Leo Hakkarainen

Assessing energy efficiency potential in a large building portfolio using Nuuka smart building software

Helsinki Metropolia University of Applied Sciences

Bachelor of Engineering

Environmental Engineering

Thesis

Date 31.5.2017

Author(s) Title Number of Pages Date	Leo Hakkarainen Assessing energy efficiency potential in a large building portfolio using Nuuka smart building software 50 pages 31 May 2017
Degree	Bachelor of Engineering
Degree Programme	Environmental Engineering
Specialisation option	Renewable energy resources
Instructor(s)	Antti Tohka, Senior lecturer, Metropolia University of Applied Sciences

Nowadays buildings consume significant share of energy and produce an increasing amount of data which is rarely utilized to its full potential. This thesis aims to find energy efficiency potential in a vast building portfolio using smart building software produced by Nuuka Solutions.

Data from all sources relating to a building are organized in the software which presents the data in various graphs and tables or it can be exported to a more versatile analysis software. The goal is to harness this data to work for the building and its owners. By combining all the possible data sources to one location improves the possibilities to utilized this data which can create more value for the building.

First analyses were performed at portfolio level to assess the share each building has on total consumption of the portfolio. Buildings were sorted by total consumption and their electricity trends inspected for anomalies.

With this information, a meeting with the customer was held which showed promise in the value of the work. Previously only monthly electricity consumption data was available and analyzing the hourly trend data provided much more insights into the consumption profile of a building. Based on the meeting a lot of useful information about the operation and use was acquired which was essential in finishing the analyses and suggestions on improving the energy efficiency.

Keywords	Energy efficiency, electricity trends, smart buildings

Author(s) Title Number of Pages Date	Leo Hakkarainen Laajan rakennussalkun energiatehokkuuspotentiaalin arvioiminen älykästä rakennus ohjelmistoa käyttäen 50 sivua 31 Toukokuu 2017
Degree	Insinööri (AMK)
Degree Programme	Ympäristötekniikka
Specialisation option	Uusiutuvat energialähteet
Instructor(s)	Antti Tohka, lehtori, Metropolia AMK

Nykypäivänä rakennukset kuluttavat merkittävän osan energiasta ja tuottavat yhä suurempia määriä dataa, mitä harvoin hyödynnetään kunnolla. Tämän opinnäytetyön tarkoitus on käyttää rakennuksen tuottamaa dataa energiatehokkaiden ratkaisuiden löytämiseen laajassa rakennussalkussa käyttäen Nuuka Solutions kehittämää ohjelmistoa.

Ohjelmistoon kootaan rakennuksen data kaikista eri lähteistä ja sitä voi tarkastella useilla erilaisilla kuvaajilla ja taulukoilla. Tarkoituksena on saada suurempi hyöty irti datasta, mikä on usein heikosti organisoitua. Kun kaikki data on yhdessä paikassa, se vähentää raportointiin liittyvää työtä, helpottaa sen analysointia ja mahdollistaa jatkuvan monitoroinnin.

Ensin analysoitiin rakennussalkkua, minkä avulla muutamien rakennuksien sähköenergian trendejä otettiin tarkasteluun. Trendeissä ilmenevistä poikkeavuuksista tehtiin muistiinpanot, joiden avulla yhdessä asiakkaan kanssa pohdittiin syitä ja ratkaisuita rakennusten energiatehokkuuden kehittämiseen. Asiakastapaamisen pohjalta löytyi useita konkreettisia keinoja parantaa energiatehokkuutta, joista osalla voi olla hyvinkin merkittävät vaikutukset portfolion energiatehokkuuteen.

Keywords	Energiatehokkuus, sähköenergian trendit, data

Contents

1 Introduction

Improving energy efficiency of existing buildings is one of the most important tasks of the coming years as buildings are responsible for consuming 40 % of final energy and produce 30 % of CO_2 emissions when construction and building material production is also considered. The European Union is in the leading role when it comes sustainable technology and achieving ambitious short and long term energy and climate targets. [1]

Today we produce increasing amounts of data and new buildings can have vast sensor networks connected to building automation as well as smart energy and water consumption meters which record consumption data at least hourly. Renovating existing buildings are updating equipment will also increase the generation of data. Data produced by building equipment and meters are often poorly organized and managed through various sources. This thesis focuses on the utilization of electricity consumption data from smart meters to improve the energy efficiency of buildings in a large portfolio.

This thesis was commissioned by Nuuka Solutions Oy which develops smart building software that integrates all these different data sources and helps building owners and managers to reduce the carbon footprint by reducing their energy consumption. This is done by providing useful information in an easily understandable format which includes the energy use of the building and its processes as well as sensors. Nuuka Solutions and their software is introduced in more detail in the following chapter.

An overview of European and Finnish policies and legislation relating to energy efficiency of buildings is also provided in the following chapters where European directives are introduced with a recent evaluation of their impacts and how they are amended to meet the more stringent energy and climate targets of the future. The policy and legislation introduced in Finland will focus on the implementation of these directives and on improving the energy efficiency of buildings.

A brief overview of the Finnish building stock is also provided with a focus on the renovating existing buildings to meet the new more stringent energy performance requirements. The concepts of near zero-energy and smart buildings are also introduced.

The practical part of this thesis is a case study of Vierumäki which is a customer of Nuuka Solution. The case study aims to show the benefits that Nuuka smart building software can provide in managing a large building portfolio and how it can be used to improve its energy efficiency. The case study will first analyse electricity consumption at a portfolio level and then focus on more in-depth analyses of individual buildings. Analysing the electricity consumption trends of all the individual buildings in a large building portfolio would have been outside the scope of a thesis.

2 Nuuka Solutions

Nuuka Solutions is a Finnish software company founded in 2012 with a focus on smart building operation and management. Nuuka software uses building data from all and any sources to improve building energy efficiency and indoor air quality by utilizing existing technology of the building which creates more value from past investments. [2]

Buildings can produce vast amounts of data which is rarely used efficiently. Nuuka solutions software as a service solution brings all the available data from energy meters, automation, indoor air quality sensors and HVAC equipment together enabling various analyses which creates value for the building and its owners.

Having all the available data meet in software is the first step in creating smarter buildings which today’s technology makes possible. Utilizing the untapped potential of this data enables continuously monitoring the performance of a building and its processes. Continuous monitoring can provide warnings of equipment failure or elevated consumption which makes building maintenance more efficient and poorly performing equipment does not waste energy before manual inspections would recognize it.

2.1 Nuuka Smart Software

Managing a large building portfolio becomes easier with Nuuka software as through its intuitive reporting portal building managers are provided information about energy performance, indoor air quality and processes of a single building or the entire building portfolio. This makes it easy to find poorly performing buildings and to perform analyses to get a better understanding on the buildings performance.

The software includes analysis and reporting on indoor climate, energy efficiency, HVAC processes, sustainability and waste streams, but it also allows the development of third party applications which bring even more functionality to the software end-user. Regardless of the equipment or systems manufacturer the software can be integrated to most data sources using well established communication protocols.

2.1.1 Analytics

With Nuuka smart software various analyses to building energy efficiency and equipment are possible. These analyses can be performed at a portfolio or a building level using various key performance indicators and raw energy consumption data.

Electricity meters which produce data at least hourly can be used to create trend graphs of the electricity consumption of a building or room. This trend data provides valuable information on the consumption profile of the building, peak and off peak consumption times and rates. Trend data is used in this thesis to indicate energy saving potential in buildings.

Various weather parameters are included in the software and can be used in correlation analysis together with energy consumption. In this thesis, this correlation analysis tool is used for leisure buildings of Vierumäki which are electrically heated, and low consumption buildings are compared to high consumption buildings of similar type. This can provide insights to the thermal performance of a building.

2.1.2 HVAC systems

Modelling and analysing building and process data is a useful tool to find optimal operation conditions for HVAC equipment which ensure proper indoor air quality with efficient energy use. Once optimal operation parameters for equipment are set, the software can alert when deviations occur.

The performance of HVAC equipment deteriorates slowly through time and continuous monitoring is more efficient in recognizing it compared to manual inspections. This is also recognized as an efficient alternative by the European Commission in its most recent amendment of Energy Efficiency Directive introduced in the next chapter. Automated alarms will make sure that equipment is serviced before inefficient operation results in financial losses.

2.1.3 Reporting

Having all the building data in one place enables reporting options which harness the data to work for the building and helps in making more informed decisions. The work required to collect data from various sources and plotting informative graphs is work intensive, and this is emphasized in larger building portfolios.

The software can also be used for providing more accurate information when invoicing tenants, and the additional feedback of historical consumption and daily trend data can help occupants change their behaviour resulting in energy savings.

2.2 Benefits of smart building software

New buildings include expensive modern technology that produce substantial amounts of data, and older buildings are often renovated to include smarter energy and water meters as well as building automation systems. These are valuable investments, but are rarely utilized to their full potential.

Improving energy efficiency will save money and can create more value to a building as consumers are becoming more knowledgeable about climate, energy and sustainability issues. Buildings with energy efficiency initiatives are more sought out, thus many have reported increase in rents compared to similar buildings. Most importantly, increased efficiency will result in less greenhouse gas emissions.

Software solutions can have many tools which aim to help building managers and owners understand and improve the energy profile of a building or large portfolio of buildings. In the fifth chapter, some of these methods are introduced. The extent of what software tools are available depends on the current equipment of the building, but with just smart electricity meters’ valuable analyses can be performed which can result in improved operational efficiency and energy saving.

3 Policy and legislation on energy efficiency

European Union is the global leader in adopting stringent energy and climate targets and regulations to achieve them. The EU has set short and long term energy and climate change targets for the years 2020, 2030 and 2050. These goals aim to improve energy efficiency, the share of renewable energy sources and the reduction of greenhouse gas emissions.

Improving energy efficiency is at the centre of all policies and legislation which aim to reach the ambitious energy and climate targets. In 2015, the European Commission released their Energy Union package which aims to unify the European energy markets and grids. The policy decisions to move towards carbon neutral future are becoming more stringent and comprehensive. [3]

European Union has adopted an energy efficiency policy and legislation focusing on various fields. The following subchapters will introduce two of the main directives on energy efficiency and show they are amended to meet the more stringent 2030 energy and climate targets. Some of the implementation methods of these directives in Finland are reviewed afterwards.

Energy efficiency is recognized to be the most cost effective method to achieve the energy and climate targets; the most sustainable form of energy is the one which is not used at all.

The following sections introduce two of the main directives which aim to improve energy efficiency and fulfil the goals of the Energy Union of empowering consumers with more accurate information on energy consumption by utilizing modern smart technology. The aim is to move further away from large coal power plants to more decentralised energy production with renewable energy such as solar panels, which can be installed on buildings.

3.1 Directives

Directives are one legislative tool of the European Union used to reach the energy and climate targets. The subchapters introduce some articles from directives which affect the energy efficiency of buildings. The European Commission studied the impacts of the Energy Efficiency Directive and Energy Performance of Building Directive in late 2016 and proposed amendments to meet the new intermediate 2030 energy and climate targets.

Member states are required by the directives to reach the wanted results, the means can be decided by the member states themselves so that they fit the national environment. Additionally, the directives set certain timetables for the implementation of the directives requirements. In most cases, member states will make changes to the national legislation to implement the directive.

The following subsections introduce two directives which complement each other in achieving the energy efficiency targets which are part of the energy and climate targets set for years 2020, 2030 and 2050. Only the parts which affect building energy efficiency and relate to data utilization are reviewed. Existing buildings are recognized to hold the single largest potential for energy savings, and these directives aim to realize this potential through energy efficiency and improved metering.

3.1.1 Directive 2012/27/EU on energy efficiency

As per the Energy Efficiency Directive member states are required to set energy efficiency targets and to notify the Commission on the targets and their rationale. Member states should ensure that 3 % of total heated and/or cooled floor area of buildings owned or occupied by the government are annually renovated to meet the minimum energy performance requirements set in Directive 2010/31/EU on energy performance of buildings and provide individual energy meters for consumers which provide more accurate data on their energy consumption when existing meters are replaced or when the building goes through major renovations. [4]

The European Commission studied the impacts of this directive in late 2016 and reported that significant progress on energy efficiency has been achieved through the implementation of this directive. Energy efficiency improvements measured in primary and final energy consumption have been reduced by 18.7 % and 21.8 % respectively, based on data available until 2014. Thus, energy efficiency targets for 2020 based on final energy consumption have already been achieved, and primary energy savings are nearly there if current levels and progress can be maintained until 2020. The improved energy efficiency is only in part achieved through this directive, and some of it can be attributed to the 2008 economic crisis which resulted in decreased energy consumption. [5]

In the impact assessment of the directive, it was stated that residential and tertiary sectors have the highest potential for cost-effective energy efficiency improvements, but their full potential has not been realized because investments barriers which should be addressed in future policies. This directive complements the Directive 2010/31/EU on energy performance of buildings by requiring member states to report actual energy savings achieved which requires the renovation of national building stocks. This directive can be characterized as the incentive which drives energy efficiency improvements by various directives which aim for more sustainable society. [5]

The impact assessment and evaluations of the directive were accompanied by a proposal to amend the directive to meet the new intermediate 2030 energy and climate targets. The new 2030 target for energy efficiency is set to 27 % and will be reviewed in 2020 to consider a more ambitious target of 30 %. The proposed amendments were directed to articles which required action until 2020 to continue the benefits of their implementation which will result in increased renovation rates. [6]

3.1.2 Directive 2010/31/EU on energy performance of buildings

Improving energy performance of existing and new buildings will greatly affect all the energy and climate goals. This directive aims to improve building energy efficiency and the use of renewable energy use such as solar panels on roofs or facades of a building, which has a significant role in achieving targets for improved energy efficiency, share of renewables in energy production and reduction of greenhouse gas emissions.

