Presentation of measures in energy audits

- Example

EFFECT4buildings Toolbox:
Financial calculations; Annex 3

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 Lease 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.

To make sure building managers invest in the best available solutions, more knowledge on different possibilities is needed as well as confirmation from colleagues that the solutions performs well. EFFECT4buildings mapped **technological solutions** for energy efficiency in buildings with the aim to share knowledge and experiences of energy efficiency solutions among building managers in the Baltic Sea Region.

This document includes a new standard template for presenting proposal of measures based on conducted energy audit. The template can be introduced and connect as a part of Total Concept Method process by presenting the package of proposed measures with the TotalTool. Furthermore, the template can be utilized in a comprehensive way as a separate excel sheet by including provided results to any calculation method published in this toolbox. Optionally template will also provide advantage to any other appropriate energy audit report and increase the implementation of energy efficiency measures.

Partners

EFFECT4buildings project is implemented with the support from the EU funding Programme Interreg Baltic Sea Region (European Regional Development Fund) and Norwegian national funding. The aim of the project is to improve the capacity of public building managers in the Baltic Sea Region by providing them a comprehensive decision-making support toolbox with a set of financial instruments to unlock the investments and lower the risks of implementing energy efficiency measures in buildings owned by public stakeholders. More information: http://www.effect4buildings.se/

Example of presentation of measures in energy audits

Summary

The following report contains the result of an energy audit and proposals regarding how the energy use and the energy costs can be decreased for XXXX.

XXXX is producing cement enclosures for fireplaces and stoves. The production plant, in this report is located in XXXXX. XXXX also has another site, west of XXXXX. This site is treated in a separate report.

At XXXX, elements of light versions of concrete is produced. The elements are used in fireplaces and stoves to store heat. Another product is Marble which is cut into smaller pieces.

XXXX production site XXXX use electricity, natural gas and diesel as types of energy. During the twelve months' period from 2015-08-01 to 2016-07-31 the total energy use was 2 799 922 kWh and the total costs associated with energy use was € 138 306.

Table 1 shows a summary of the quantified measures in this report.

Process	Measure	Savings [kWh/year]	[€/year]	Investment cost [€]	Payback time [year]	Net present value [€]	Internal rate of return
Building	Building 6: Apply an extra insulated glass unit on specified windows and decrease the transmission losses.	14 800$_{n.gas}$	550	4 000	7,3	1 000	11 %
Building	Building 7: Construct a well-insulated wall that replaces specified windows and decrease the transmission losses.	26 800$_{n.gas}$	990	7 200	7,3	3 000	12 %
Building	Building 7: Repair broken window and decrease the transmission losses.	3 500$_{n.gas}$	130	260	2,0	1 000	50 %
Building	Seal industrial doors in Building 2 and 7.	42 000$_{n.gas}$	1 550	500	0,3	10 000	310 %
Lighting	Converting from T8 fluorescent tubes to T5 in production areas, building 3 and 12.	51 400$_{el}$	4 900	14 410	2,9	18 000	32 %
Lighting	Converting from T8 fluorescent tubes to LED tubes and ECO/ES in specified premises.	42 200$_{el}$	4 250	15 560	3,7	13 000	24 %
Ventilation	Sand blasting: equip fan motor with a variable frequency drive, VFD.	25 000$_{el}$	2 200	5 000	2,3	10 000	43 %
Compressed air	Invest and install a compressor with variable speed and use this as the main compressor.	60 000$_{el}$	5 300	8 900	1,7	27 000	59 %
Compressed air	Kaeser ASD 37 T: recover heat to building 3 and fix current air transportation.	1 500$_{el}$ 70 000$_{n.gas}$	2 700	3 000	1,1	15 000	90 %

Compressed air	Kaeser Airtower 19: recover heat to building 12 and replace filter more regularly.	$14\ 000_{n.gas}$	550	2 000	3,6	2 000	24 %
Production	Furnaces, building 12: Keep gas-fired furnaces instead of switching to electricity. Recover heat from the furnaces through a heat exchanger, without transferring CO_2 to premises where people work.	Not quant.	----	Not quant.	----	----	----

Table 1: Shows a summary of the quantified measures in this report.

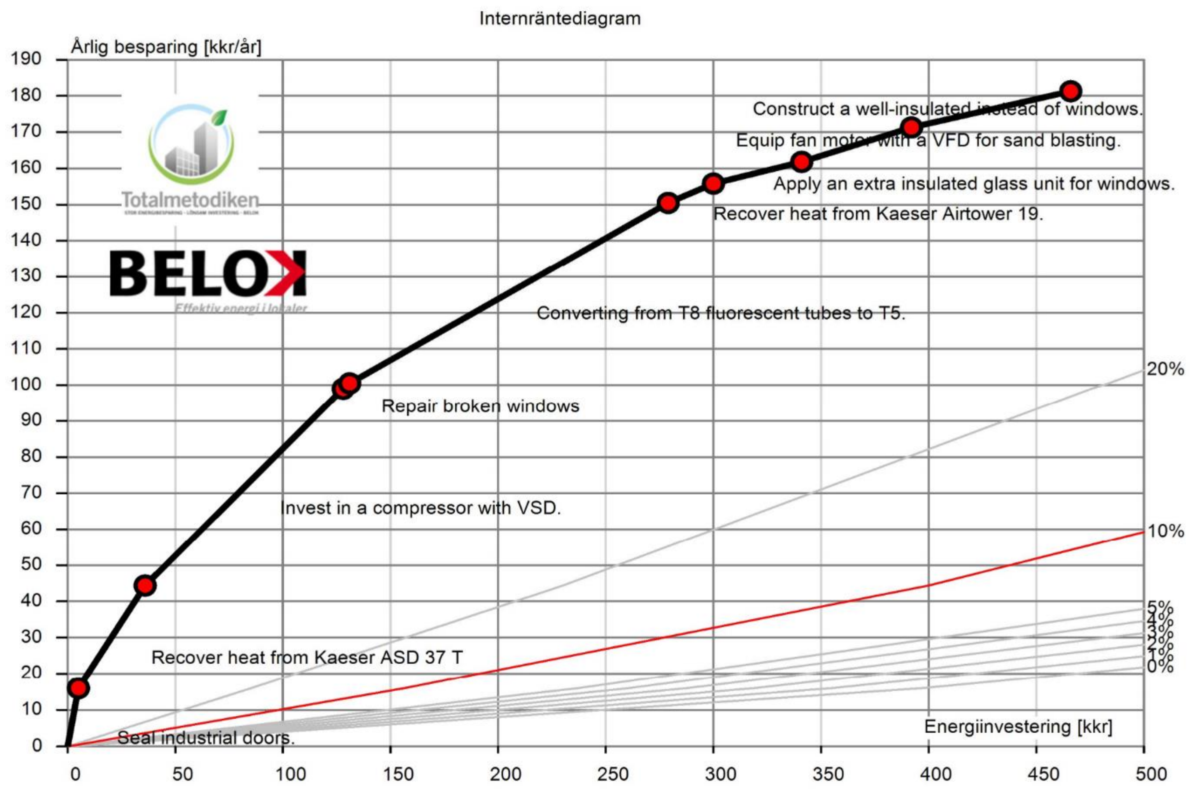

Table 22: Total concept method, by BELOK. Summary of the quantified measures in this report presented with a graph to show return of investment. Y-axis showing yearly savings in SEK/year and X-axel showing cost of energy investment in SEK.

Table of Contents

Introduction

Costs, related to energy are a major part of most manufacturing companies' total costs. Due to the fast growth of some large countries and the fact that it is becoming more difficult to increase the oil production and also the extraction of other natural resources, the price of many different types of energy has increased. It is therefore important for companies to start working with questions regarding energy consumption and to manufacture in a way that is energy efficient.

Another reason for reducing the energy consumption is the environmental problems that the world is facing. Reduced energy consumption usually means a reduced environmental impact.

Aim

The aim is to perform an energy audit of the company's energy use and to identify any proposals for actions to reduce the energy costs. The audit is essential in order to find any proposals for action and it also has an intrinsic value as it shows how the energy is distributed among the various support- and production processes.

Method

The total energy consumption of the company has been studied. The energy statistics shows how much electricity and thermal energy the company is using during a year and how the energy use is distributed over time. Thereafter measurements have been performed and different data have been collected in order to understand how the power and energy use is distributed among different processes. The operation times have been obtained both by measurements and by discussions with operating personnel.

Measuring instruments with data logging function, shown in *Figure 1*, measures the current over time and then by using numerical integration the electrical power and the energy use can be determined. The time duration of the measurements has been about a week so that both the weekdays and the weekend are represented. Finally, the measurements have been analysed in order to find proposals for action regarding possibilities to reduce the energy costs.

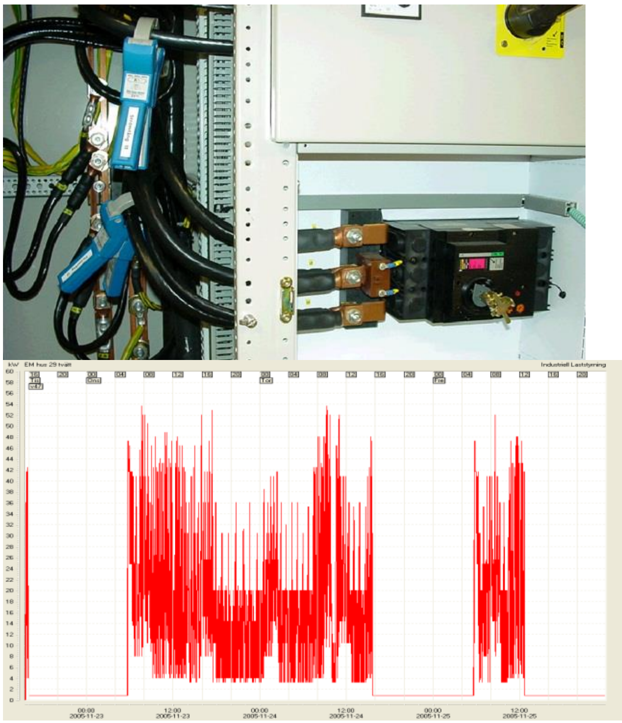

Figure 1: The picture to the left shows two installed measuring instruments with logging function. The picture to the right shows the result of the measurement as a graph where the power use is plotted against the time.

Boundaries

- For this energy audit, the production site XXXX premises and associated activities, are used as boundaries. XXXX also has a production site on the other side of XXXX. This site is treated in a separate report.
- To make the energy audits easier to read and understand all transports between the production sites in XXXX and other external transports is included in this energy audit, of the production site XXXX.
- This energy audit has been performed during the period XXXX.
- This report and the work performed in this energy audit, following these standards:
    - EN 16247-1, General requirements
    - EN 16247-3, Processes
    - EN 16247-5, Competence of energy auditors
- In order to include all support and production processes, the measures are demarcated to provide a good base for investment. The proposals should not be interpreted to be anywhere close to technical design. In case that the calculations for the proposed technical measures include design parameters, such as number of light fixtures in case of alternative lighting or installed capacity for alternative heating sources, the used numbers shall be considered as approximate numbers and the proposals be considered as a part of a pre-design study. The reason that we show our calculations, in appendices, are to clarify how the base for the proposed investment has been developed and also as a tool for the company to check the credibility of the proposals. The calculations can also be used in final evaluation of the proposals. We recommend the technical design of the proposed measures to be made by an authorised design firm.

