV - SS soe vesi	100	42	m³
	SV - SS systeemi t2ide	100	0	m³
	SV - Tsirkulatsiooni pealevool	100	0	m³
	SV - Tsirkulatsiooni tagasivool	100	587	m³

Annex 3 – Impact of technological solutions

The project EFFECT4buildings explored different technological solutions in the buildings studied. The following table lists the most important or somewhat more specific solutions that affect the consumption of buildings and the internal climate.

Technological solution	Impact of the solution on the resource and internal climate	Outreach	
Need ventilation with VAV valves	Great	Significantly reduces air flow rates and, in this connection, the energy consumption of ventilators electricity and after-heating and aftercooling.	H
Ledlights	Great	Significantly reduces the electricity consumption of lighting, especially when needs-based management (presence, level of enlightenment, etc.) is built in some form. In addition, the cooling energy cost decreases in cooling rooms.	
Cooling logs	Average	Causes less traction-related problems and allows for lower temperature ventilation.	L
Automated Roller blinds to block excessive sunlight	Medium/Large	Reduces cooling energy consumption/overheating of rooms, significantly reduces the light hash.	
Passive solutions to block excessive solar radiation	Medium/Large	Reduces cooling energy consumption/overheating of rooms, reduces light-flux.	a w
Local electricity production with PV panels	Great	Significantly reduces the amount of electricity purchased online.	P
Use of rainwater for rinsing of toilets	Great	Water quality of drinking water is significantly reduced.	

EFFECT4buildings

Building automation	Great	Gives an opportunity to get an overview of what is happening in the building.	c
HVAC Automation	Great	Provides an opportunity to get an overview of the technical systems.	
Monitoring and configuration of building automation	Great	There is a constant overview of what is happening in the building, helps you find energy saving and optimization opportunities, identify problems, etc.	
Energy Monitoring	Average	Helps to identify overconsumption and analyze consumption data.	
Monitoring and setting up of building automation and full service of energy monitoring	Great	There is a constant overview of what is happening in the building, helps you find energy saving and optimization opportunities, identify problems, etc. Allows you to identify overconsumption, analyze consumption data and assess the impact of the implemented settings and changes on the energy consumption of the building or system.	

In order to assess the impact of each technological solution in a given building, the measuring system must be structured in such a way as to allow the consumption of the systems affected by the specific solution to be measured. There is also a need for each solution in the reference moment – before and after. The project Effect4buildings did not result in this comparison, and therefore it is not possible to assess the impact of specific solutions. The only exception may be the use of the sludge for the rinsing water of the Põlva County, which has been measured. Based on the monitoring exercise, it can be argued that most of the solutions have a significant impact.

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