Existing buildings which undergo major renovations must meet the minimum energy performance requirements of this directive. New buildings are also expected to meet these requirements and the directive also aims to increase the construction of near zero-energy buildings. New public buildings should meet near zero-energy standards by the end of 2018 and all new buildings by the end of 2020. [7]

The market for energy efficient buildings is increasing and people are becoming more aware of issues of sustainability, to further improve the market for energy efficient buildings, the directive requires member states to establish a certification system for energy performance of buildings. These energy performance certificates should be displayed on buildings such as shopping centers, supermarkets, restaurants, theaters, banks and hotels which are in public use to inform the public that energy efficiency and the environment are taken into consideration. When selling or renting a building or building unit the certificate should be shown to the prospective buyer or tenant and handed over once the deal is done. [7]

HVAC systems are becoming more common and are responsible for a significant portion of a buildings energy consumption, which is why improving the thermal performance of buildings is so important. Regular inspections and maintenance of HVAC equipment should be established by member states, and they should include the assessment of its efficiency and size compared to the thermal requirements of the building. [7]

The impacts of the directive were studied by the European Commission and were reported to have been effective in achieving its goals. Comparison of 2014 energy use to the baseline of 2007 revealed savings of 48.9 Mtoe, most of which resulted from reductions in space heating, cooling and hot water use. The impact assessment of 2008 estimated that the directive would achieve savings of 60 – 80 Mtoe of final energy savings by 2020, and considering the progress by 2014, it seems likely that these estimations will be reached. [8]

Member state strategies for energy performance certification of buildings have been delivering a demand driven market for energy-efficient buildings by encouraging consumers to buy and rent energy-efficient building and encouraging investments in energy efficient technology. Developing the market for energy-efficient renovations the Smart Finance for Smart Buildings Initiative aims to provide better access to finance removing the major barriers in realizing the cost-effective potential of energy savings in existing buildings. [8]

The proposal for amending the Energy Performance of Buildings Directive strives to accelerate the cost-effective renovations of existing buildings by mobilizing financing and encouraging the adoption of ICT and smart technologies to ensure efficient operation of buildings. Smart technologies are presented as the alternative to physical inspections of

HVAC systems to ensure efficient operation over time. Electronic monitoring of building and equipment performance is a cost-effective solution compared to physical inspections and enables building managers to predictively order maintenance for equipment before diminishing performance of equipment results in unnecessary financial losses. [9]

The proposal also introduces a smartness indicator to assess the technological readiness and the ability to use information and communication technology to optimize its operation. The smartness of a building includes the ability to interact with occupants and the grid to ensure efficient operation considering the comfort of occupants and the ability to perform demand response during peak consumption. The smartness indicator aims to raise awareness of building owners and occupants on the value of building automation and electronical monitoring which provide actual information on energy savings and other functionalities such as continuous monitoring of building equipment. [9]

3.2 Energy efficiency development if Finland

The following subchapters introduce Finnish energy efficiency law and the development of energy efficiency in Finland focusing on the building sector. To realize the vision of a carbon neutral building environment various policy and legislation solutions have been created. The Energy Efficiency Committee stablished by the Ministry of Economic Affairs and Employment recognized 125 energy efficiency measures in Finland to achieve 2020 targets. Of these measures 52 are for the building sector and 22 for households. The measures focus on new buildings, renovations, metering, urban structure and zoning as well as use and management of buildings. These measures include the implementation of European directives on energy efficiency, energy performance of building, eco design and energy end-use and energy service. These methods are divided into groups based on the implementation method such as legislation, finance, information, education and research. [1]

3.2.1 Energy efficiency law

The law on energy efficiency was set before the end of 2014 and is one of the measures taken to implement the energy efficiency directive. The law applies to energy producer and distributor companies as well as on large companies. The main goals of this law are to increase energy efficiency by requiring large companies to assess their energy performance profile and by advancing the co-production of electricity and heat.

Large companies exceeding over 250 employees or revenue of over 50 M€ are required to assess and report the energy performance profile of the company including all energy consuming activities such as buildings, transportation and industrial and commercial activities. Energy audits are to be performed every 4 years and to include site surveys of the most energy intensive buildings. Companies which already have certification for ISO 50001 or 14001 systems may be released from the requirements if they conform to the minimum requirements of this law. [10]

New or renovated power plants and industrial facilities with thermal power exceeding 20 MW need to perform cost-benefit analyses on the ability to co-produce heat or to utilize process waste heat in district heating networks. The cost-benefit analyses and the decision whether the company will or will not produce heat energy will be reported to the Finnish energy authority before construction or renovations take place. [10]

The law also includes a chapter on metering and billing of district heat and cooling consumers. This includes clauses for providing competitively priced meters when existing ones are replaced or when new connections are made. Clauses for billing include requirements for the frequency and historical information similar to what the energy efficiency directive requires. [10]

3.2.2 Energy efficiency agreements

The Ministry of Economic Affairs and Employment oversees a voluntary energy efficiency agreement initiative which implements some requirements of the Energy Efficiency Directive. The agreements play an important role in achieving the national energy and climate targets. These agreements are adopted by hundreds of Finnish companies from many different sectors. Between 2008 and 2015 theses agreements had a significant impact on energy efficiency in industry and energy production. Total savings during this period are 10.64 TWh of heat energy and fuels; 3.59 TWh of electricity which resulted in total savings of 500 M€; and 4.3 million tons of less carbon dioxide emissions. As much as 70% of these savings were achieved in industry and 21 % in energy production. The implementation of these energy saving methods required an approximate of 1050 M€ in investmets. [11]

The Finnish Association of Building Owners and Construction Clients (RAKLI ry) signed the real estate sector energy efficiency agreement for the period 2010-2016. The first energy efficiency measure of the agreement was for residential rental buildings. Currently 26 different residential organizations are taking part in the measures. In 2015, the over 80 % of buildings which are a part of RAKLI ry reported building information. These measures aimed to achieve at least 9 % improvement in energy efficiency by 2016 and reduce energy consumption of residential buildings by 20 % before 2020. In 2015 these measures resulted in savings of 36 GWh. [12]

4 Finnish building stock

The following subsections will introduce the building stock of Finland including its composition and age structure which will be followed with a look into the renovation of buildings and energy efficiency. The concepts of near zero-energy and smart buildings are also introduced.

Buildings consume 40 % of the final energy and produce 30 % of the CO2 emissions when the consumption of building construction and building material production is considered with respect to building heat energy and electricity consumption. Around 20 % of the final energy consumed by residential and commercial buildings goes to heating. [1]

Building energy use is affected by various factors such as the building envelope, local climate, occupant behavior and the context of the building, i.e. whether it is a residential, commercial, industrial or something else.

4.1 Finnish building stock characteristics and renovations

The Finnish building stock is relatively young and consists mostly of residential buildings which account for 85 % of buildings and 63 % of the floor area. As much as 56 % of the residential apartment buildings were built between 1950 and 1970, and it is estimated that the renovation rates should increase 2 or 3-fold to meet the renovation needs of these buildings. Approximately 40 % of the total building area was built during 1970 and 1989. The Uusimaa region has 17 % of the buildings and 26 % of the building area and most of it is in the Helsinki metropolitan area. [1] [13]

Building renovations are required when maintenance operations cannot ensure that the building and its equipment perform optimally. Predictive maintenance and renovations can prevent expensive renovations form moisture and mold damage, which are common because of the Finnish climate. The Ministry of Environment released a strategy for renovation of existing buildings in 2007, which aims to improve the culture of predictive building management and maintenance and the adaption of the building stock to changing demands. [13] [14]

Information about building renovations are scarce, but condominium type buildings have renovation data from the years 1999 to 2011. HVAC systems represent the most significant portion of renovation during the years 2010 and 2011. Renovations to the exterior structure have been on average the most significant focus of renovations between the years 2000 and 2011. Renovations in 2000 focused mostly on residential buildings which represented 51 % of exterior renovations, 37 % of technical system renovations and 56 % of interior renovations. Building renovations by construction year shows that buildings built during 1961-1989 represented a significant portion of all renovations. These renovations focused mostly on technical systems controlling heat and water and interior renovations of kitchens and bathrooms. [13]

Exterior renovations were done mostly because of already occurred damage especially on roof structures, but preventive maintenance came in close second. Around 20 % of windows and doors were renovated to improve the quality which can contribute greatly to the thermal performance of a building. Predictive and preventive renovations to exterior structures are important because when moisture and mold damage occur the renovation costs can become too high and demolition becomes a more preferred option. Interior renovations were mostly focused on improving the quality and on changing the use of indoor space. [13]

The situation with building technical systems was more evenly divided between improving the quality, preventive maintenance and occurred damage. For HVAC and electrical systems improving quality was the main reason for renovations while heating and water systems were mostly renovated because of damage or reduced performance. [13]

Issues of moisture and mold in public buildings were attributed mostly to mistakes in planning and construction, which represented 42 % and 28 % of the reasons in 2005 respectively. The cause of these issues was attributed to precipitation and soil moisture, which represented 51 % and 34 % of moisture and mold damage. Indoor humidity was the cause of moisture damage in only 2 % of cases in 2005 and 5 % in 2000. Indoor humidity can cause moisture damage together with poor thermal performance in spaces where temperature allows the condensation of water into the structures. Moisture and mold damage occurred mostly in roofs and foundations except for office buildings, where most of the damage occurred in exterior walls. [13]

Building renovations have been on a steady rise for many decades in Finland. The revenue of large construction companies was mostly from new buildings while smaller and more specialised companies performed mostly renovations. Renovations done by a large company were on a large part done for commercial and industrial buildings, while the smaller and more specialised companies renovated more residential buildings. [15]

Figure 1 below, compares the value from renovation of existing buildings and construction of new ones. The values after 2009 are not comparable with the previous years because the reporting criteria changed. During previous years, the statistics included the renovation revenue of companies with over 20 employees and the records starting from 2009 included companies with over 10 employees. Additionally, the renovation value of the Figure is the sum from renovation revenue by large construction companies and the value of renovations performed in condominiums. Renovations in more recent years has continued to increase in value: 5618 M€ in 2012, 6125 M€ in 2013, 6636 M€ in 2014 and 6848 M€ in 2015. [16]

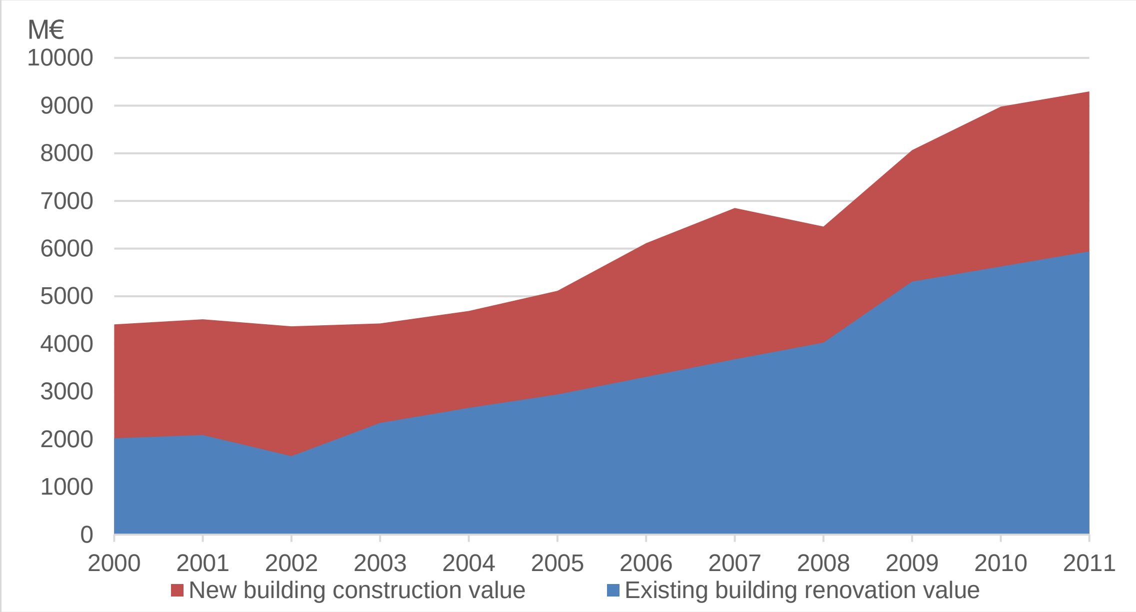


Figure 1 Value of building renovation and construction of new buildings [17] [18]

Improving the habits of building occupants and optimizing the use of building systems and equipment are estimated to have a similar energy saving potential as the construction of new more efficient buildings and energy efficient renovation activities. The Energy Performance of Buildings Directive is implemented through building codes, energy performance certificates and decrees considering the inspection of HVAC systems. The building codes set requirements for ecologically, economically, socially and culturally sustainable ways to use land and to build. [1]

The legislation introduced in the previous chapters will accelerate the renovation of existing buildings and requires them to meet higher energy performance levels. An increasing number of buildings will include smart meters for energy and water, which will enable software solutions to monitor and find solutions to improve efficiency. Predictive maintenance of HVAC systems and building envelope is possible by continuously monitoring the thermal performance of a building and the efficiency of its equipment. The same software solutions can also affect occupant behavior by improved feedback on energy and water consumption to realize a more sustainable future.

4.2 Energy efficiency in new buildings

Building codes have become more stringent in the recent years; new and renovated buildings must meet minimum energy performance requirements. The demand for energy-efficient housing and buildings is increasing, and as demanded by the Energy Performance of Buildings Directive new buildings must to meet near zero-energy levels after 2020. The following sections will introduce a few energy efficient building types which are becoming more common in Finnish building stock

For a building to meet zero-energy or near zero-energy levels higher initial investments are needed. A zero-energy building consumes and produces the same amount of energy annually. This is achieved by a building design which depends on the local climate to achieve efficient thermal performance, using energy efficient technology in the building and by in-situ power generation from renewable sources.

For efficient thermal performance during the summer and winter the following aspects should be taken into consideration. The building site should be analysed and proper orientation chosen based on the available sun path. It should have sufficient insulation, shading to reduce heating during summer and materials which can store heat from the sun during winters. Window size and location are also a key aspect. While these aspects can be applied to any building, it requires accurate planning, know-how and possibly modelling to achieve consumption levels which can be balanced with on-site energy production.

Achieving near zero-energy or zero-energy buildings, the production of onsite renewable energy is required. Options for renewable energy production depend on the building location but include solar electricity and heat production, possible wind production near the building and geothermal heat pumps. It is not required and it is also unlikely that the building will always consume and produce the same amounts of energy, but the goal is to annually reach these levels. Renewable energy can also be bought from the grid to achieve the zero-energy levels.