Assumptions

- In normal cases the measurements, although performed during normally just one week, are assumed to be representative for the full year.
- The savings calculated for the proposed measures are not related to each other. It means that the savings is presented as if just the single, current proposal was implemented. This could be changed if many proposals, which interact with each other, were implemented.
- The presented investment costs for the proposed measures are based upon experiences from previous implementation at other industrial sites. In situations where e.g. large pipe systems are proposed to be installed it may be difficult to correctly predict the investment costs since the final design will determine quantities etc. In order to make the final evaluation of the proposed measures the company is recommended to request sharp offers from a number of potential suppliers.
- LCC calculations are based on a nominal interest rate of 10 % and a nominal annual energy cost increase of 2 %.

Description of the company

XXXX is producing cement enclosures for fireplaces and stoves. The production plant, in this report called XXXX, is located in XXXX. XXXX also has another site, west of XXXX. This site is treated in a separate report.

At XXXX, elements of light versions of concrete is produced. The elements are used in fireplaces and stoves to store heat. Another product is Marble which is cut into smaller pieces.

The support processes which consumes most energy is space heating, lighting and compressed air. In the production the largest energy consumer is thermal treatment.

The number of employees at XXXX is 170. The normal working hours in production is 1 shift between 06.00 am and 02.00 pm. Two of seven divisions are also working 2 and 3 shifts. Sometimes there is production on Saturdays, which was the case during the week of measurements.

The working hours at the office is between 08.00 am and 04.00 pm. The production is normally closed for holidays during four weeks per year, of which two weeks are during the summer.

XXXX is certified in both ISO 9001 and ISO 14001 and is working with questions regarding energy consumption. This report should be used as guideline of how the energy is used today and how it could be used more effectively.

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Buildings

The site consists of several buildings as shown in Figure 4 in appendices. The total area of all buildings is 13 400 m^2 of which the heated area is 11 100 m^2.

Most buildings are used for production but there is also an office building and a building for staff where dressing rooms and canteen is located. There are also several unheated tents.

The building envelopes vary but most of them have walls which are plastered and consists of 20 cm concrete with an insulating layer of 10 cm foam. The average U-values for ceilings and walls of these buildings have been calculated to 0,34 W/m^2K.

Some building envelopes have obvious defects and these building are the reason why the need of heating is higher on XXXX compared to XXXX (see separate report). The key-value for heating is 113 kWh/m^2 (based on period for energy statistics, see chapter 0) compared to 99 kWh/m^2 for XXXX. Measures for these buildings are given in the text below.

Roof, Building 6

During our visit we noticed that a crew of construction workers were in operation on the roof of building 6, replacing/repairing the tar roof layer.

Unfortunately, nothing more was done; Building 6 has a building envelope that is in miserable condition and annual heating costs must be soaring. It would therefore have been a golden opportunity to add at least 10 cm of insulation on the existing roof at the time that the crew worked on the roof. There would of course be an additional investment cost associated to the insulation but it would be a marginal cost, adding some value in terms of energy savings instead of only keeping the roof waterproof.

Our recommendation to the management is to evaluate this marginal investment the next time that a bad roof will be repaired and the work crew is already in place. We can help you in calculating the energy savings when such an evaluation will be done.

Measure, apply an extra insulated glass unit on the windows in Building 6.

Saving	
Natural gas:	14 800 kWh/year
Cost reduction	550 €/year
Costs	
Investment cost:	€ 4 000
Financial calculations	
Payback:	7,3 years
LCC (cost saving 15 years):	€ 710

Apply an extra insulated glass unit on the windows in Building 6 and thereby reduce heat losses through the windows.

A place built insulated glass unit means only about a quarter of the cost compared to the cost of replacing the entire window. The unit is applied from the inside and therefore does not affect the building's appearance. The windows U-values are considered to be reduced from 6 W/m^{2}K to 1,3 W/m^{2}K.

In addition to energy savings the measure also reduces cold drafts in the winter and therefore contributes to a better working environment.

Measure, construct a well-insulated wall that replaces the windows in Building 7.

One long side of Building 7 consists of two rows of windows where the windows on the bottom row are insulated glazing (IG) windows with an estimated U-value of 1,5 W/m^{2}K. One of these windows is broken and should be repaired immediately (see measure below)

The windows on the upper row are old windows with only one glass. These windows have an estimated U-value of 5 W/m^{2}K and are considered to be the part of the building which contributes most to transmission losses, relative to size.

Figure 2: Windows on building 7.

Construct a well-insulated wall that replaces the one glass windows in Building 7 and decrease the transmission losses.

The working environment is not expected to get worse by replacing the windows, because the IG windows will let daylight in.

It is considered possible to decrease the U-value from 5 W/m^{2}K to 0,3 W/m^{2}K.

Saving	
Natural gas:	26 800 kWh/year
Cost reduction	990 €/year
Costs	
Investment cost:	€ 7 200
Financial calculations	
Payback:	7,3 years
LCC (cost saving 20 years):	€ 2 520

Measure, repair window in Building 7.

Saving	
Natural gas:	3 500 kWh/year
Cost reduction	130 €/year
Costs	

Repair broken window in Building 7 (see Figure 2) and decrease the transmission losses.

Investment cost:	€ 260
Financial calculations	
Payback:	2,0 years
LCC (cost saving 20 years):	€ 1 020

Measure, seal industrial doors in Buildings 2 and 7.

The industrial doors in Buildings 2 and 7 are leaking in outside air and should be sealed.

In building 2, three doors are in bad shape and can be seen in Figure 3

The savings is difficult to calculate but have been estimated with standard value based on the size of the area that is leaking.

Saving	
Natural gas:	42 000 kWh/year
Cost reduction	1 550 €/year
Costs	
Investment cost:	€ 500
Financial calculations	
Payback:	0,3 years
LCC (cost saving 10 years):	€ 9 900

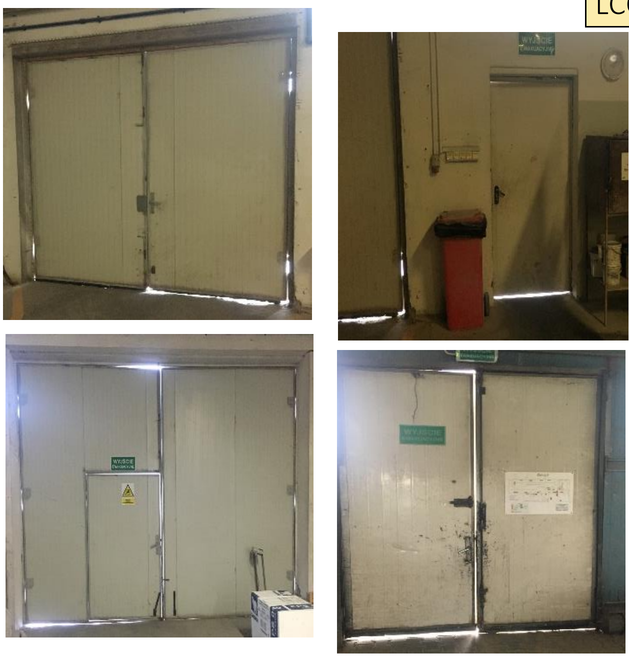


Figure 3: Shows industrial doors in Buildings 2 and 7

Energy statistics

This chapter presents all purchased energy and the costs associated with energy use broken down by individual types of energy. All costs are excluding VAT.

XXXX's production site XXXX use electricity, natural gas and diesel as types of energy. During the twelve months' period from 2015-08-01 to 2016-07-31 the total energy use was 2 799 922 kWh and the total costs associated with energy use was € 138 306.

Electricity

The total electricity use during the twelve months' period from 2015-08-01 to 2016-07-31 was 686 710 kWh[1] according to *Chart 1*. The cost for electricity during the same period was € 58 522[2].

The variable cost of electricity, i.e. the cost that depends on the electricity use, amounts to 0,088 €/kWh[3]. The cost depending on the electricity demand amounts to 28,9 €/kW and year[4]. These are the costs that are used when the savings regarding energy use are calculated to reduced energy costs, for proposed measures.

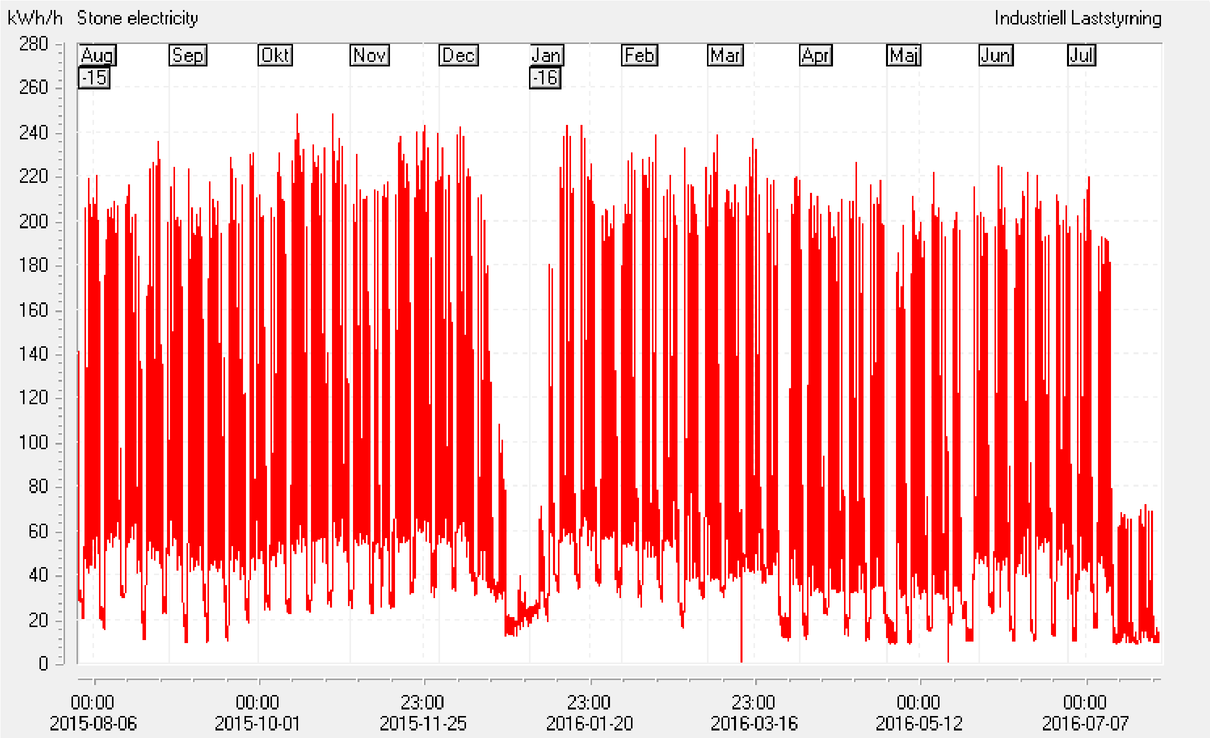


Chart 1: Shows the load curve for electricity during the twelve months' period from 2015-08-01 to 2016-07-31.

Unit	Name	Avr	Min	Max	Energy [kWh]
kW	Power	78,18	0,00	247,60	686 710

Natural gas

[1] XXXX.
[2] XXXX.
[3] XXXX.
[4] XXXX.

The total consumption of natural gas during the twelve months' period from 2015-08-01 to 2016-07-31 was 1 952 786 kWh[5] according to *Chart 2*. The cost for natural gas during the same period was € 66 469[6].

The variable cost of natural gas, i.e. the cost that depends on the use of gas, amounts to 0,037 €/kWh[7]. This is the costs that is used when the savings regarding energy use are calculated to reduced energy costs, for proposed measures.

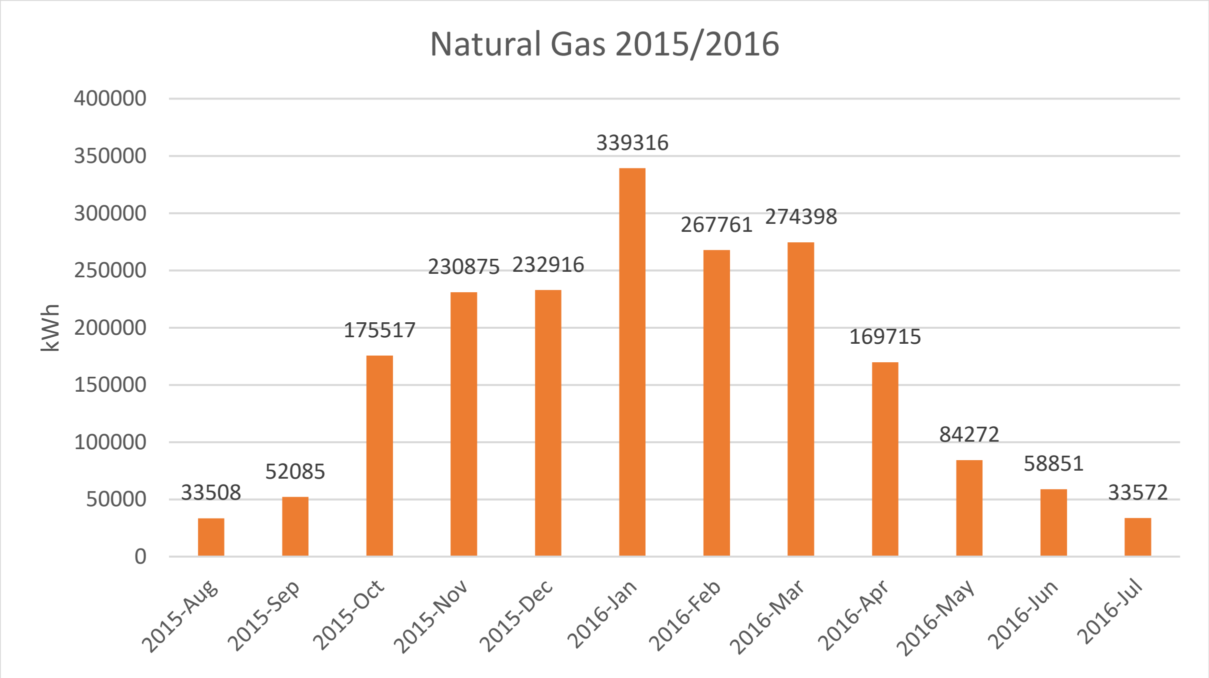


Chart 2: Shows the consumption of natural gas for each month during the twelve months' period from 2015-08-01 to 2016-07-31.

Diesel

The total consumption of diesel during the twelve months' period from 2015-08-01 to 2016-07-31 was 160 426 kWh[8]. The cost for diesel during the same period was € 13 315[9].

The variable cost of diesel, i.e. the cost that depends on the use of diesel, amounts to 0,083 €/kWh[10]. This is the cost that is used when the savings regarding energy use are calculated to reduced energy costs, for proposed measures.

[5] XXXX
[6] XXXX
[7] XXXX
[8] XXXX
[9] XXXX
[10] XXXX

Situation analysis and proposals

The following chapter describes how the energy is used at present and also presents proposals on how energy can be used more efficiently. *Chart 3* shows how electricity, natural gas and diesel consumption is distributed among the various support and production processes, which are described in more detail under the headings below.

Calculations on how the energy is used are based on:

- The performed measurements, shown in the appendices.
- The energy statistics during the twelve months' period from 2015-08-01 to 2016-07-31, described in chapter 0.
- The inventory of installed power and capacities.
- Observed operating patterns.
- Identified energy recovery.

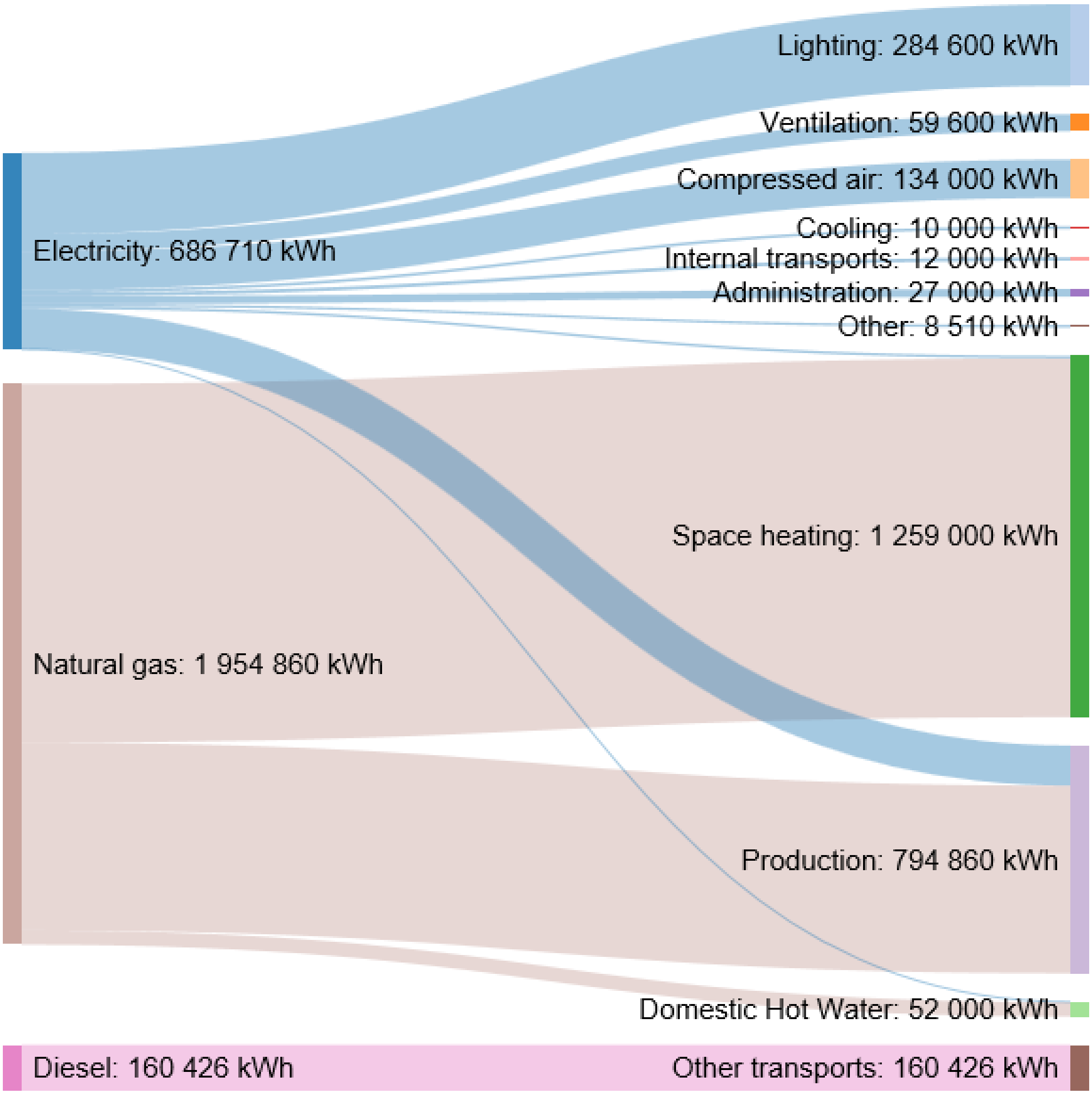


Chart 3: Energy balance, shows how the energy use is distributed among the various support and production processes.

Lighting

The lighting annually uses approximately 284 600 kWh_{el} according to the lighting survey that can be found in the appendices. The total installed power for the lighting is 96,7 kW.

The majority of all lighting consists of T8 fluorescent tubes 58W and 36W. In building 12 and 6 a few new LED fixtures that replaces the T8 fixtures can be find.

The general lighting is considered to provide a good working environment. The lux value varies between 150 to 400 lx and is lowest in warehouses and highest in premises with work that requires better lighting such as mounting.

As a KPI value (Key performance indicator) for lighting, installed power per square meter is used. The key value does not include how strong the lighting is. I high KPI value can be explained by great need of lighting. The lux value has therefore been measured.

In *Table 3* the KPI and lux value is shown for chosen premises. All of these premises have T8 fluorescent as general lighting and the different in KPI-value is explained by difference in lux-value and parameters specific for the premises such as ceiling height and colours of walls, ceiling and floor.

Premises	Installed power [kW]	KPI-value [W/m^2]	Lux [lx]
Building 2 - Marble	5,4	9,3	250
Building 3 - Fireplaces	22,2	7,9	160
Building 3 - Fireplaces warehouse	6,8	5	200
Building 7	10,1	13,3	400
Building 10 - Slate 1	4,4	8,9	400
Building 10 - Slate 2	3,1	6,4	350
Building 11 - Warehouse SL. TH	3,1	3,6	150
Building 12 - Thermotte	12,2	8,3	350

Table 3: Shows KPI value for chosen premises. An overview of buildings and premises are shown in appendices in Figure 4. *Lux values are an average value that represents the entire premises. Higher and lower Lux value can appear in specific parts of the premises.*

Measure, Converting from T8 fluorescent tubes to T5.

Saving	
Electricity:	51 400 kWh/year
Cost reduction	4 900 €/year
Costs	
Investment cost:	€ 14 410
Financial calculations	

Payback:	2,9 years
LCC (cost saving 10 years):	€ 18 470

The premises with highest electricity use during one year are the production area in building 3 (fireplaces) and building 12 (Thermotte).