4.3 Smart buildings

The term smart building is used quite generally, but it usually includes the use of building automation systems which automates certain aspects of the buildings operation such as HVAC equipment and lighting while monitoring indoor air quality. Buildings can have varying levels of smartness depending on the technology available in the building.

Smart buildings of tomorrow should be able to monitor and optimise building operation and equipment to work as efficiently as possible; this includes the integration of all building systems and technology. The service provided by Nuuka Solutions is a step to the right direction integrating data from energy producers, building systems and other third-party members such as waste management companies to provide a holistic overview of building inputs and outputs.

Further investments into smart technology which enables the communication with energy producers and smart grids makes it possible to implement demand response solutions during peak consumption. The technology already exists to remotely control equipment with significant energy demand, but is not widely used and the implementation of such technology together with on-site renewable energy production will be an important step to transfer our energy markets from centralized large-scale production towards more distributed small-scale energy production.

Smart building applications are key in realizing the vision of carbon free buildings. Together with green design solutions that utilize the local climate to achieve an optimal building environment with minimal energy use and smart technology which optimize the building operation it is possible to produce most of the energy needed in-situ. Analysing the building site before the construction and planning process will provide insights to designers, architects and engineers who can use the information about wind directions to help ventilate the building and to design shades which can help heat the building during winter and block the heat during summer. This is especially viable in the Nordic environment where the angle of the sun differs significantly from summer to winter.

5 Vierumäki Case study

Vierumäki village is part of the city of Heinola and accommodates the Sport Institute of Finland. The Sport Institute was founded in 1927, and the area has been expanded steadily during the years. After the turn to 21st century, Vierumäki has grown at an increasing pace, and the area hosts various outdoor and indoor activities.

Vierumäki has a total of 283 buildings in Nuuka software and 174 of the buildings are currently generating electricity consumption information. The integration of Vierumäki building portfolio to Nuuka software is still in progress, and heat energy for 2017 can only be found in its entirety from March. Therefore, the analyses will focus on electric consumption.

The buildings are managed by various companies which work together. It became evident quite early that performing, portfolio analyses to each company would have been too much work in the confines of a thesis; therefore, it was decided that the focus would be on buildings with different uses and major contributions to electricity consumption. The first part of the work was to sort and analyse buildings at a portfolio level and use the tools available in Nuuka software to choose which buildings to focus on with more in-depth electricity consumption analyses.

Portfolio analyses were performed for three companies which manage the most energy intensive buildings and with various uses such as sport, education and leisure buildings. Nuuka portfolio analyses performed for the companies included total electricity consumption of 2015, 2016 and 2017 and electricity index comparisons for the leisure buildings as they are similar in equipment and building characteristics. The data was exported to Excel where the consumption of 2017 was compared to total consumption of 2016 and individual buildings were compared to the total consumption of the portfolio to acquire information of their contribution to the total consumption of the portfolio.

Companies which rent leisure buildings for customers of the area represent the largest building portfolio but consume significantly less electricity when compared to companies which manage the various sport and education buildings. Analysing the trends of the entire portfolio is not practical; therefore, similar comparisons were done for the historic electricity consumption and consumption indexes at a portfolio level in Nuuka and Excel.

The following subsections will introduce the buildings with significant contributions to the electricity consumption of the company which manages them. Examining the trends of the entire portfolio was not practical considering the scope of this thesis as the aim was to introduce the possibilities that analysing building electricity consumption trend data would provide.

Electricity use per floor area of the building is a useful index to assess how energy intensive the building use and its equipment are. The index is also a valuable tool when comparing similar buildings as elevated kWh/m^2 can indicate excessive energy use or sub optimal performance. In the case of the leisure buildings a large share of electricity is used for space heating and the total electricity consumption values of Figure 2 are not temperature normalized. Average temperature was lower during 2017 than in 2016 as can be seen from Figures 3 and 4, which is part of the reason for the decrease in consumption presented in Figure 2.

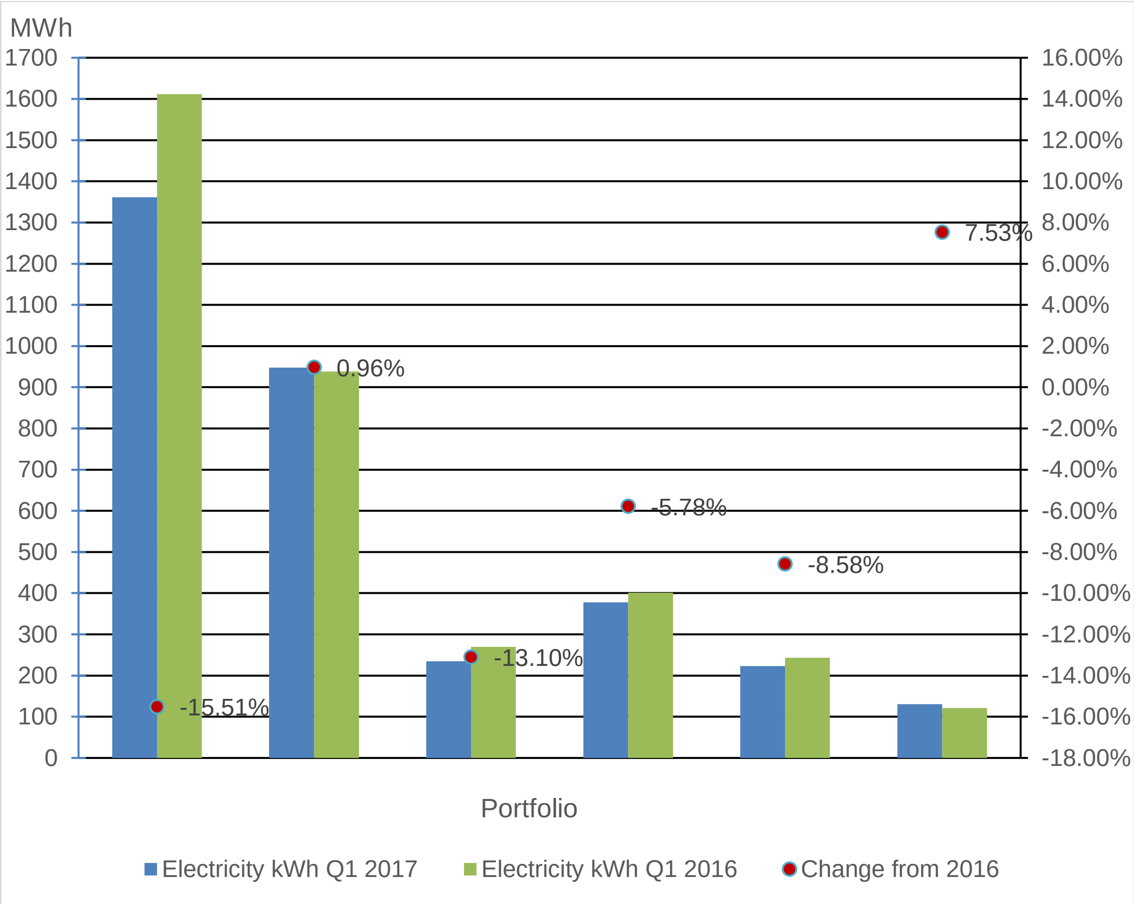


Figure 2 Vierumäki electricity consumption by portfolios in Q1 2016 and 2017

Figures 3 and 4 present the temperature trends and average temperature during the first quarter of 2016 and 2017. The temperature difference is not that significant, but 2017 has on average been a few degrees warmer. As the focus is on electricity consumption the effect of outdoor temperature can be seen from buildings which are electrically heated. All the leisure buildings are electrically heated and the electricity consumption of some of these buildings will be correlated to outdoor temperature and compared between similar buildings.

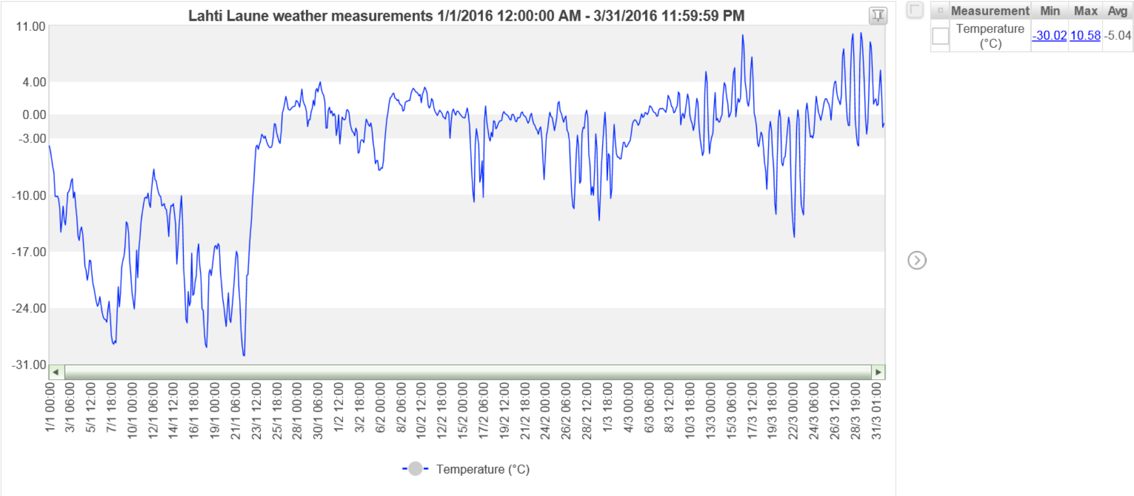


Figure 3 Temperature in Lahti 2016

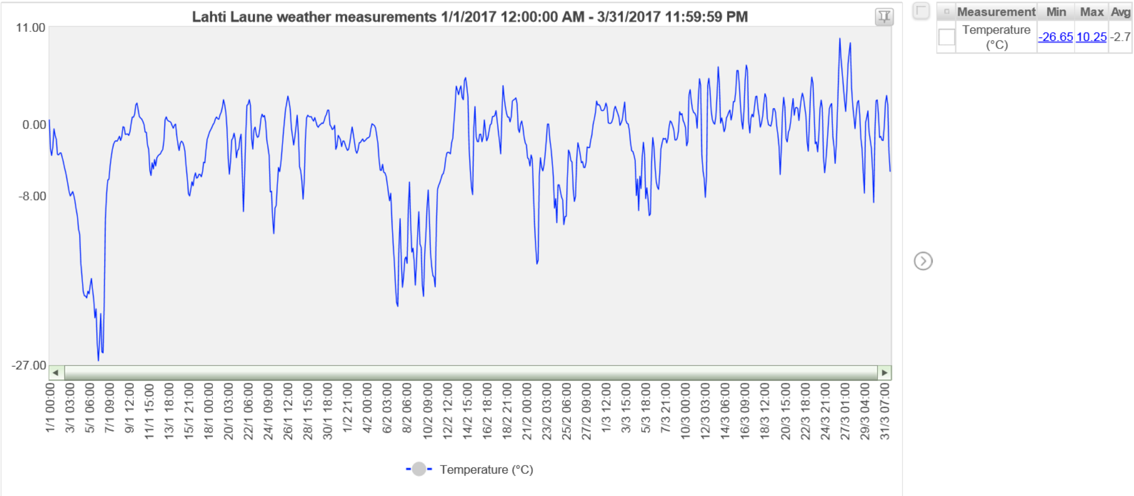


Figure 4 Temperature in Lahti 2017

5.1 Sport buildings

This portfolio includes various sport buildings and is the most energy intensive building portfolio in Vierumäki consuming over 2 times the electricity of the next most intensive portfolio.

The sports hall 3 has seen a significant reduction in electricity consumption from 521080 kWh in 2015 to 285706 kWh in 2016. In the first quarter of 2017 the sports hall has consumed 57287 kWh which is about 20 % of the total consumption of the previous year and over 40 % lower than the first quarter of 2016.

Electricity consumption of snow machines nearly doubled from 2015 to 2016. During the meeting with Vierumäki representatives, it was observed that some of the equipment was still plugged in which resulted low but constant consumption rates. Power leaking is a real problem and will result in significant unnecessary consumption annually. During the meeting with Vierumäki representatives service personnel was called about this to see if there is still equipment plugged in. The consumption decreased to 0,1 – 0,2 kWh from around 1 – 2 kWh, this change in consumption occurred 26.4.

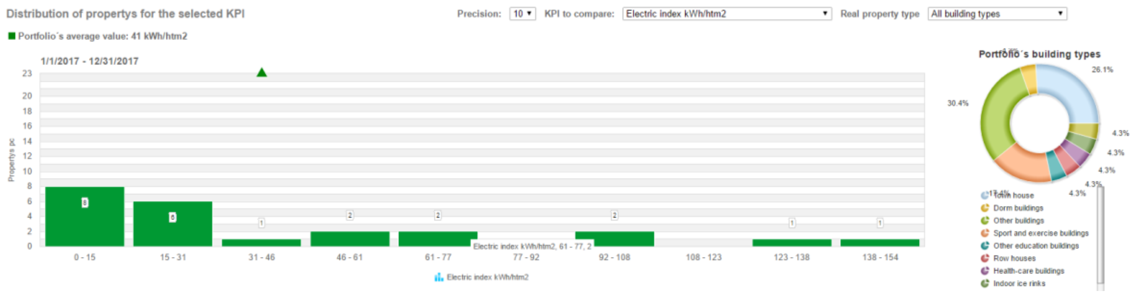
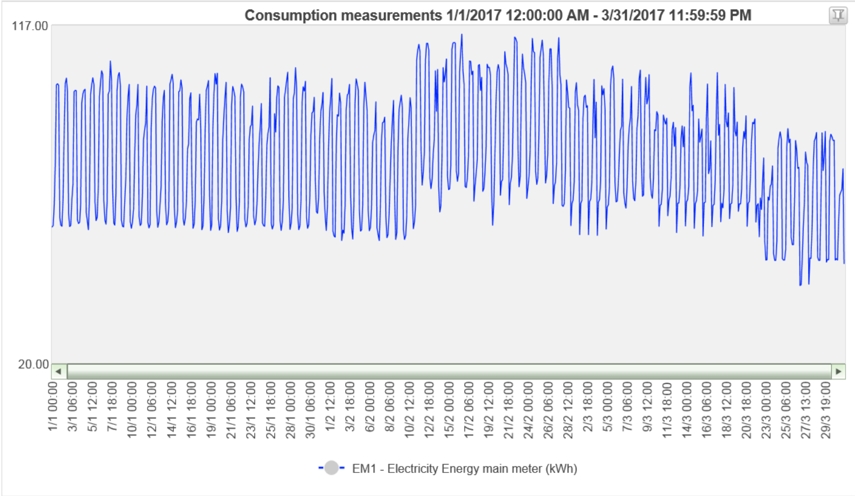


Figure 5 Example of portfolio analysis on electricity consumption index of the portfolio and the building types

5.1.1 Sports hall 1

The building has a floor area of 6765 m^2 and contains a tennis court, a store, a café and massage services. The building electricity consumption trend is quite periodic, but as can be seen from Figure 6 the average consumption during 10.2 – 26.2 is quite elevated and then from 22.3 to 31.3 the average consumption is below what it was during January. Figure 7 will provide a closer look of the consumption trends during these three periods.