In these premises it is profitable to change from T8 fluorescent tubes. The lighting technology that is considered to be most suitable is T5 fluorescent tubes with a higher light output per Watt and a more efficient drive than T8 fluorescent tubes.

The reason that LED is not suggested in these premises is that it would be too high investment compared to savings. LED tubes are not suggested because most existring fixtures are old and need to be changed.

Measure, Converting from T8 fluorescent tubes to LED tubes.

Saving	
Electricity:	42 200 kWh/year
Cost reduction	4 250 €/year
Costs	
Investment cost:	€ 15 560
Financial calculations	
Payback:	3,7 years
LCC (cost saving 10 years):	€ 12 960

In the other premises a combination between changing from T8 fluorescent tubes to LED-tubes and ECO/ES tubes would be the best alternative. T5 tubes are not profitable here because of too low run time and too low installed power for current lighting.

Current fixtures are old but are expected to last a few more years. LED technology is moving forward fast and new fixtures for industrial premises will be cheaper and better in a few years and therefore keeping current fixtures but changing light source is suggested.

For fixtures with least wear, LED tubes is the best alternative and for the other fixtures ECO/ES tubes should be applied. Both of these lighting technologies are explained under headings below. The calculations for these measures have been made with the assumption that half of the current T8 fluorescent tubes are changed for LED tubes and the half for ECO/ES tubes.

In building 10 personnel are worried that changing light source would mean a cooler light. Both LED tubes and ECO/ES are available as warmer light down to 3000 K, why this is not an argument.

LED tubes

Converting from T8 fluorescent tubes to LED tubes which can be applied in existing fixtures and therefore means a lower investment cost than most other alternatives.

The T8 58W (including drive means 68W) are exchanged for LED 25W (including drive means 30 W) and T8 36W (including drive means 43W) for LED 21W (including drive means 24W). The power varies slightly between different providers.

LED tubes produce less light than T8 fluorescent tubes but directs all the lights downwards. Therefore, LED tubes are suitable with existing fittings with poor reflectors that can´t take advantage of the higher light output of the T8 fluorescent tubes. Before converting all the light sources, a smaller number of LED tubes should be purchased to ensure that the lighting still provide a good working environment.

The LED tubes have a higher life expectancy than T8 fluorescent tubes which means that the tubes don’t have to be replaced so often. The maintenance cost is thereby reduced.

It is important to have a guarantee of at least 5 years because there are LED tubes of poor quality on the market.

ECO tubes

The conventional T8 tubes used today, can be exchanged for the equivalent ECO/ES tubes that use 10 % less energy. These tubes are called ECO by Philips and ES by Osram and can be applied in existing fixtures (also other manufactures have the same type of fluorescent tubes).

ECO/ES tubes provide basically the same light output and last as long as current fluorescent tubes. The investment cost is an additional cost compared with the conventional T8 tubes and amounts to approximately € 3 each.

Because the payback time is shorter than the expected technical lifetime of the conventional T8 tubes, and the LCC calculation gives a positive result, the measure is profitable.

Ventilation

Ventilation is using approximately 59 600 kWh_{el}/year. Most of the buildings are not ventilated and the majority of the energy consumption is used by the filter for sand blasting and polishing (see measure below).

There is also a ventilation unit for building 7a with heat recovery that runs 1-shift.

Sand blasting

Our logging of the electricity use for sand blasting filter (ventilation fan, 18 kW) show that this fan is in operation between 06.00 and 21.30 weekdays, with a 30 minute break in the morning (09.30 – 10.00) when the fan is switched off. The base level for the fan is at 14,5 kW and when actual operations are done the power demand increases to 17,6 kW. It seems that the main part of the electric energy use here is for keeping the fan running, not necessarily transporting anything out from sand blasting or/and polishing to the filter.

Measure, fan with variable frequency drive

We propose that the fan motor be equipped with a variable frequency drive, VFD; that can reduce the fan speed (motor frequency) to 20 Hz when there are no operations going on. In addition to this there should be automatic dampers installed for every work station/exhaust point so that there is no suction when no work is being done (except a small flow in order to keep the motor running at 20 Hz). As one or more dampers open there will be a change in duct pressure and the fan can increase its speed via the VFD.

Saving	
Electricity:	25 000 kWh/year
Cost reduction	2 200 €/year
Costs	
Investment cost:	€ 5 000
Financial calculations	
Payback:	2,3 years
LCC (cost saving 10 years):	€ 9 760

Calculating annual electric energy use for this fan gives us a number of 50,000 kWh/year. The proposed modification/investment can easily reduce the annual electric energy use by 50 %, or 25,000 kWh of electric energy per year, worth 2,200 Euros per year.

The investment cost is estimated to be approximately 5,000 Euros, giving a pay-off time of 2.3 years.

Compressed air

The compressed air system is using 134 000 kWh/year and is served by three compressors, model Kaeser ASD 37 with rated power of 22 kW, Kaeser Airtower19 with rated power of 11 kW and Speiarke Lialter with rated power of 5,5 kW. Speiarke Lialter is only used if pressure is too low in building 2a.

The average power use during one day of production is 20,5 kW. The air pressure in the system is around 7.5 bar.

Because some divisions are working 2 and 3 shifts there is a need for compressed air from Monday morning to Friday afternoon.

Measure, compressor with variable frequency drive

Invest and install a compressor with variable speed and use this as the main compressor. Keep Kaeser ASD 37 T as a reserve compressor only used during stop for main compressor.

Saving	
Electricity:	60 000 kWh/year
Cost reduction	5 300 €/year
Costs	
Investment cost:	€ 8 900
Financial calculations	
Payback:	1,7 years
LCC (cost saving 10 years):	€ 26 660

The need for compressed air varies widely during a production day. According to measurements made by Kaeser, spring 2016, the airflow during peaks around 7 am and 1 pm is above 5 m^3/min. During the third shift the airflow is only 0.6 m^3/min.

The power consumption for compressors does not vary as much. The average power for compressors during first shift (with peak loads) is 20,5 kW and during third shift 15,6 kW.

A compressor with variable frequency drive would much better adapt the production to the need for compressed air and reduce the power consumption when the need is low.

Measure, Kaeser ASD 37 T, air transportation and heat recovery

Saving	
Electricity:	1 500 kWh/year
Natural gas:	70 000 kWh/year
Cost reduction	2 700 €/year
Costs	
Investment cost:	€ 3 000
Financial calculations	
Payback:	1,1 years
LCC (cost saving 10 years):	€ 15 120

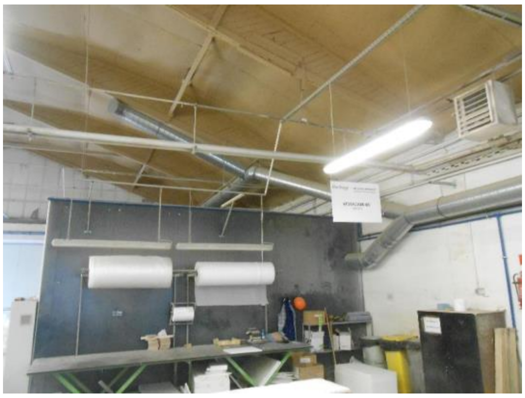
The air compressor located in the compressor room between buildings 2 and 3 at XXXX XXXX site has a non-functioning heat recovery/cooling system that can be fixed so that two main significant goals can be achieved:

The system, with a ventilation duct leading from outside into the compressor room, does not have sufficient cooling capacity. Therefore, a split cooling unit, with 800 W electricity use and 2.2 kW cooling capacity is placed in the compressor room to help during warm days.

The system does not have appropriate exhaust capacity either. A hood on top of the compressor is located too close to the top of the compressor and the exhaust air duct is broken/separated up at ceiling level before the duct leaves the room and continues to the

environment (outdoors) or into the marble grinding/polishing room. See photos:

This system must be re-constructed so that cooling air can be drawn from outside during the summer and from the marble department (or from the cleaner part of Kominki, building 3) in the winter and so that the exhaust can be evacuated to the outside during the summer and back to where the air was taken from, during the winter. By fixing this the compressor can get sufficient supply of fresh air and the warm air that is exhausted from the compressor can be used to replace the use of natural gas for heating during the cold season. Parts of the existing air distribution system can be used also in the future:



By fixing the system it is calculated that the extra cooling unit does not have to be used anymore, saving 1,500 kWh of electricity during the summer. The energy recovered from the compressor during the heating season can be used instead of natural gas, saving a total of 60,000 kWh of natural gas every winter, net savings. With an expected annual efficiency of the gas boilers at 85 % the gross natural gas savings amount to over 70,000 kWh per year. Total savings, 1,500 kWh of electricity and 70,000 kWh of natural gas, are worth 2,700 Euros per year.

The investment cost is estimated to be around 3,000 Euros, making the pay-back time as short as 1.1 years.

Measure, Kaeser Airtower 19, heat recovery and filter change

Saving	
Natural gas:	14 000 kWh/year
Cost reduction	550 €/year
Costs	
Investment cost:	€ 2 000
Financial calculations	
Payback:	3,6 years
LCC (cost saving 10 years):	€ 1 690

This compressor is located in a small building located close to warehouse 11 and not far from building no. 12. Measured data for this compressor shows that it annually uses approximately 22,500 kWh, every week approximately 430 kWh of electricity.

When visiting the compressor room, we noticed that the compressor's air filters were very dirty, see photo. This makes the compressor run very inefficiently since it cannot easily get the air that it needs to generate the compressed air. It is like breathing through a straw, like having asthma.

Our recommendation is that the air intake filters should be replaced more regularly, maybe as often as once every month if needed. This will increase the compressor efficiency significantly although it is not easy to calculate the savings.

Also the heat that this compressor generates could be used to heat buildings instead of only using natural gas for heating. Since the compressor house is closest to warehouse 11 it should be most natural to utilise the recovered compressor heat in this warehouse. However, the warehouse already utilises recovered heat from the sand blasting filter, located outside building 10, why we recommend installation of a fan, a manual damper to choose summer or winter operation and an insulated duct leading the recovered heat into building 12 which is also close by the compressor house for compressor ASD 19.

The energy recovered from the compressor during the heating season can be used instead of natural gas, saving a gross total of over 14,000 kWh of natural gas every winter, worth 550 Euros per year.

The investment cost is estimated to be around 2,000 Euros, making the pay-back time become 3.6 years.

Space heating and domestic hot water

Natural gas is used for space heating and domestic hot water. The heat is distributed through a hydronic heating system with radiators and aerotempers. Smaller local systems also exist, for example building 6 has its own gas burner. The amount of natural gas used for space heating was 1 250 000 kWh and for domestic hot water 50 000 kWh during the twelve month period from 2015-08-01 to 2016-07-31.

The KPI value for space heating amounts to 113 kWh/m^2 and year (based on the same twelve months' period) which doesn´t seems to be particularly high. However, if one takes into account that most buildings are not ventilated and therefore do not have any ventilation losses this KPI-value is higher than for a normal building with similar production.

The high KPI-value is explained by deficiencies in the building envelopes. Measures that decrease the need for space heating are given in chapter 0, 0, 0 and 0.

The electricity for space heating and domestic hot water shown in *Chart 3* is the energy used by the main circulation pumps which annually amounts to 9 000 kWh_{el} respective 2 000 kWh_{el}.

Production

The processes in the production annually use 140 000 kWh_{el} and 655 000$kWh_{n.ags}$. Separate measurement has been done for the water cutting machine. Other processes have been estimated by measuring electricity centrals for different buildings. These measurements can be found in appendices.

There is small idle power consumption during weekends and this is not derived from production according to measurements. The idle power is as low as 10 kW and is believed to be from circulation pumps for heating system and from outside lighting.

Furnaces, building 12

In building 12 there are some gas-fired furnaces that are used to cure some of the finished products. The process is now in operation during night time and the temperature in the furnaces vary between 80 and 120^{o}C. According to the personnel it is not easy to maintain the correct temperature (or even to know which is the correct temperature) in the furnaces because it varies so much depending on how close to the openings the products are.

Before the furnaces were installed the products cured in room temperature but it took longer time and of course this also requires larger space for storage of products while curing.

There also used to be a heat recovery system, using excess heat from the furnaces to heat some of the premises (a warehouse) but that system is no longer in use due to problems with CO_2 in the air (rest product from combustion of natural gas). When heat could be used also for heating during the heating season, then at least the usage of natural gas had a doubled value. Now it is questioned whether to continue to use gas-fired furnaces, to switch to electric furnaces or to go back to getting the products cured in room temperature.

After evaluating the power situation, costs of various energy sources etc. we strongly recommend that there should not be a change to electric furnaces; costs will be too high for the electricity and there will also be some implications on the rate structure and the potential power interruptions that follow with exceeding a demand of 300 kW.

From an energy efficiency point of view it is best to not use any furnaces at all but we realise that productivity goals may call for some increased curing time. In case furnaces must be used we recommend gas-fired furnaces but that some investments are made to recover heat from the furnaces through a heat exchanger, without transferring CO_2 to premises where people work.

Appendices

Overview of site

Figure 4: Overview of site XXXX with building numbers.

Lighting survey

Premises	Type	Installed power [kW]	Run time [h/year]	Energy use [kWh/year]
Building 2 - Marble	T8 58W	5,4	2 160	11 800
Building 2a - Wood department	T8 58W	3,3	2 160	7 100
Building 2 - Compressor room	T8 36W	0,1	2 160	200
Building 2 - Electricity central	T8 36W	0,1	2 160	200
Building 3 - Fireplaces	T8 58W	22,2	2 880	63 800
Building 3 - Fireplaces warehouse	T8 58W, Metal halide 120W	6,8	2 880	19 500
Building 3a - World warehouse	T8 58W	4,5	2 160	9 700
Object 4a - Tent warehouse	T8 36W	0,5	2 880	1 500
Building 5 - Wood	T8 36W, High pressure sodium 150W	1,1	2 160	2 400
Building 6	T8 58W	1,2	2 160	2 600
Tent warehouse "C"	T8 58W	1,5	2 160	3 200
Building 7	T8 58W, T8 36W	10,1	2 160	21 800
Building 7a - Foundry	T8 36W	2,1	2 160	4 600
Building 8 - Welding	T8 58W	2	2 160	4 400
Crusher	T8 58W	1	2 160	2 100
Office	T8 36W, T8 18W	2	2 400	4 900
Building 10 - Slate 1	T8 58W	4,4	2 400	10 400
Building 10 - Slate 2	T8 58W	3,1	2 400	7 500
Building 11 - Canteen	T8 58W	1,4	2 160	2 900
Building 11 - Dressing room	T8 58W	2,9	2 160	6 200
Building 11 - Corridors, Staircase	T5 28W	0,1	2 160	300
Building 11 - Warehouse SL. TH	T8 58W, LED 102W	3,1	2 400	7 300

Building 12 - Thermotte	T8 58W	12,2	5 760	70 500
Building 13 - Laboratory	T8 58W, T8 18W	1,7	2 160	3 600
Outside	Metal halide 120W, High pressure sodium 150W, Hg 125W	4	4 000	16 100
Total		**96,7**		**284 600**

Table 4: Performed lighting survey. An overview of buildings and premises are shown in appendices in Figure 4.

Calculations

Building

Seal the industrial door in Building 2 and 7.

Transmission losses have been estimated by standard value to 60 kWh / year and cm^2. The area of the field is measured to 700 cm^2.

$$Saving\ (energy) \ = \ 60\left[\frac{kWh}{year}\right]\cdot 700[cm^2] \approx 42000\left[\frac{kWh}{year}\right]$$

$$Saving\ (cost) \ = \ 42000\left[\frac{kWh}{year}\right]\cdot 0{,}04\left[\frac{€}{kWh}\right] \approx 1550\left[\frac{€}{year}\right]$$

The investment cost used in the calculation is € 500.

$$Payback \ = \ \frac{500[€]}{1550\left[\frac{€}{year}\right]} \approx 0{,}3[year]$$

The parameters for the LCC calculation is, calculation period 10 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving \ = \ 6{,}71\cdot 1550\left[\frac{€}{year}\right] \ - \ 500[€] \approx 9900[€]$$

Apply an extra insulated glass unit on the windows in Building 6.

U-value for the current window is estimated to 6 W/m^2K. It is considered possible to reduce to 1,3 W/m^2K with an extra insulated glass unit. The window area amounts to 36 m^2 and the indoor temperature to 18°C.

$$Saving\ (energy) \ = \ \frac{6\left[\frac{W}{m^2\cdot K}\right] \ - \ 1{,}3\left[\frac{W}{m^2\cdot K}\right]}{1000}\cdot 36[m^2]\cdot(18[°C] \ - \ 8[°C])\cdot 8760[h] \approx 14800\left[\frac{kWh}{year}\right]$$

$$Saving\ (cost) \ = \ 14800\left[\frac{kWh}{year}\right]\cdot 0{,}04\left[\frac{€}{kWh}\right] \approx 550\left[\frac{€}{year}\right]$$

The investment cost used in the calculation is € 4 000.

$$Payback \ = \ \frac{4000[€]}{550\left[\frac{€}{year}\right]} \approx 7{,}3[year]$$

The parameters for the LCC calculation is, calculation period 15 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving \ = \ 8{,}56\cdot 550\left[\frac{€}{year}\right] \ - \ 4000[€] \approx 710[€]$$

Construct a well-insulated wall that replaces the windows in Building 7.

U-value for the current window is estimated to 5 W/m^2K. It is considered possible to reduce to 0,3 W/m^2K. The window area amounts to 65 $m^2$and the indoor temperature to 18°C.

$$Saving\ (energy) = \frac{5\left[\frac{W}{m^2 \cdot K}\right] - 0{,}3\left[\frac{W}{m^2 \cdot K}\right]}{1000} \cdot 65[m^2] \cdot (18[°C] - 8[°C]) \cdot 8760[h]$$
$$\approx 26800\left[\frac{kWh}{year}\right]$$

$$Saving\ (cost) = 26800\left[\frac{kWh}{year}\right] \cdot 0{,}037\left[\frac{€}{kWh}\right] \approx 990\left[\frac{€}{year}\right]$$

The investment cost used in the calculation is € 7 200.

$$Payback = \frac{7200[€]}{990\left[\frac{€}{year}\right]} \approx 7{,}3[year]$$

The parameters for the LCC calculation is, calculation period 20 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving = 9{,}82 \cdot 990\left[\frac{€}{year}\right] - 7200[€] \approx 2520[€]$$

Repair broken window in Building 7.

U-value for the current window is estimated to 35 W/m²K. It is considered possible to reduce to 1,3W/m²K. The window area amounts to 1,2 m² and the indoor temperature to 18°C.

$$Saving\ (energy) = \frac{35\left[\frac{W}{m^2 \cdot K}\right] - 1{,}3\left[\frac{W}{m^2 \cdot K}\right]}{1000} \cdot 1{,}2[m^2] \cdot (18[°C] - 8[°C]) \cdot 8760[h]$$
$$\approx 3500\left[\frac{kWh}{year}\right]$$

$$Saving\ (cost) = 3500\left[\frac{kWh}{year}\right] \cdot 0{,}037\left[\frac{€}{kWh}\right] \approx 130\left[\frac{€}{year}\right]$$

The investment cost used in the calculation is € 260.

$$Payback = \frac{260[€]}{130\left[\frac{€}{year}\right]} \approx 2[year]$$

The parameters for the LCC calculation is, calculation period 20 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving = 9{,}82 \cdot 130\left[\frac{€}{year}\right] - 260[€] \approx 1020[€]$$

Lighting

Change of lighting to T5

The new lighting is calculated to provide an estimated key value. The change applies to the room(s) Building 12 Thermotte, Building 3 Fireplaces.

$$Saving\ (energy) = (12{,}2[kW] - 7{,}3[kW]) \cdot 5760 \left[\frac{h}{year}\right] + (22{,}2[kW] - 14{,}1[kW]) \cdot 2880 \left[\frac{h}{year}\right] \approx 51400 \left[\frac{kWh}{year}\right]$$

$$Saving\ (cost) = 51400 \left[\frac{kWh}{year}\right] \cdot 0{,}088 \left[\frac{€}{kWh}\right] + 13[kW] \cdot 28{,}9 \left[\frac{€}{kW}\right] \approx 4900 \left[\frac{€}{year}\right]$$

The investment cost used in the calculation is € 14410.

$$Payback = \frac{14410[€]}{4900 \left[\frac{€}{year}\right]} \approx 2{,}9[year]$$

The parameters for the LCC calculation is, calculation period 10 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving = 6{,}71 \cdot 4900 \left[\frac{€}{year}\right] - 14410[€] \approx 18470[€]$$

Change of lighting to ECO/ES tubes

The following savings have been calculated for the measure: Electricity 42 200 kWh/year. The reduced energy costs have been estimated at 4 250 €/year.

The investment cost used in the calculation is € 15 560.

$$Payback = \frac{15560[€]}{4250 \left[\frac{€}{year}\right]} \approx 3{,}7[year]$$

The parameters for the LCC calculation is, calculation period 10 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving = 6{,}71 \cdot 4250 \left[\frac{€}{year}\right] - 15560[€] \approx 12960[€]$$

Ventilation

Sand blasting, fan with variable frequency drive

The following savings have been calculated for the measure: Electricity 50 000 kWh/year. The reduced energy costs have been estimated at 2 200 €/year.

The investment cost used in the calculation is € 5 000.

$$Payback = \frac{5000[€]}{2200 \left[\frac{€}{year}\right]} \approx 2{,}3[year]$$

The parameters for the LCC calculation is, calculation period 10 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving\ =\ 6{,}71\cdot 2200\left[\frac{€}{year}\right]\ -\ 5000[€]\approx 9760[€]$$

Compressed air

Compressor with variable frequency drive

The following savings have been calculated for the measure: Electricity 60 000 kWh/year. The reduced energy costs have been estimated at 5 300 €/year.