Measurement	Sum	Min	Max	Avg
EM1 - Electricity Energy main meter (kWh)	170837.4	21	116.7	79.13

Figure 6 Electricity consumption trend of Sports hall 1 during the first quarter of 2017

The consumption profile of the building remains similar while there is significant variation during these three periods presented in Figure 7. The lowest consumption of 20-30 kWh occurs every day around 23:00 but only for an hour and the night time use is around 60 kWh. Around 05:00 and 06:00 the consumption begins to increase reaches peak consumption of around 100 kWh and then quickly decreases after around 20:00.

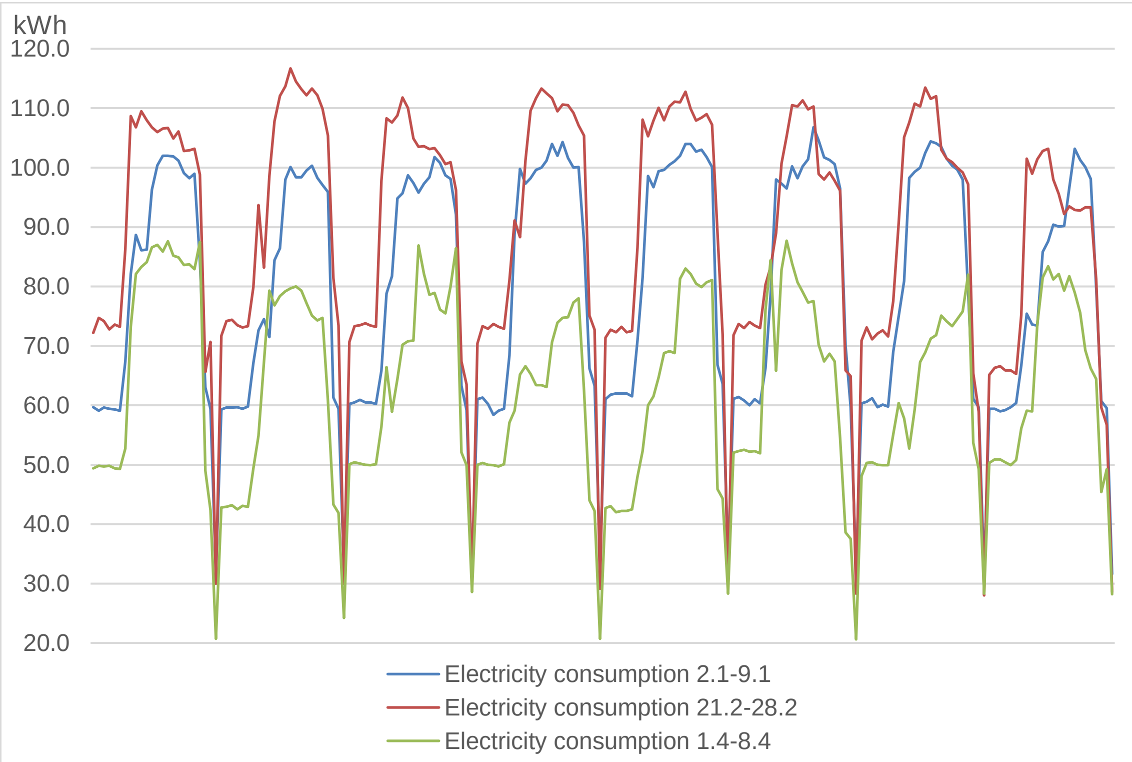


Figure 7 Electricity consumption comparisons of Sports hall 1

The three different weeks have been plotted into the same graph to show the similarities in electricity consumption profile and to highlight the difference in off-peak and peak consumption. Electricity consumption during 1.4 and 8.4, is on average lower than the other periods, this includes both lower peak and off-peak consumption. The consumption profiles for all these time periods are extremely similar but the magnitude in consumption varies significantly. During 1.4 – 8.4, peak consumption ranged from 70 - 90 kWh and off-peak consumption was between 40 - 50 kWh instead of the 95-105 kWh and 60 kWh during 2.1 – 9.1 and 100-110 kWh and 70 kWh during 21.2 – 28.2.

If electricity consumption can be maintained at 1.4 – 8.4 levels without negatively affecting the building use and its occupants, it will be a significant improvement in the buildings energy efficiency and result in major annual energy savings. On the basis of Figure 7 this seems to be already possible. If consumption is maintained at the level of week 2.1 – 9.1 the difference in monthly consumption is over 10000 kWh if compared to monthly levels maintained at 1.4 – 8.4 levels.

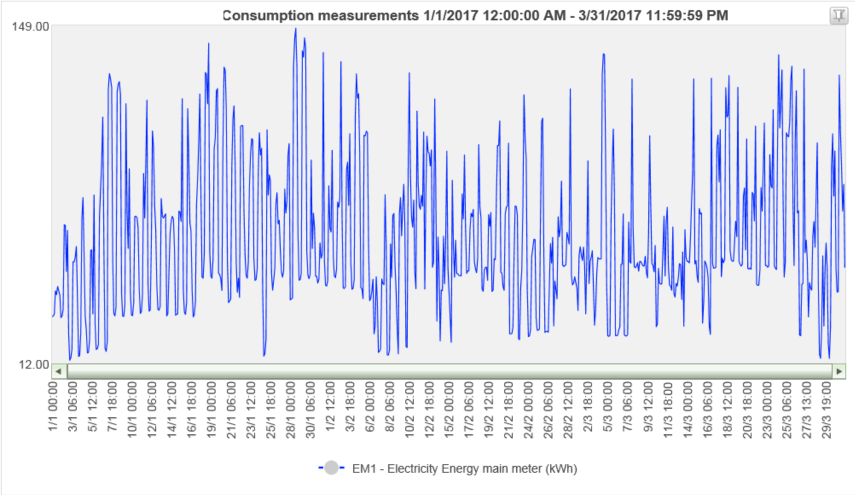
During the meeting with Vierumäki representatives, the electricity consumption trends were studied together, and with their knowledge of the building and its use, it was speculated that the nightly drop in consumption is likely caused by a one minute delay in HVAC equipment before they start to operate at half power during the night. The building has seen a cost-effective renovation in its lighting technology during May of 2016 which improved efficiency when comparing the first quarter of 2017 to 2016.

The front of the building is heated with district heating but around 70 % of the floor area where the tennis courts are located are electrically heated. This part of the building is poorly insulated and there are two service hatches with no insulation and the indoor environment is in direct contact with cool outdoor air. This is a likely reason for a large difference in off-peak electricity consumption as the space needs to be heated more intensely when the temperature difference between indoor and outdoor air grows. Sealing the doors properly would reduce thermal losses and result in lower heating needs.

The HVAC equipment of the building run at 50 % power at night, which likely is too much. When the lifecycle of the blower comes to it might be worthwhile to invest in a frequency controlled blower which allows for much more control over the system. With a CO_2 sensor, it would be possible to optimally ventilate the space during the day depending on the exact needs based on occupancy and during the night once the space is ventilated the whole system could be stopped until the morning.

5.1.2 Sports hall 2

The building has a floor area of 7524 m^2, and it hosts multiple sport courts for badminton, volleyball and floorball, it is also used for large events such as fairs and concerts. The building contributes around 10 % of total electricity consumption by the portfolio.



	Measurement	Sum	Min	Max	Avg
	EM1 - Electricity Energy main meter (kWh)	137429.1	12.2	148	63.65

Figure 8 Electricity consumption profile of Sports hall 2 during the first quarter of 2017

The electricity consumption profile of the building differs significantly on day to day basis. Off-peak consumption can vary from around 15 kWh to 50 kWh and peak consumption from 40 kWh to 150 kWh. Figure 8 provides an overview of electricity consumption during the first quarter of 2017 and as can be seen from the graph, there are periods when off-peak consumption stays at same levels for multiple days. Maintaining lower off-peak consumption should not affect the building use and the higher off-peak consumption is likely caused by unnecessary equipment.

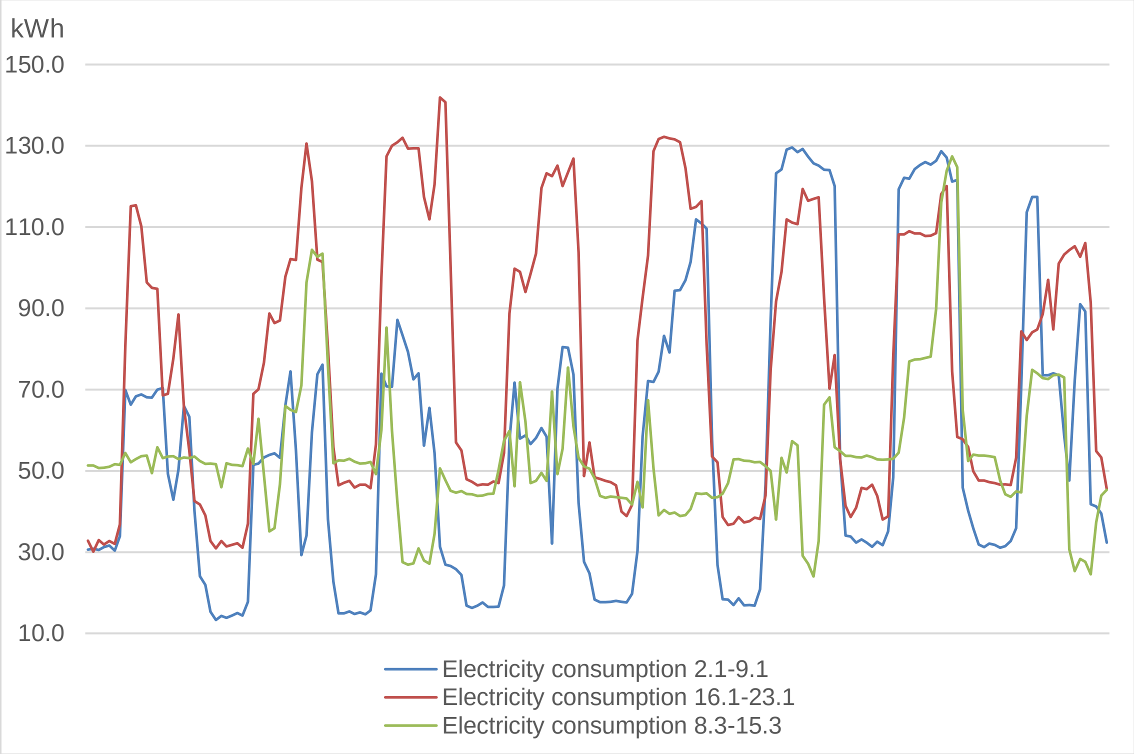


Figure 9 Electricity consumption comparisons of Sports hall 2

Electricity consumption profiles during the different periods presented in Figure 9 differ significantly in both peak and off-peak consumption. Off-peak consumption of the building is relatively low compared to the Sports hall 1, which has a smaller floor area but similar use. This is likely due to the electrically heated tennis court of Spots hall 1.

During the meeting with Vierumäki representatives the cause for varying peak consumption was suspected to be caused by a hundred energy intensive lights which have a power rating of around 1 kW. The building is divided into three parts for each sport area, and each area has around 30 of these energy intensive lights. The difference in peak consumption is caused by the use of these spaces as having lights on or off in one of the spaces will have an effect of around 30 kW.

The building also hosts various large events, which have further increased the peak consumption as in addition to the lighting, there has been various audio equipment and heating plates for buffets. Some of these events also require a large amount of preparations such as building event areas, which has caused increased off-peak consumption because the building process has been done at night.

During the meeting, it became evident that it is also possible that lighting has accidentally been left on for the night which can cause significant unnecessary consumption. With the proper implementation of Nuuka software these situations can be corrected before they result in financial losses. Increased off-peak use can be addressed by sending an alert and lighting can be shut off before the night.

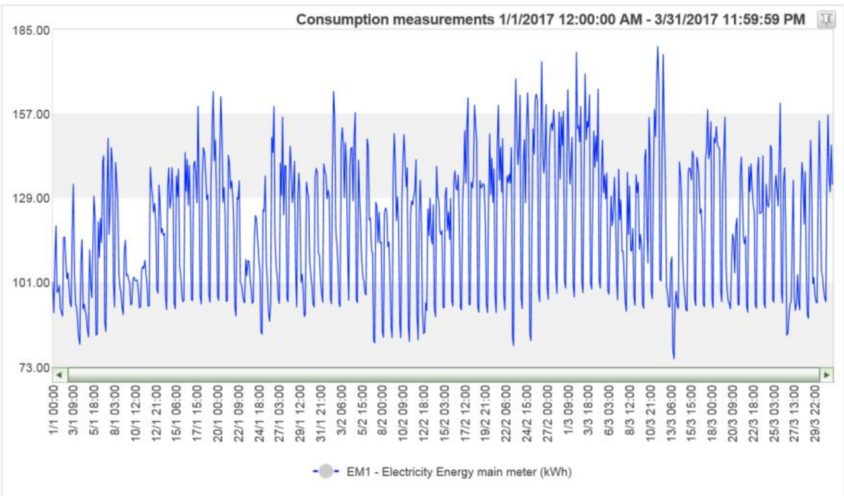
It could also cost effective to automate the lighting in these sport buildings with a movement sensor. Sport courts in use rarely have no movement of any kind thus by controlling the lights with a movement sensor it could be made sure that the lights are off during the day when the courts are not in use and there would be no human error to leave the lights on during the nights

5.2 Education and accommodation

The buildings managed in this portfolio are the second largest contributor to the electricity consumption of Vierumäki area and a few of the buildings are introduced. These buildings were mostly chosen based on their total electricity consumption and their electricity consumption profile which are presented in the following subchapters.