The investment cost used in the calculation is € 8 900.

$$Payback\ =\ \frac{8900[€]}{5300\left[\frac{€}{year}\right]}\approx 1{,}7[year]$$

The parameters for the LCC calculation is, calculation period 10 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving\ =\ 6{,}71\cdot 5300\left[\frac{€}{year}\right]\ -\ 8900[€]\approx 26660[€]$$

Kaeser ASD 37 T, air transportation and heat recovery

The following savings have been calculated for the measure: Electricity 1 500 kWh/year, Natural gas 70 000 kWh/year. The reduced energy costs have been estimated at 2 700 €/year.

The investment cost used in the calculation is € 3 000.

$$Payback\ =\ \frac{3000[€]}{2700\left[\frac{€}{year}\right]}\approx 1{,}1[year]$$

The parameters for the LCC calculation is, calculation period 10 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving\ =\ 6{,}71\cdot 2700\left[\frac{€}{year}\right]\ -\ 3000[€]\approx 15120[€]$$

Kaeser Airtower 19, heat recovery and filter change

The following savings have been calculated for the measure: Natural gas 14 000 kWh/year. The reduced energy costs have been estimated at 550 €/year.

The investment cost used in the calculation is € 2 000.

$$Payback\ =\ \frac{2000[€]}{550\left[\frac{€}{year}\right]}\approx 3{,}6[year]$$

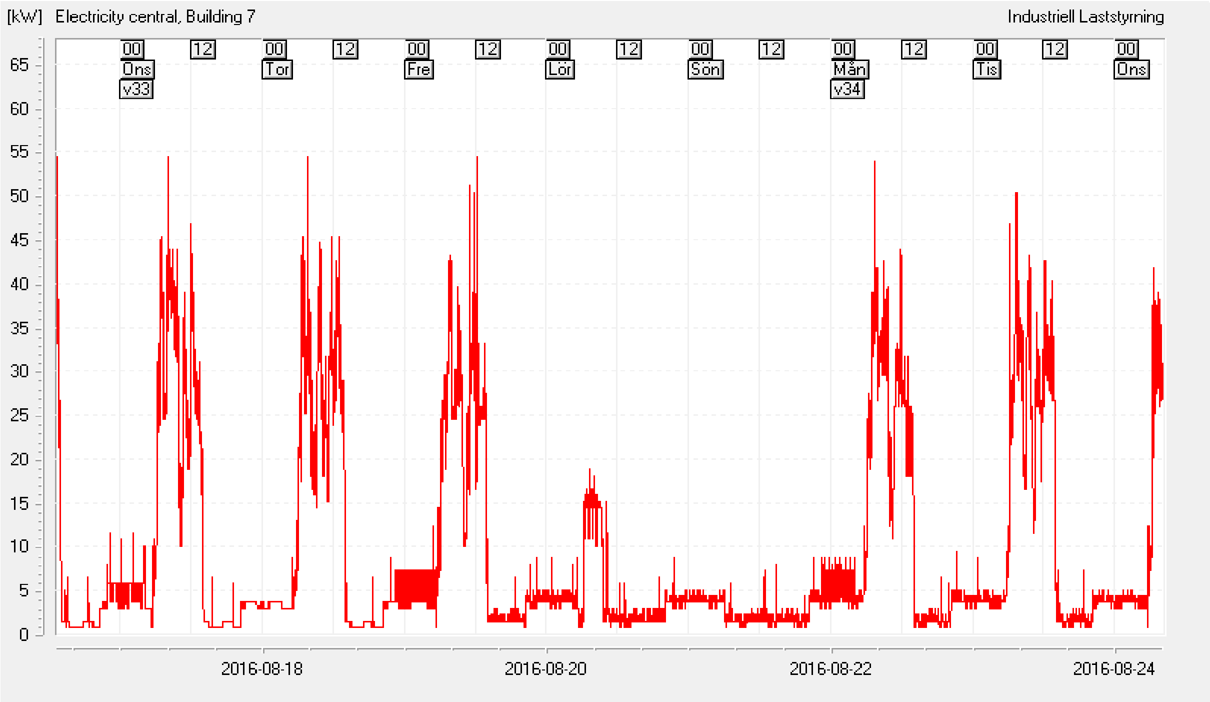
The parameters for the LCC calculation is, calculation period 10 years, discount rate 10 % and annual energy price increase 2 %.

$$LCC\ cost\ saving\ =\ 6{,}71\cdot 550\left[\frac{€}{year}\right]\ -\ 2000[€]\approx 1690[€]$$

Measurements

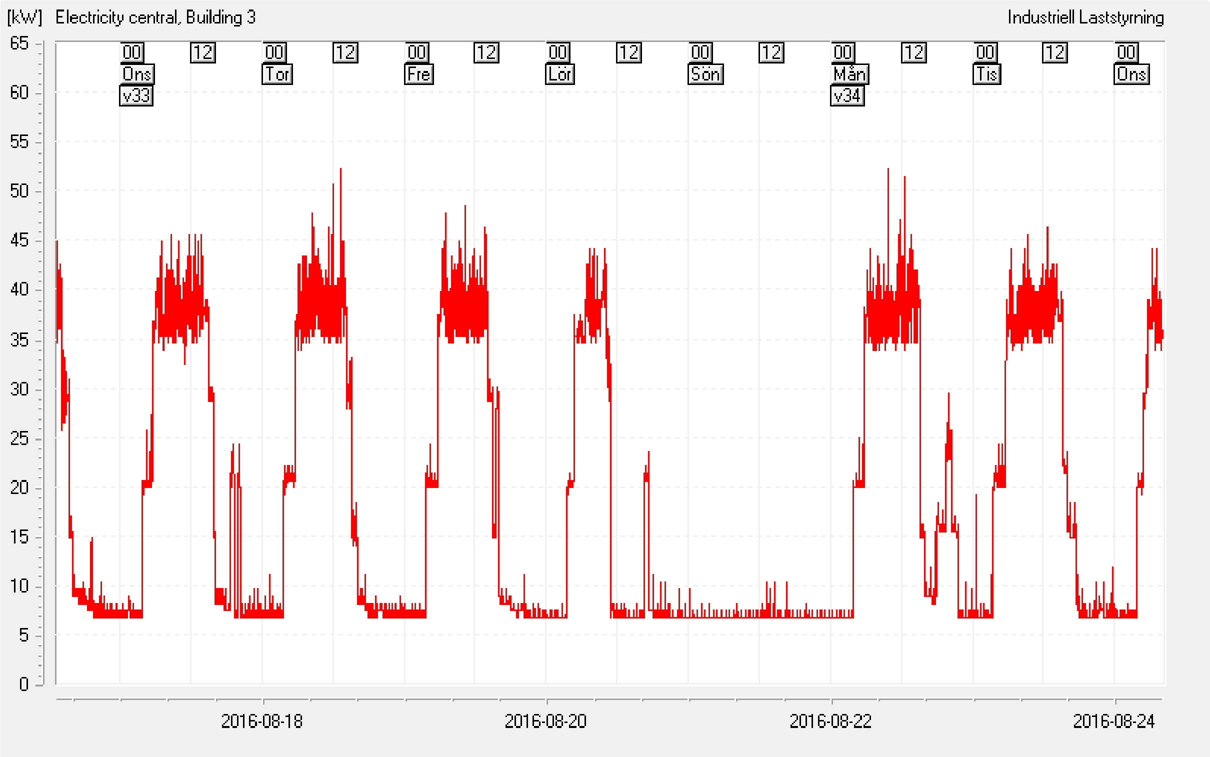
Measurement 1: Production, Water cutting.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	1,22	0,00	58,94	226



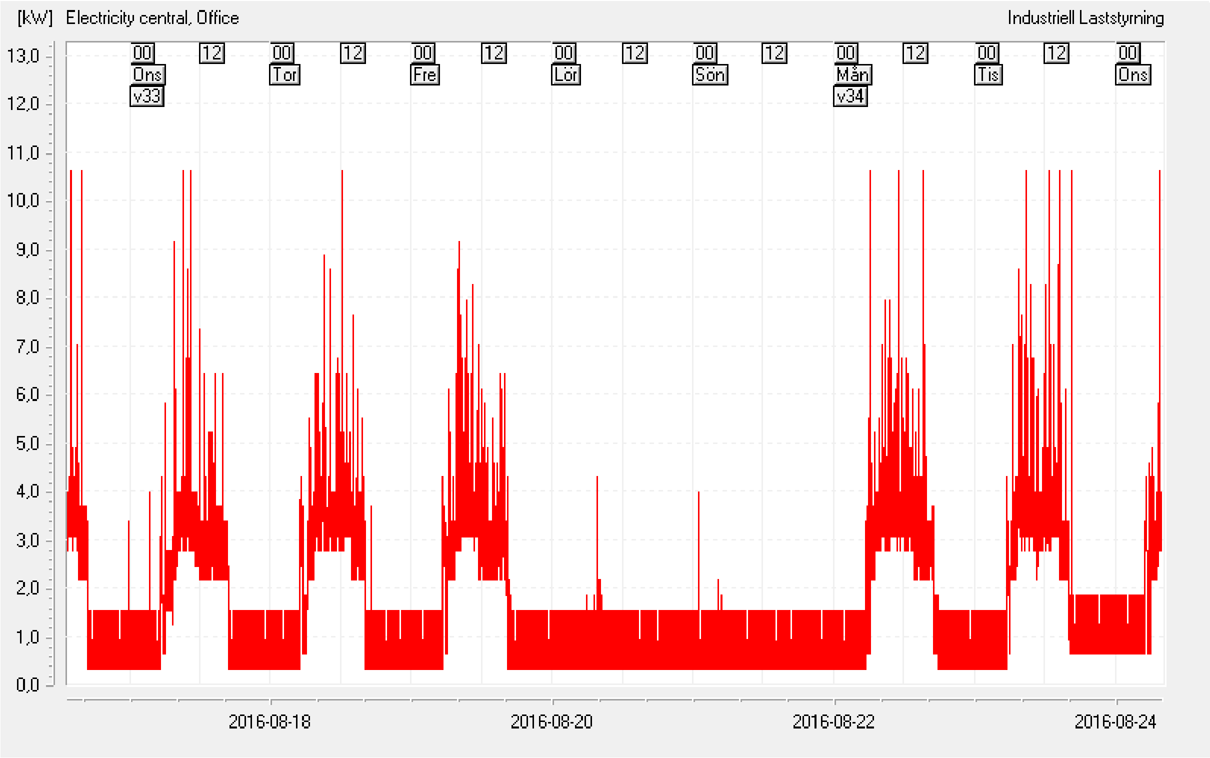
Measurement 2: Electricity central, Building 7.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	8,68	0,72	54,25	1 619



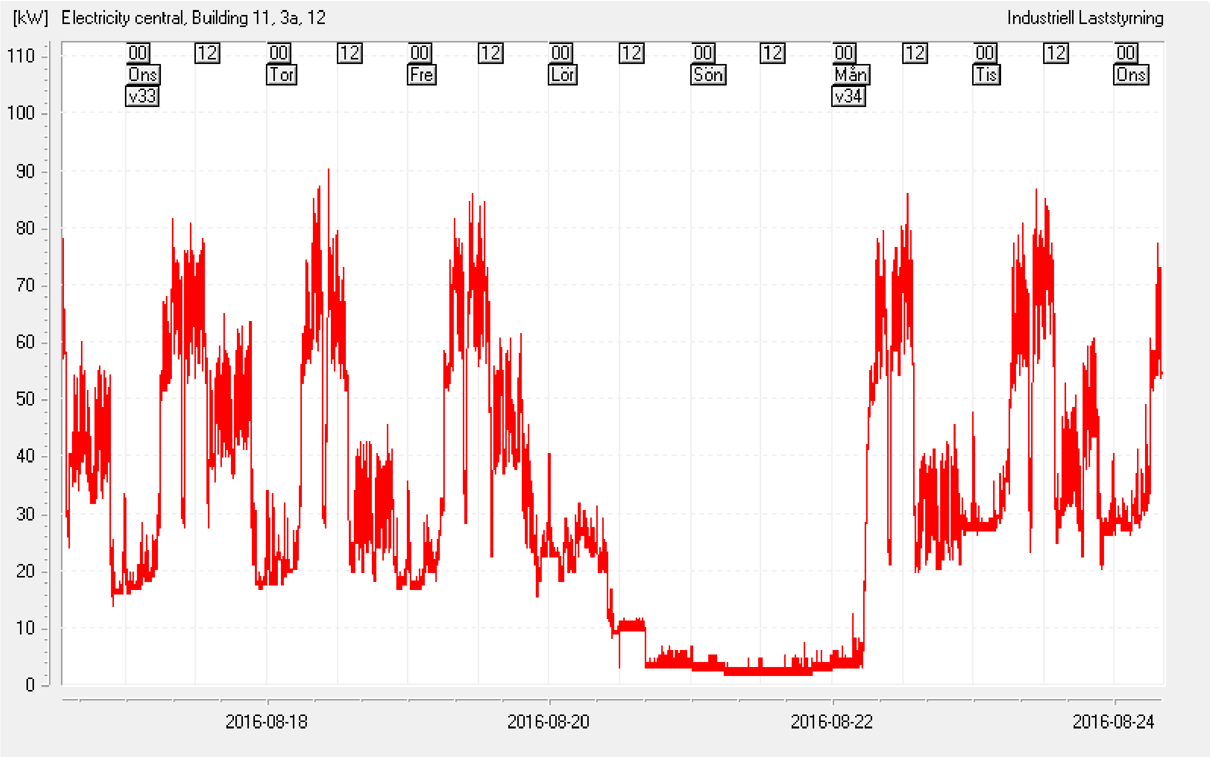
Measurement 3: Electricity central, Building 3.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	18,20	6,60	52,05	3 396



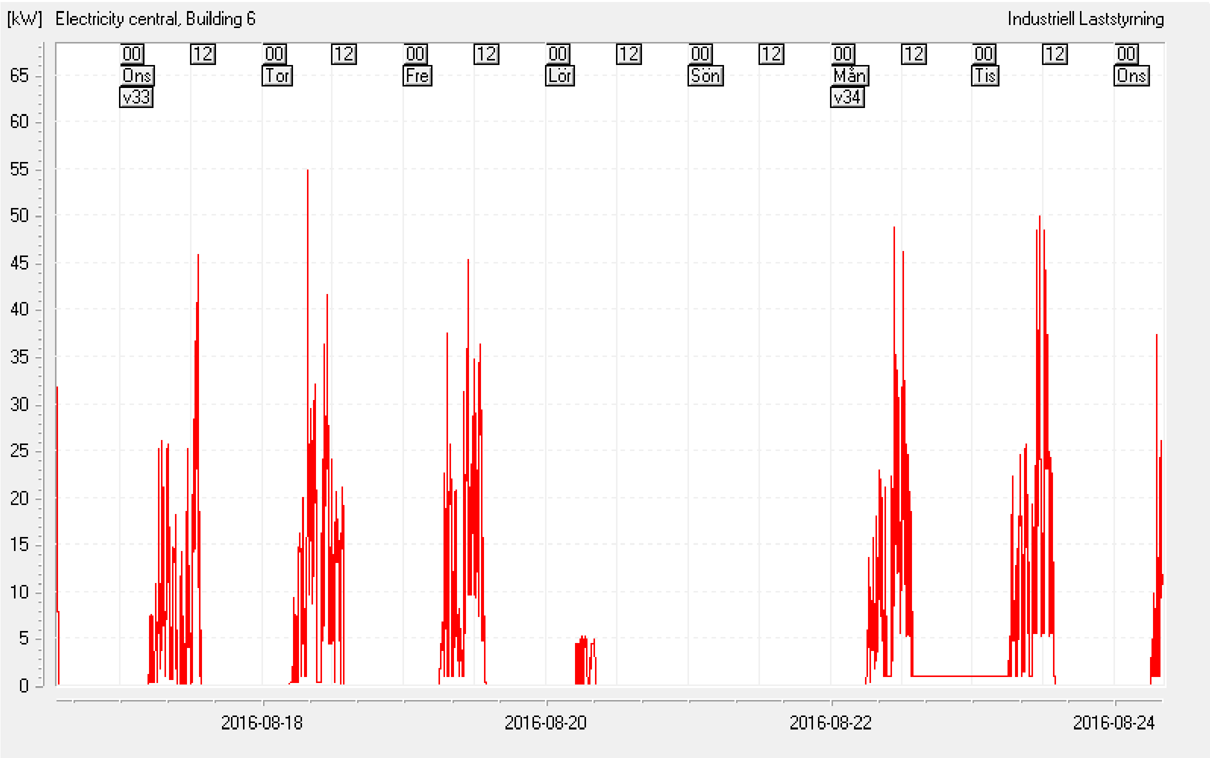
Measurement 4: Electricity central, Office.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	1,34	0,31	10,56	250



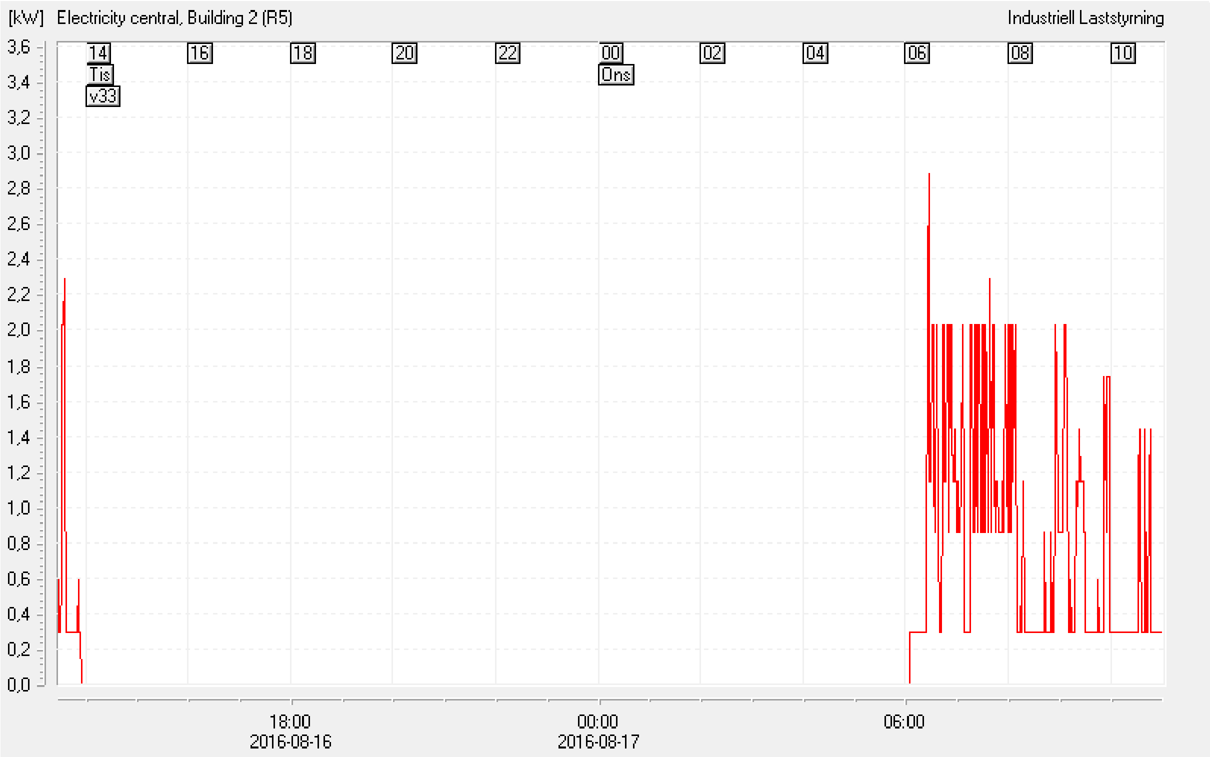
Measurement 5: Electricity central, Building 11, 3a, 12.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	31,28	1,44	89,84	5 835



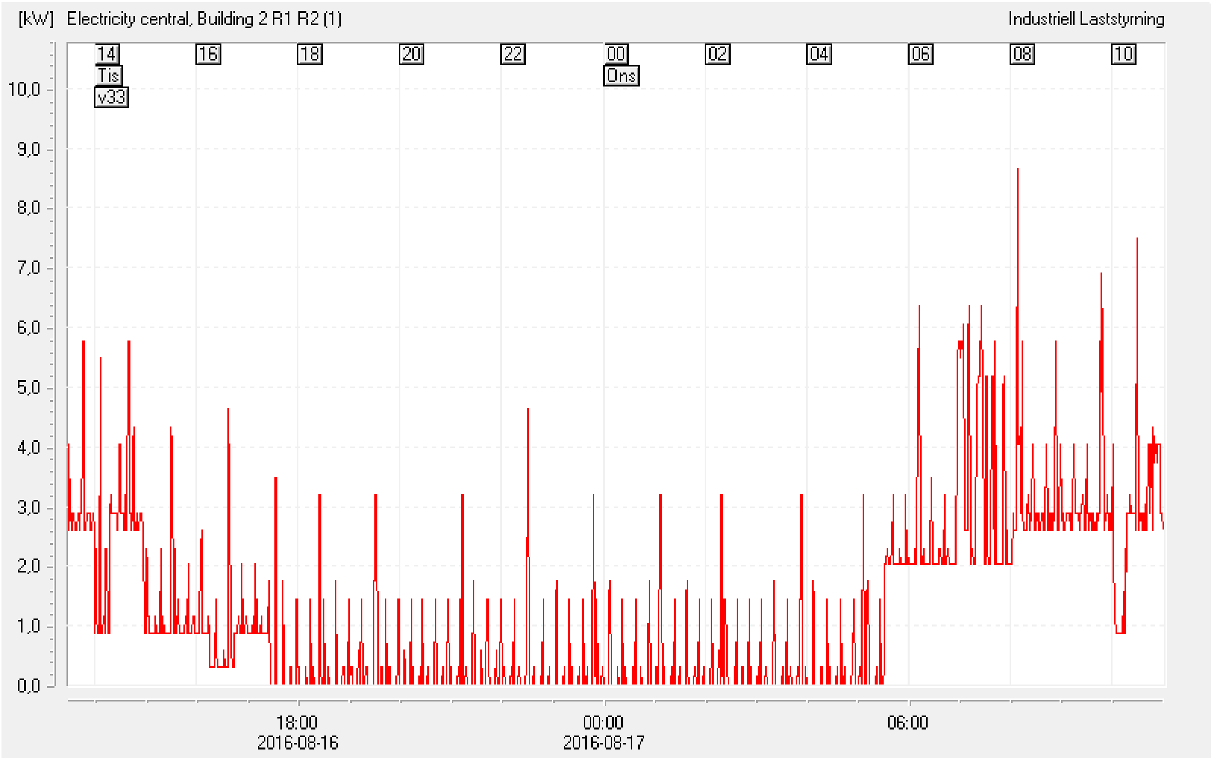
Measurement 6: Electricity central, Building 6.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	2,78	0,00	54,63	519