5.2.1 Education center

The building has a floor area of 3605 m^2 and hosts multiple conference and group working rooms and some rooms for accommodation. The building has been expanded three times after its construction. The electricity consumption profile of the building is periodic in the sense that peak and off-peak consumption are during the day and night. The magnitude of peak consumption can vary significantly as can be seen in Figure 10. Off-peak consumption does not vary as much as peak consumption, but there are times that consumption during the nights is significantly lower than the average.



	Measurement	Sum	Min	Max	Avg
	EM1 - Electricity Energy main meter (kWh)	257804.6	73.3	184.7	119.41

Figure 10 Electricity consumption trend of Education center during the first quarter of 2017

On average the off-peak consumption is around 90 kWh – 100 kWh and lasts for about 6 hours; during the rest of the day the consumption varies considerably but is around 120 kWh – 160 kWh. Just on the basis of the electricity trend graphs of this building, it is hard to suggest any action, but a traditional in-situ assessment could likely find room for improvement in the buildings efficiency.

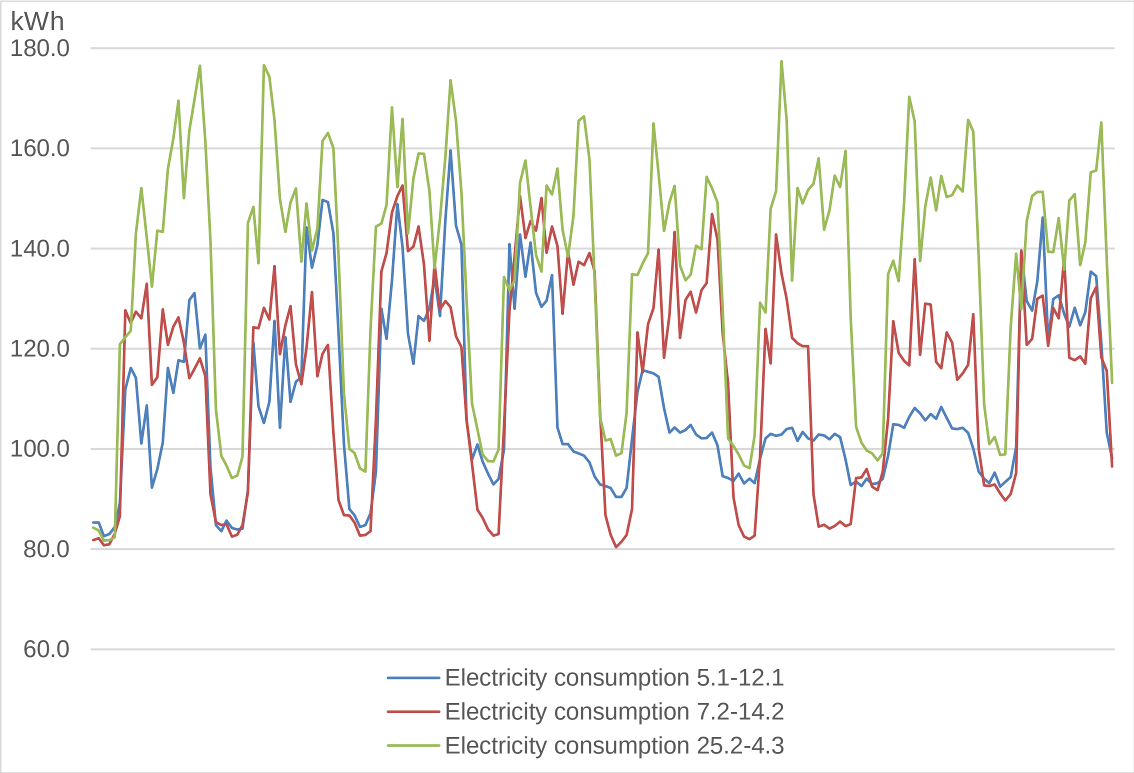


Figure 11 Electricity consumption comparisons of Education center

According to the Vierumäki representatives, the difference in off-peak consumption can be caused by ramp heating systems which are either on or off depending on outside temperature. Further analysis of off-peak consumption and temperature trends presented earlier would suggest that during the coldest periods during 3 – 6 of January and 6 – 11 of February the off-peak consumption was lower than average.

At the beginning of the meeting service personnel was called about the ramp heating systems and was asked to make sure that all of them are off. This resulted in shutting off the ramp heating system of Education center, which had been on for almost a month longer than the one at Lecture wing.

5.2.2 Lecture wing

Lecture wing building has a floor area of 642 m^2 and the space use is mostly designated for lecture halls and an auditorium. Electricity consumption of Lecture wing has been increasing significantly during the first quarter of 2017 and has already reached over 50 % of the total consumption of 2016. The first quarter of the year was the most energy intensive period for 2016 consuming over 6 times the electricity compared to summer months. The first quarter of 2017 has consumed around 8000 kWh more than the first quarter of 2016.

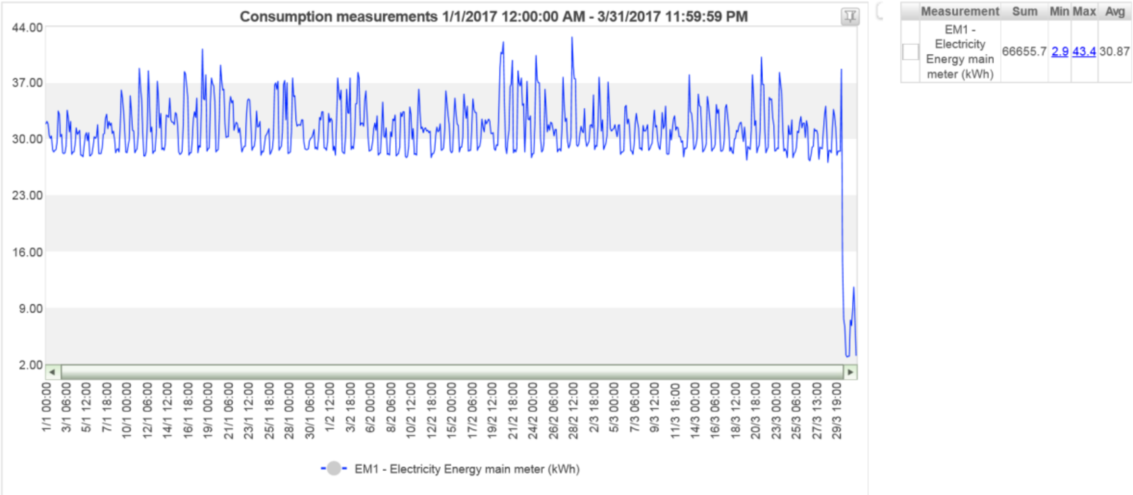


Figure 12 Electricity consumption trend of Lecture wing during the first quarter of 2017

The electricity consumption for the summer months of 2016 was between 2800 kWh and 3500 kWh, while the consumption of January and February reached over 20000 kWh. During the first quarter of 2017, each month had a consumption of over 20000 kWh. Significant drop in consumption occurs at the end of March seen in Figure 12. The decreased consumption remained at that level and only 3367 kWh of electricity was consumed in April, which fits the trends of the previous year.

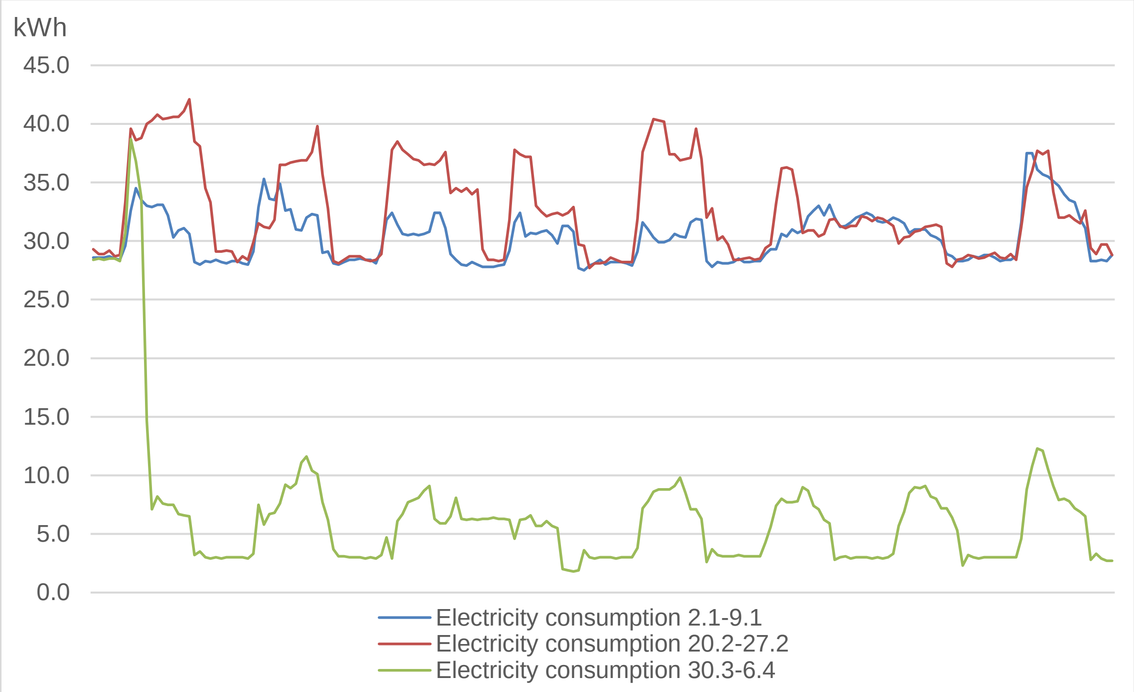


Figure 13 Electricity consumption comparisons of Lecture wing

Figure 13 presents the drastic reduction in electricity consumption in more detail with a comparison to two other weeks before the decrease consumption. The average electricity consumption went from 30 kWh to around 5 kWh, with daily peaks of 30 - 40 kWh decreasing to 7 – 12 kWh, and off-peak consumption fell from 28 kWh to around 3 kWh.

These trends were inspected together with Vierumäki representatives and the probable cause in the rapid drop in consumption is the ramp heating systems by the front doors of one of the many sports hall buildings. Lecture wing is a relatively new extension and during the construction the ramp power was connected to it.

5.2.3 Lakeside sauna and restaurant

The lakeside sauna and restaurant building has a total floor area of 488 m^2 and accounts for about 6 % of total electricity consumed by the company. The major consumption sources of the building are its restaurant, sauna, ramp heating, and during the winter, a hole in the ice is maintained for swimming using pumps and warm water. The building has already consumed over 50 % of the total electricity of 2016, and even though the first quarter was the most energy intensive period of 2016, the consumption during the first quarter of 2017 has increased by over 15000 kWh. If this trend continues, the building will increase its consumption drastically for the year 2017.

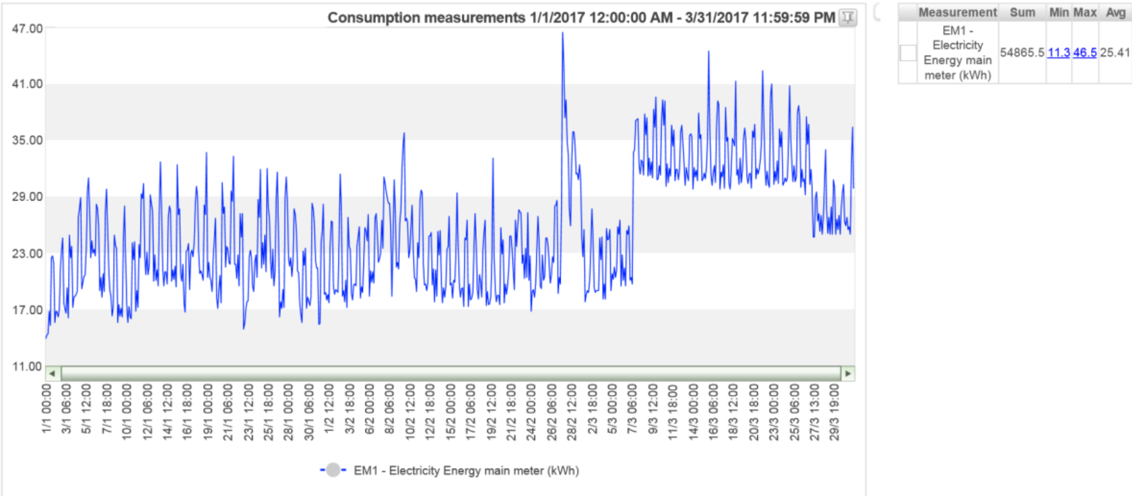


Figure 14 Electricity consumption trends of Lakeside sauna and restaurant building during the first quarter of 2017

Figure 14 presents the electricity trend of the building and additionally, to the already elevated electricity consumption compared to the previous year, after the first week of March the peak consumption increased to about 35 – 45 kWh from 25 – 35 kWh and the off-peak consumption to around 30 kWh from 15 – 20 kWh. Towards the end of March, the consumption decreased slightly, but still not to the levels it was during January and February. Figure 15 below provides comparisons during three different weeks including the elevated consumption at the end of March.

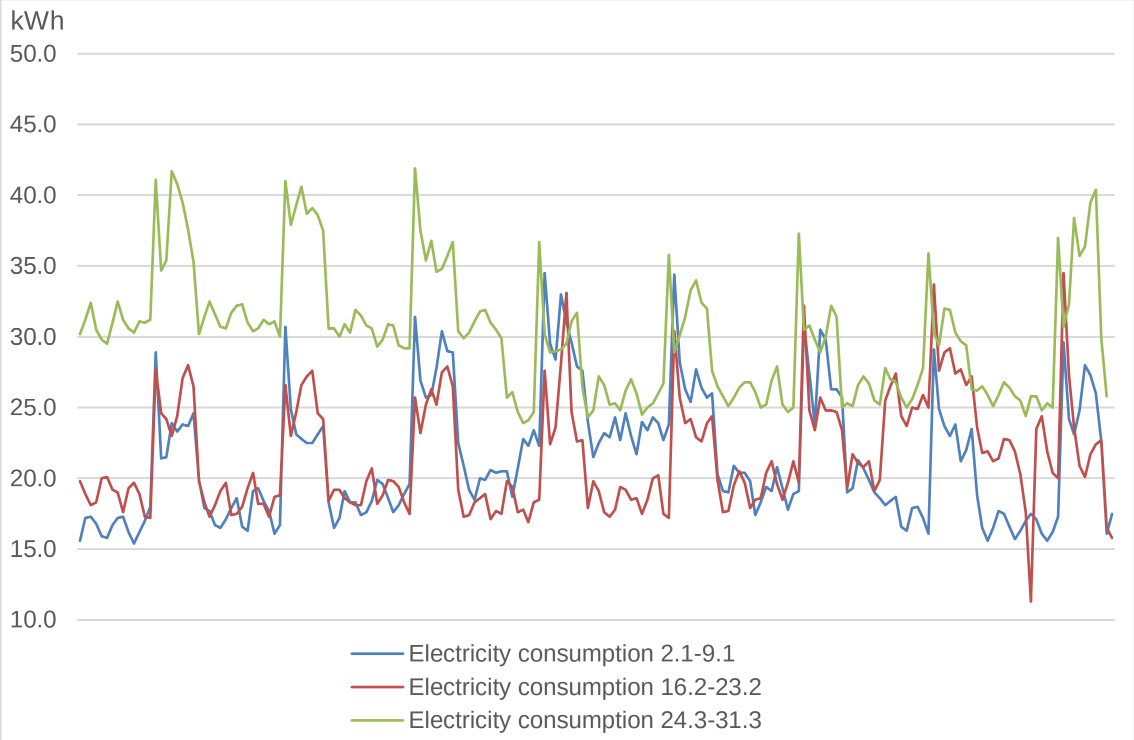


Figure 15 Electricity consumption comparisons of Lakeside sauna and restaurant building

This building has seen a significant increase in both peak and off-peak consumption. Daily consumption during 24 – 25 of March is 60 % higher, and during 28 – 29 of March, it is 30 % higher when compared to 16 – 17 of February. Considering that the first quarter has already been more energy intensive, even without this additional increase in consumption, there should be a more in-depth investigation into the causes.

In the meeting with Vierumäki representatives, a call was made to service personnel, who was surprised by the elevated consumption and had assumed it would have decreased as the ramp heating elements had been shut off some time ago. The effect of shutting down the ramp heating might be represented by the drop occurring on 27 of March.

During a tour of the area, the site was visited and a heated construction cabin used as a changing room by ice swimmers was inspected. The heating equipment in the cabin was off but the room temperature seemed to be higher than normal indoor temperatures. The heating equipment was still plugged in and the power line was quite hot to the touch, which suggests temperatures higher than 36℃. The power line was unplugged, and it remains to be seen if the power leaking caused by this equipment was the cause of elevated electricity consumption.

Inspecting the electricity trends of the building after the visit, a noticeable drop of 3 kW during off-peak consumption was found. At that rate, the plugged-in equipment would consume around 2160 kWh a month. On its own this doesn't affect the energy efficiency of the portfolio by much, but finding and amending such power leaks in other buildings will amount to significant energy savings.

5.3 Leisure buildings

Leisure buildings were built in 1987 and they can be divided into three groups based on size. There are 7 buildings with a floor area between 110,5 m^2 and 111 m^2**,** 7 buildings with a floor area between 91 m^2 and 99 m^2 and finally the largest group of 15 buildings with a floor area between 75 m^2 and 78 m^2. The buildings are electrically heated and have forced exhaust. The buildings also have a fireplace and similar equipment.

Figure 16 below presents the distribution of electricity consumption of the leisure building portfolio. The data used for these graphs was exported to Excel for further sorting. The following sub chapters will focus on comparing a few of the leisure buildings which are similar in size but represent the high and low end of energy consumption in 2017. Electricity consumption index of the years 2015 and 2016 will be also taken into consideration when choosing buildings for more in-depth analysis.

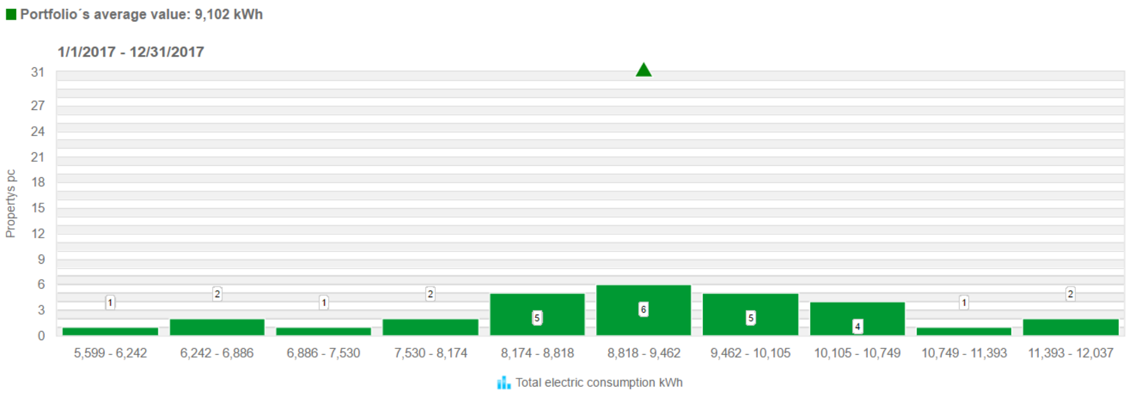


Figure 16 Leisure building portfolio electricity consumption distribution for the beginning of 2017

Only looking at the total consumption of these buildings does not convey much information as occupancy and occupant behaviour can have significant contributions. Therefore, the highest and lowest consumers are plotted into the same graph and times with no or little occupancy can be compared in more detail. This can provide insights of reduced thermal performance of a building or inefficient operation by occupants such as leaving windows or fireplace ventilation open and letting heat escape.

5.3.1 Leisure building large

Large leisure buildings 2, 3 and 4 are compared to Leisure large 1 as their consumptions represent the high and low end of consumption. The consumption trends of these buildings are compared and as there is no information on the use of these buildings, the consumption spikes are used as indicators of occupancy. The difference in consumption between the highest and lowest is about 4000 kWh.

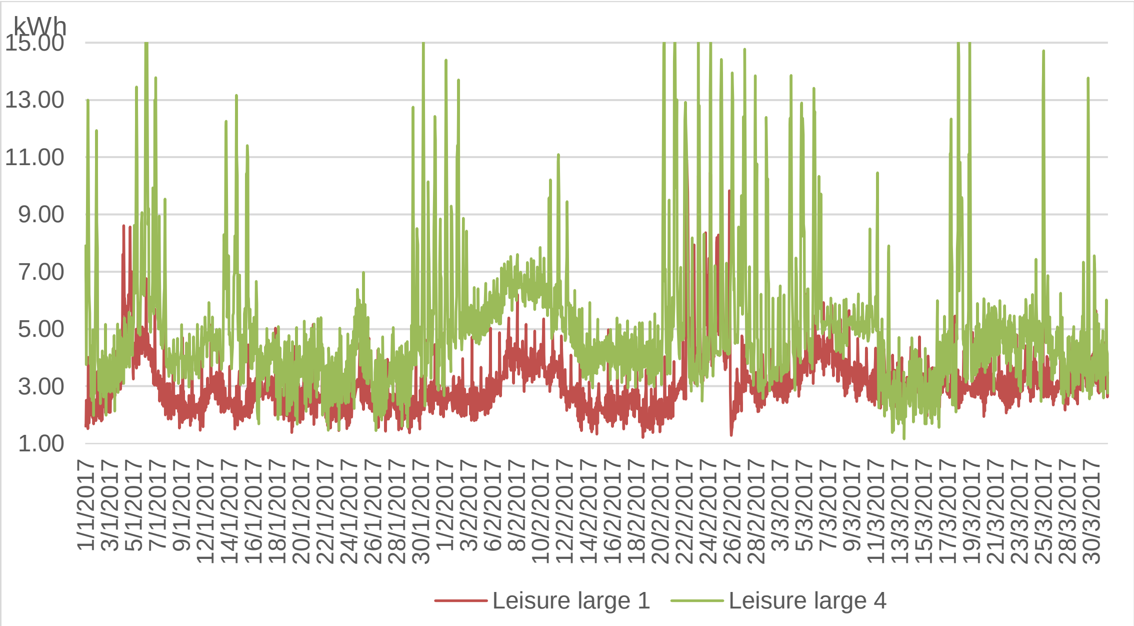


Figure 17 Electricity consumption comparisons of the highest and lowest consumers.

During the first quarter Leisure large 1 consumed 6633 kWh of electricity which is in the low end of all the leisure buildings regardless of size. From Figure 17 it can be seen that there are only a few consumption spikes for the building; hence the low consumption is partly due to low occupancy rates. Leisure large 4 was the highest electricity consumer of large buildings with 10602 kWh, but was occupied more than building 1.

From Figure 17 it can also be seen that when neither building is occupied the base consumption rates are slightly higher for Leisure large 4 even though the profile is quite similar which is to be expected as both buildings are electrically heated. Comparing the period 14 – 20 of February building 4 consumed over 80 % more electricity. Similar difference is found during 6 – 10 of February. The difference is extreme, but considering that during 13 – 17 of March the difference is only around 10 %, it would suggest that the consumption difference does not come from poorer thermal performance, but from inefficient operation, such as having windows or fireplace ventilation open without a fire.

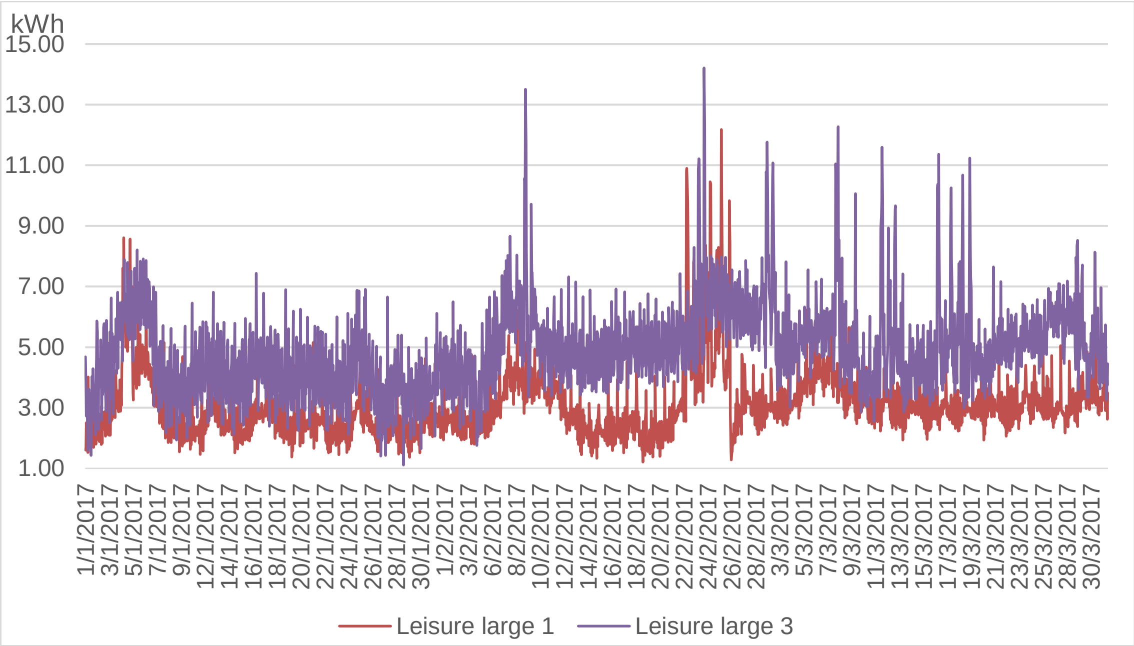


Figure 18 Electricity consumption comparisons of the highest and lowest consumers.

During the first quarter Leisure large 3 consumed 10532 kWh of electricity so the difference is similar, but as can be seen from Figure 18 there are only a few consumption spikes which would suggest that the occupancy of the building has been quite low. For Leisure large 3 and 1, a longer comparison period can thus be chosen as both have had quite low occupancy rates. During January Leisure large 3 consumed around 50 % more electricity and similar difference can be found during 12 – 22 of February. Because the difference is quite significant during the entire first quarter, the thermal performance of the building might be inferior.

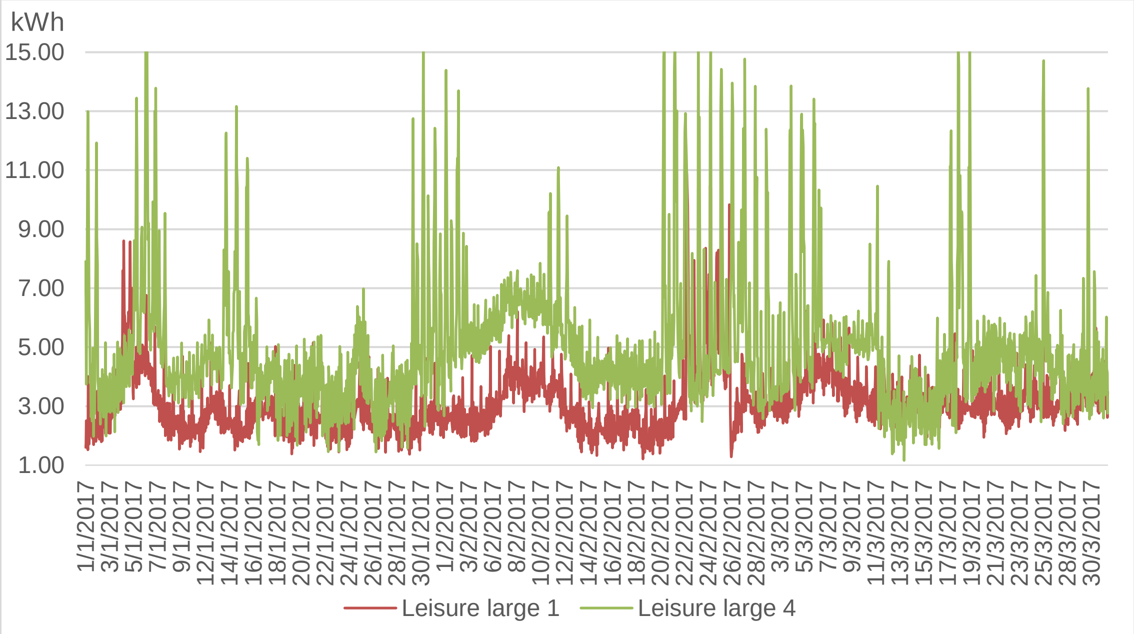


Figure 19 Electricity consumption comparisons of the highest and lowest consumers.

Leisure large 4 consumed 8968 kWh of electricity during the first quarter so the difference is not as significant as that of the previous buildings. The consumption of this building is still quite high compared to the other buildings and especially during January the consumption profile seems elevated. During the end of March, the consumption profiles of these buildings are quite similar which might suggest that the difference in consumption can be due to inefficient operation.

5.3.2 Leisure building medium

This group represents the high end of consumption as 6 of the 9 buildings are found to be in the top half in electricity consumption for the entire stock. Two are in the middle and one is in the bottom four. The difference in consumption between the highest and lowest is only 1444 kWh. Leisure medium 2 and 3 are compared to Leisure medium 1 as their consumptions represent the high and low end of consumption.

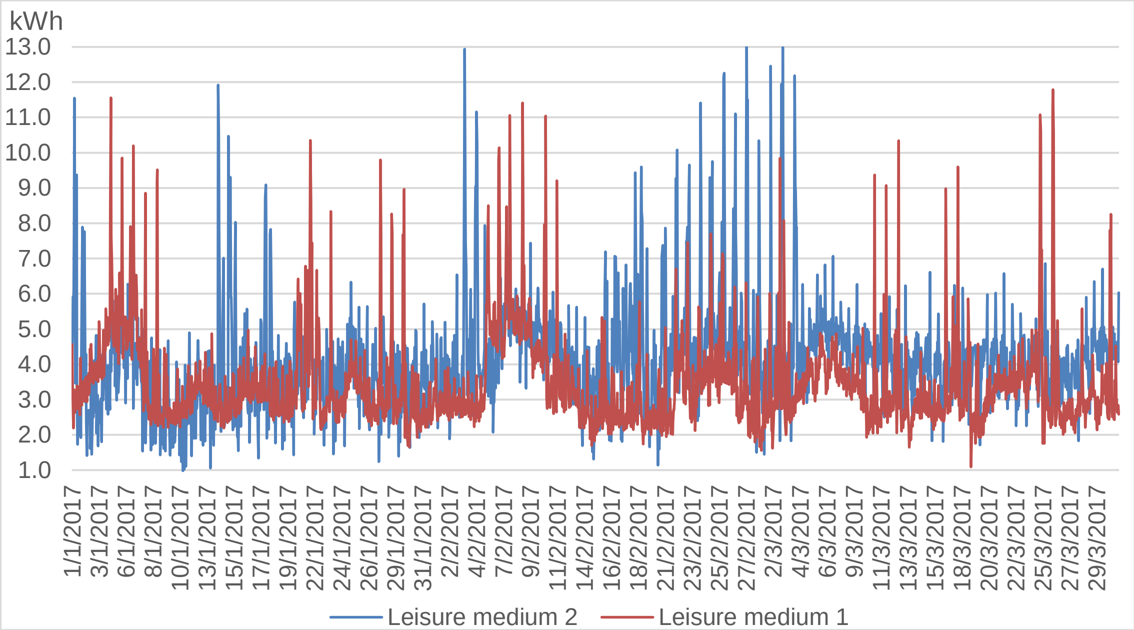


Figure 20 Electricity consumption comparisons of the highest and lowest consumers.

Unlike with the larger leisure buildings, the difference in consumption when comparing the highest and lowest contributor is not much and on the basis of Figure 20 it is mostly due to occupancy and occupant behaviour. At the beginning of January Leisure medium 2, which consumed 8760 kWh during the first quarter, has lower off peak consumption than Leisure medium 1, which consumed 7414 kWh during the first quarter. In March, however, Leisure medium 2 seems to have a slightly higher consumption. The elevated consumption of both buildings can be due to inefficient operation such as not closing the fireplace ventilation when the fire is out.

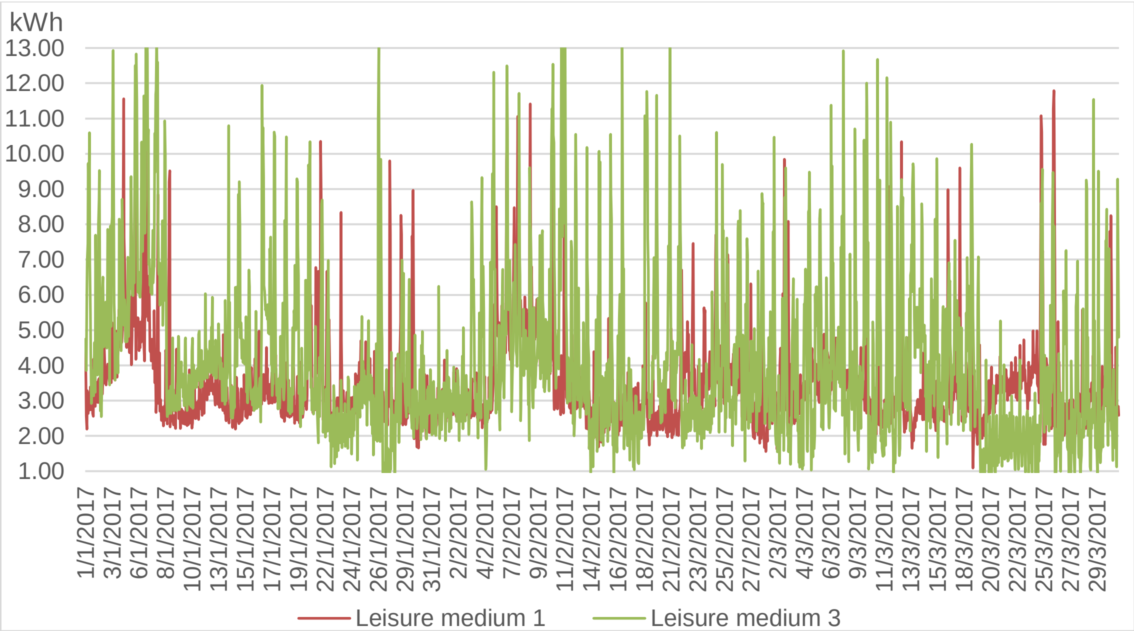


Figure 21 Electricity consumption comparisons of the highest and lowest consumers.

Leisure medium 3 consumed 8792 kWh of Electricity during the first quarter of 2017 but compared to the other buildings it was occupied most of the time as can be seen form the green spikes in Figure 21. When the building was not occupied during end of January and between 20 – 25 of March, it had consumption rates at the same level as Leisure medium 1 or even lower.

5.3.3 Leisure building small

This group has on average the lowest consumption of the entire portfolio, but the average electric index in 2015 and 2016 was higher than in the larger groups. In 2016, the buildings with the largest consumption were Leisure small 2 and 3, which had a consumption of 45882 kWh and 37371 kWh, respectively. The consumption of these small leisure buildings was nearly 10000 kWh higher than that of the other high consumption buildings which are part of the larger building groups.

Buildings Leisure small 2, 3 and 4 represent the high end of consumption and are compared to Leisure small 1 which had the lowest electricity consumption during the first quarter of 2017. Unlike rest of the buildings, Leisure small new 5 was built in 2015 after the original building burned down and is built according to newer regulations and has a heat recovery unit, the building is compared to Leisure small 1.

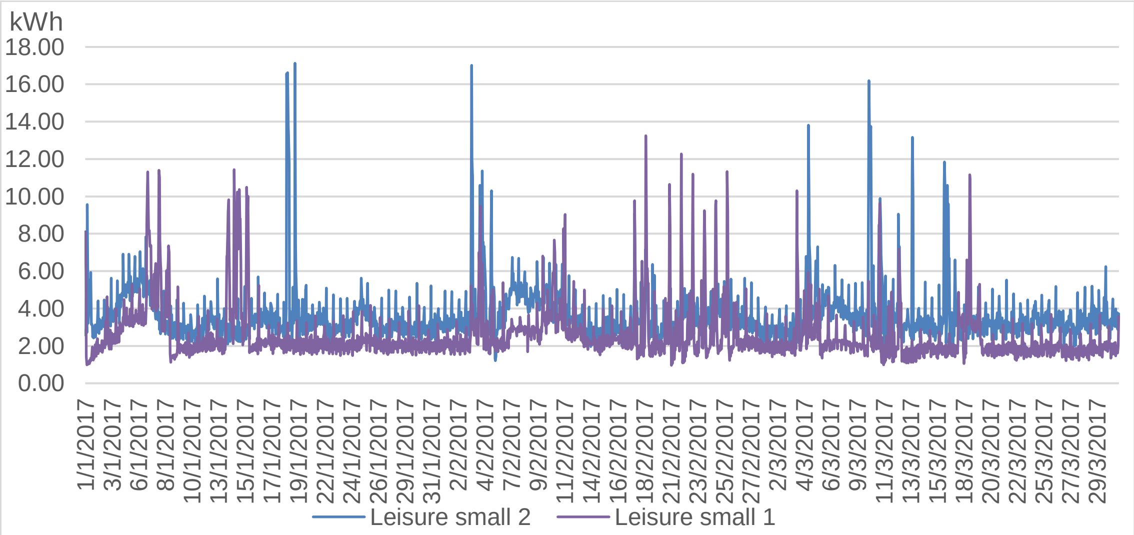


Figure 22 Electricity consumption comparisons of the highest and lowest consumers.

During the first quarter, Leisure small 2 consumed 7782 kWh of electricity while Leisure small 1 consumed 5521 kWh. Leisure small 2 consumed 75 % more electricity during the 22 – 31 of March, and a similar difference can be observed during the entire period as seen in Figure 22. Because the difference in consumption can be observed during the entire period and as Leisure small 2 consumed significantly more electricity during previous years, it might be worth investigating the buildings thermal performance in more detail.

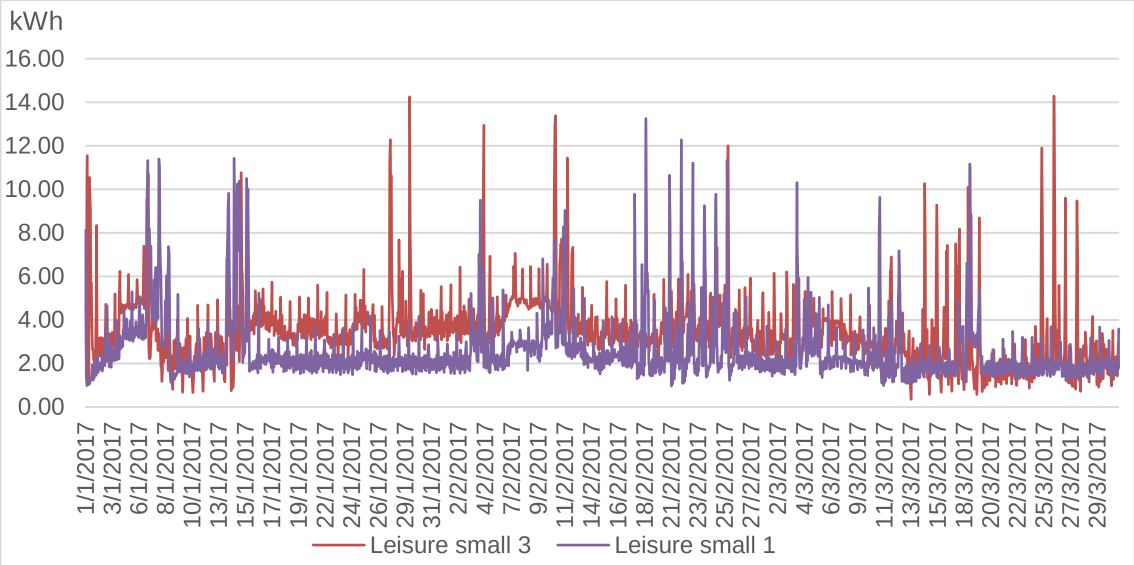


Figure 23 Electricity consumption comparisons of the highest and lowest consumers.

Leisure small 3 consumed 7334 kWh of electricity during the first quarter and has had significant contributions to electricity consumption during the previous years. As observed from Figure 23 the consumption of Leisure small 3 is elevated through most of the first quarter, although during the end of March the consumption seems to be lower than that of Leisure small 1, thus the elevated consumption might be caused by inefficient operation.

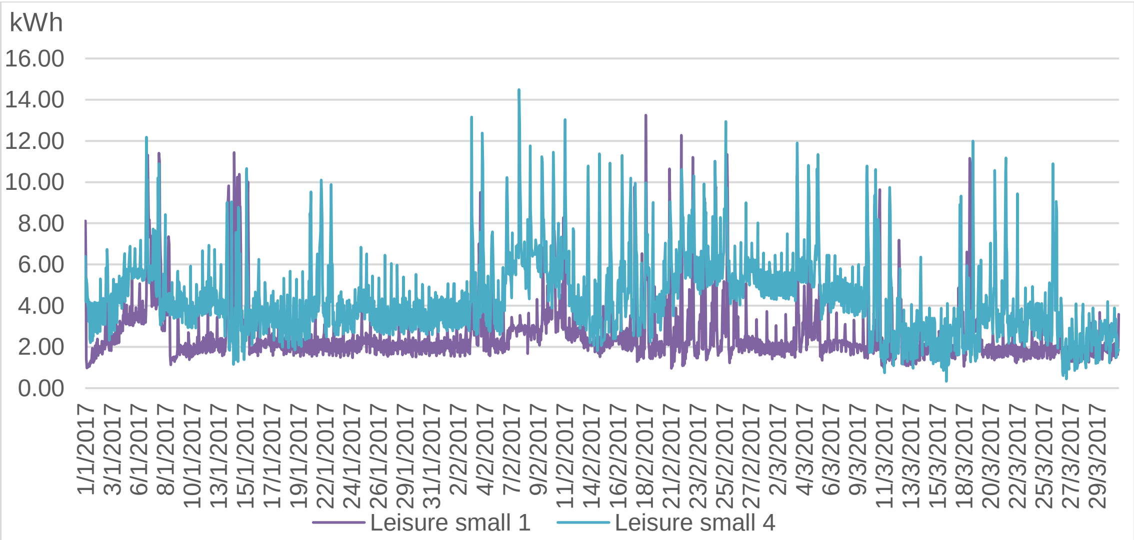


Figure 24 Electricity consumption comparisons of the highest and lowest consumers.

Leisure small 4 consumed 9337 kWh of electricity during the first quarter of 2017, which is among the highest when considering all the building groups. As seen from Figure 24 the consumption profile is elevated during most of the quarter and at times it is quite significant. During 27.2 – 4.3 Leisure small 4 consumed 130 % more electricity than Leisure small 1, but during 11.3 – 18.3 the consumption rates seem quite similar. The difference in total consumption is still quite significant but considering the period of 11.3 – 18.3 the reason might be inefficient operation.

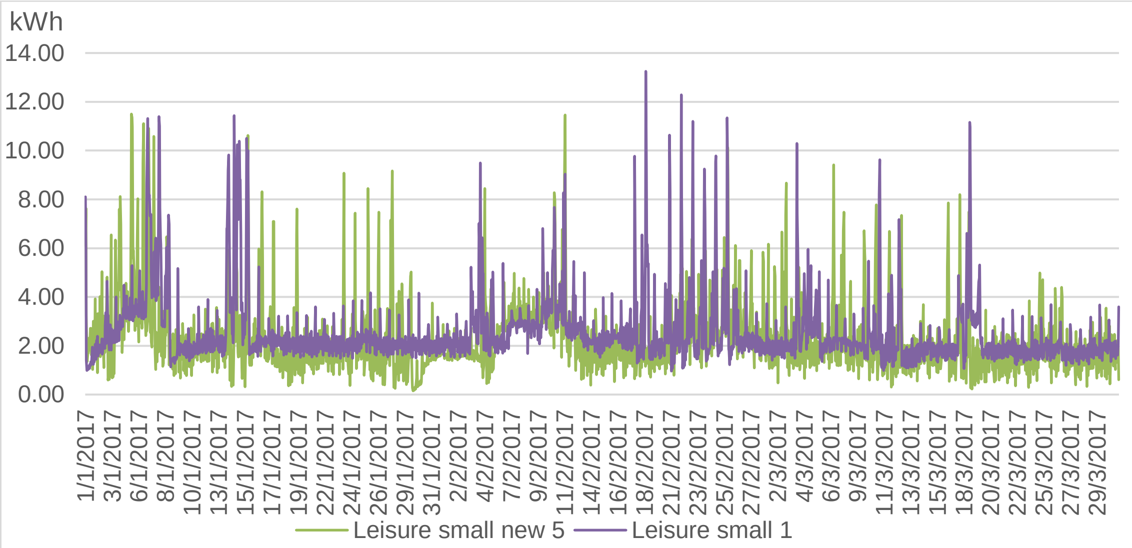


Figure 25 Electricity consumption comparisons of the highest and lowest consumers.

Leisure small new 5 which is installed with heat recovery consumed 4853 kWh of electricity during the first quarter and had decent amount of occupancy as can be observed from the consumption spikes in Figure 25. The difference between the new Leisure small new 5 and the highest consumers of old Kuntokylä buildings is considerable, but compared to the lowest consumer of the old buildings the difference is not that significant. Still as can be observed from Figure 25 the off-peak consumption of Leisure small new 5 is lower than that of Leisure small 1. The difference is relatively small and annual consumption should be estimated to gather more information about the value of upgrading the older buildings with heat recovery units.

6 Conclusions

Performing analyses at portfolio level was an efficient way to figure out which buildings to focus on. It would be useful to analyse each building in-depth as the energy efficiencies of buildings can vary and just choosing the largest consumers might not result in analysing the most inefficient buildings.

It is essential to have contact with the building owners or managers as analysing electricity trends without knowing the use and equipment in the building doesn't entail enough information to suggest concrete energy efficiency measures. Having all the data in one place makes it easier to perform analyses and once the optimal operating parameters have been found for each building the software ensures that it is maintained through continuous monitoring, analyses and alerts.

6.1 Portfolio analyses

Sorting the building portfolios by total electricity consumption was used to choose which electricity trends to focus on, the leisure buildings were also sorted by size to make the analyses more comparable.

After sorting the buildings by total consumption, the buildings which represented a major share had their electricity trends inspected and based on anomalies in consumption and similar use and size the two sports halls were chosen for more in-depth analyses.

Similar analyses were performed on the education and accommodation portfolio, but these buildings are not comparable with each other. The buildings with high consumption or anomalies in electricity trends were inspected together with Vierumäki representatives which resulted in shutting down unnecessary power intensive equipment.

The leisure buildings were also sorted by size and electricity consumption index as the buildings have similar use and equipment making them very comparable. The electricity consumption of these buildings is quite low so unlike the other buildings the focus was not on peak or off-peak consumption anomalies for individual buildings but on the entire trend compared to similar buildings.

6.2 Electricity trends

The value of hourly trend data was proved to be useful during the meeting at Vierumäki as previously only monthly electricity consumption data was available. Monthly electricity data is usually received every three months and at most can only provide information on the trend of total consumption which doesn't provide much useful information. Hourly electricity consumption data provides much more information and the use of energy intensive equipment and occupancy can be recognized.

The electricity trends of the chosen buildings were analysed more in-depth and notes on anomalies were taken. These trends were then analysing together with Vierumäki representatives to find the source of the anomalies in consumption. With the knowledge of the use and equipment in the buildings Vierumäki representatives provided much useful information on the operation and equipment of the buildings.

6.2.1 Sport halls

Sports hall 1 has uninsulated service doors which enable direct convection of electrically heated indoor air to outdoors. The warm indoor air is naturally pushed out with no resistance and the power of heat loss through these holes are likely more than if they had conduct through the wall material or insulation material on the frame of the door. The effect of this is easily investigated by calculating the total area of these holes, but that might be more work than just sealing the doorframes. The HVAC equipment of this building run at 50 % power during the nights and there might be room for improvement by driving the equipment using temperature sensors in a way that ensures that temperatures don't drop too much to cause mold damage but also not wasting power on heating and ventilating the building when it is not in use.

There has already been plans for improving the energy efficiency of Sports hall 2 by replacing the energy intensive lighting with LED-lights. One this is done the electricity trend graphs are likely more informative as currently most of the deviation in consumption is caused by the lighting and other information is lost in the noise. Using the software to set alarms for elevated off-peak use could be used to inform personnel who can react before lights left on during the night result in unnecessary financial losses.

6.2.2 Education and accommodation

The inspection of the trends of these buildings resulted in useful information for Vierumäki and action which resulted in reduced electricity consumption. The drastic reduction in electricity consumption of Lecture wing was caused to be the ramp heating equipment which had just been shut off. Ramp heating equipment was also the source of the high electricity consumption of Education center which was shut down after it was recognized by service personnel. Off-peak electricity consumption of the building was around 20 kWh lower the night after the equipment was shut down. Comparing to Lecture wing where the ramp heating was shut off nearly a month before. The financial losses for a 20 kW ramp heating which is on unnecessarily for a month is over 1700 € using electricity price of 0,12 €/kWh which includes the price of electricity and its transfer.

Automating the ramp heating equipment using air or surface temperature sensors could result in significant energy savings annually. Vierumäki has many ramp heating elements for buildings which are used throughout the year. The power of Lecture wing ramp heating system is over 25 kW which costs over 2000 €/month. If the size of other systems is similar and all of them are automated they could be on or off exactly as needed without having to manually go around and turning them on or off. This would also make sure that no systems are on too late unnecessarily.

Lakeside sauna and restaurant building is used during the cold months by ice swimmers and they were provided with a construction cabin changing room with a heater. During the tour of the building it was noticed that plugged in heater was leaking power from the outlet and heating the room. Inspecting the electricity trends afterwards showed that off-peak consumption dropped around 3 kWh when compared to previous nights. This alone doesn’t result in significant reduction in electricity consumption but if similar power leaks in other buildings can be recognized could improve the energy efficiency at portfolio level. Similar situation might be present in Lumenteko has not been in used after first half of February has an average consumption of around 2 kW.

6.2.3 Leisure buildings

Individually the leisure buildings don’t contribute much to the total electricity consumption of Vierumäki, but as they are the most numerous building type together their effect can be quite significant. The electricity trends of leisure buildings provided insights into the operation of these buildings.

In most cases the elevated consumption could be due to inefficient operation. In efficient operation of these buildings can mean leaving fireplace ventilation open when the fire is already out or leaving a window open which allows warm heat to escape and results in increased heating needs. It is also possible that lights have been left on which directly results in increased electricity consumption. This could be alleviated by inspecting that the ventilation is blocked during cleaning after the occupants have left. Alternatively, occupants could be reminded by having a note next to the ventilation plate to open during use and close after the fire is out.

Some of the buildings had elevated consumption during the entire first quarter and these buildings might have reduced thermal performance which requires more heating. Performing these electricity trend analyses can direct thermal performance assessments towards such buildings which can be done by using a thermal camera to recognize heat losses through the building envelope. Thermal imaging is an effortless way to recognize thermal leaks and bridges which result in increased heating needs.

6.3 Consumption alerts

Based on the building electricity trend analyses alerts can be set to warn of elevated consumption. It should also be decided to whom direct these alerts as the point is to be able to react before the elevated consumption results in unnecessary financial losses. Using alerts can ensure efficient operation of the portfolio once they are set for each building and there is someone to react to them. This will also reduce user error in operation of the buildings.

Alerts have more benefits for some buildings than others, for example Sports hall 2 in its current state has energy intensive lighting which can easily be distinguished from the electricity trends and alerts for off-peak consumption can be set to levels when all the sport court lights are off. This would improve the operational efficiency significantly if the lights were off every night. Alert could be sent during the evening so that someone could react and shut them down before they cause unnecessary losses during the night.

Alerts for leisure buildings are not as useful and is more work intensive to implement, but once set for each building the portfolio can become more efficient. One way to implement these would be to use the consumption spikes and the knowledge of optimal off-peak consumption and outdoor temperature. When there are no consumption spikes caused by occupancy the consumption of the following nights is checked and if the level is too high considering outdoor temperature and alert could be sent. Although if the buildings are cleaned after guests have left it might be worthwhile to have the cleaning personnel check that the windows and fireplace ventilation are closed.

7 Bibliography

1. Energiatehokkuustoimikunta. Ehdotus energiasäästön ja energiatehokkuuden toimenpiteiksi. Helsinki:; 2009.
2. Nuuka Solutions. Nuuka Solutions. [Online].; 2017 [cited 2017 April 10. Available from: www.nuukasolutions.com.
3. The European Commission. COM(2015) 80 Energy Union Package. Brussels:; 2015.
4. The European Parliament and the Council. Directive 2012/27/EU on Energy Efficiency. Brussels:; 2012.
5. The European Commission. Impact assessment of Directive 2012/27/EU SWD(2016) 405 Final. Brussels:; 2016.
6. The European Commission. Amending Directive 2012/27/EU COM(2016) 761 Final. Brussels:; 2016.
7. The European Parliament and the Council. Driective 2010/31/EU on energy performance of buildings. Brussels:; 2010.
8. The European Commission. Impact assessment of Directive 2010/31/EU. Brussels:; 2016.
9. The European Commission. Amending Directive 2010/31/EU COM(2016) 765 Final. Brussels:; 2016.
10. Oikeusministeriö. Energiatehokkuuslaki 1429/2014. Helsinki:; 2014.
11. Motiva Oy. Energiatehokkuussopimukset. [Online].; 2010 [cited 2017 March 31. Available from: http://www.energiatehokkuussopimukset.fi/en/activities_and_results/.
12. Motiva Oy. Vuokra-asuntoyhteisöjen toimenpideohjelman vuosiraportti. Helsinki:; 2015.
13. Työterveyslaitos. Korjausrakentaminen suomessa - Rakennustekniset Kustannukset. Helsinki:; 2013.
14. Ympäristöministeriö. Korjausrakentamisen strategia 2007-2017. Helsinki:; 2007.
15. Tilastokeskus. Talonrakennusalan yritysten korjausrakentamisen urakoista kertyi 6,8 miljardia euroa vuonna 2015. [Online].; 2016 [cited 2017 May 29. Available from: http://www.stat.fi/til/kora/2015/02/kora_2015_02_2016-12-08_tie_001_fi.html.

16. Tilastokeskus. Liitetaulukko 1. Talonrakennusalan yritysten urakat toimialoittain, milj. euroa. [Online]. Helsinki: Tilastokeskus; 2016 [cited 2017 May 29. Available from: http://tilastokeskus.fi/til/kora/2015/02/kora_2015_02_2016-12-08_tau_001_fi.html.

17. Tilastokeskus. Suurimpien talonrakennusyritysten korjausrakentaminen. [Online].; 2012 [cited 2017 May 29. Available from: http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__rak__kora/010_kora_tau_1 01_fi.px/table/tableViewLayout1/?rxid=7035b3fa-3090-44b7-884e-34a0c4b88298.

18. Tilastokeskus. Asunto-osakeyhtiöiden korjauskustannukset. [Online].; 2012 [cited 2017 May 29. Available from: http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__rak__kora/020_kora_tau_1 02_fi.px/table/tableViewLayout1/?rxid=7035b3fa-3090-44b7-884e-34a0c4b88298.