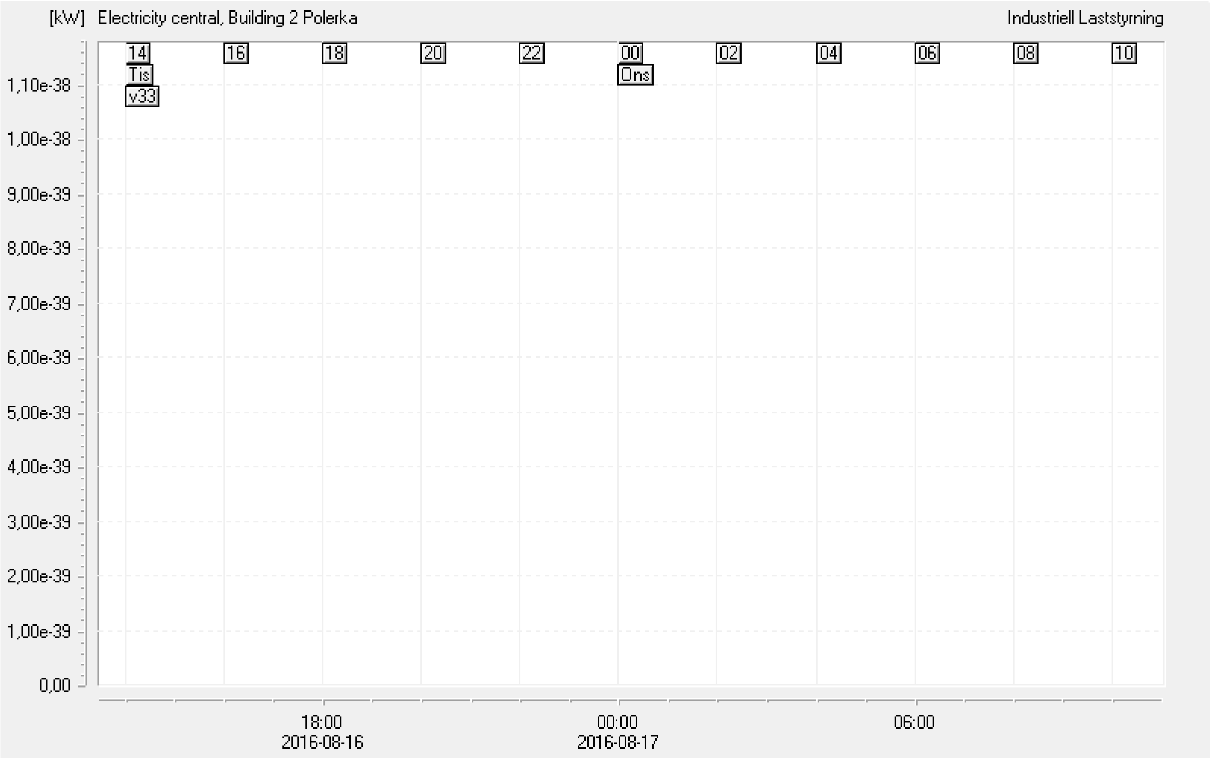
Measurement 7: Electricity central, Building 2 (R5).

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	0,20	0,00	2,87	4



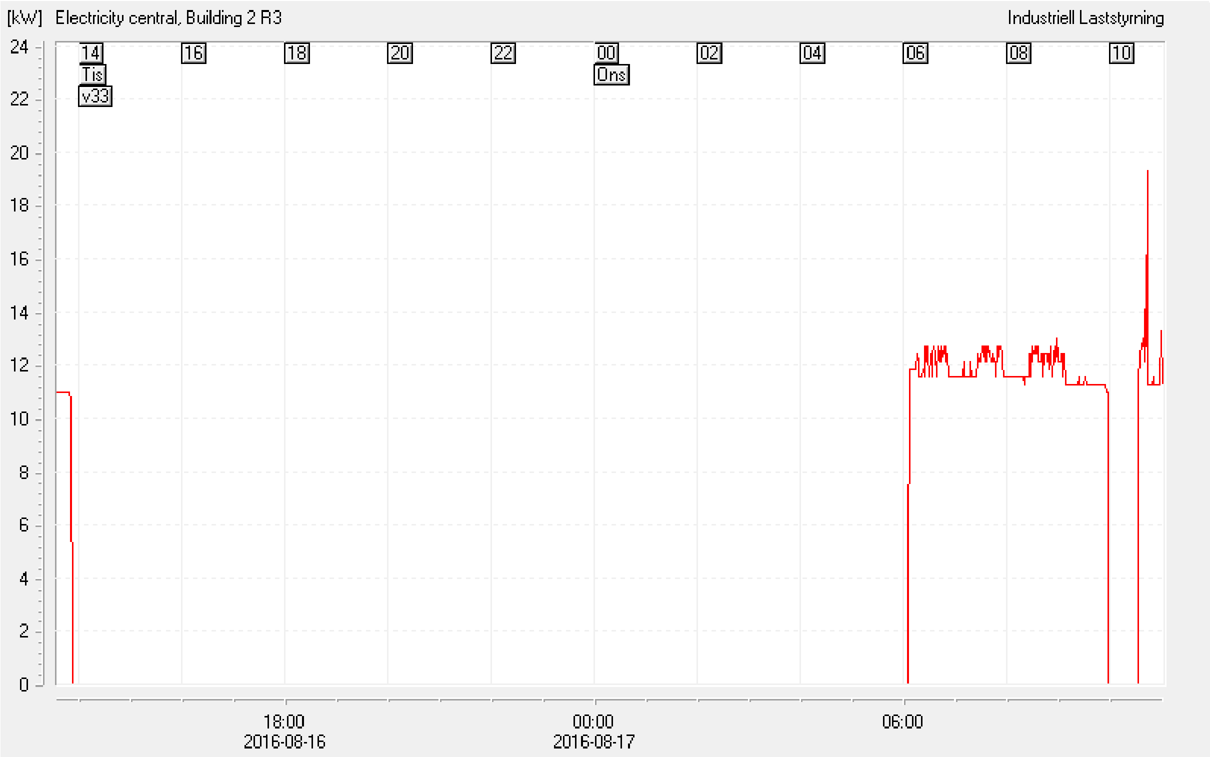
Measurement 8: Electricity central, Building 2 R1 R2 (1).

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	1,20	0,00	8,62	25



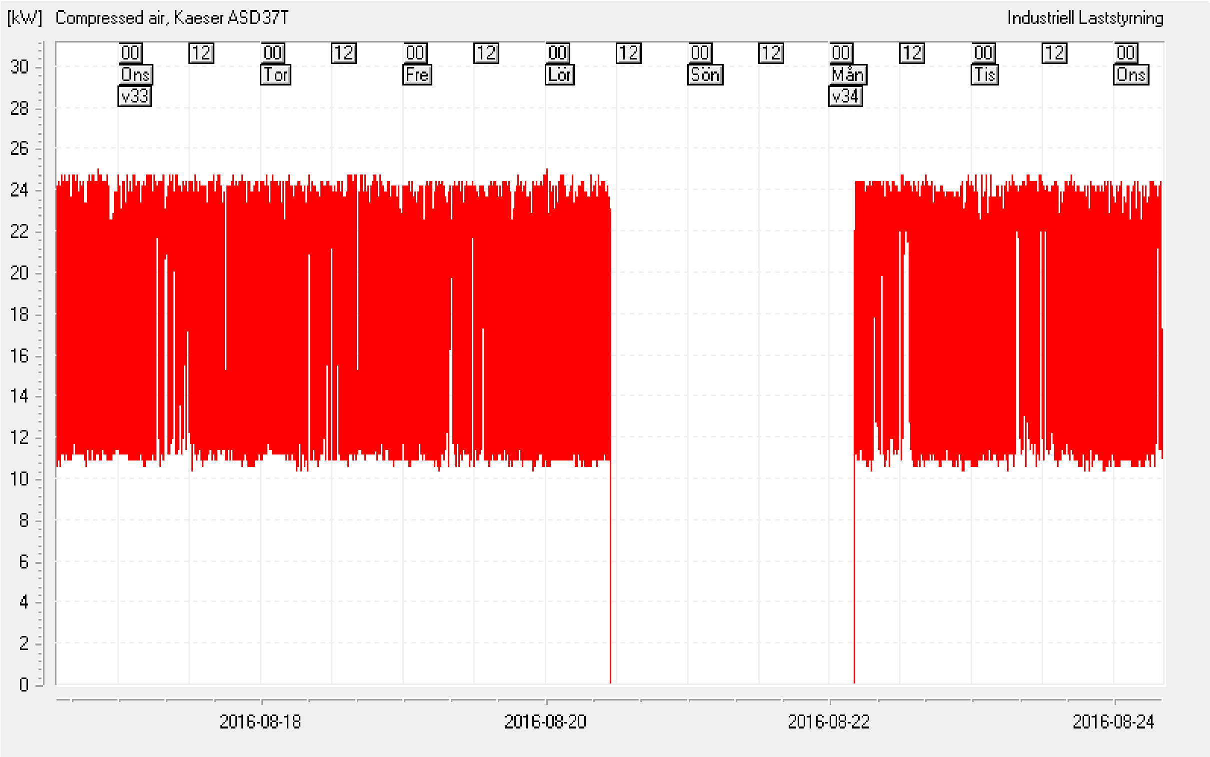
Measurement 9: Electricity central, Building 2 Polerka.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	0,00	0,00	0,00	0



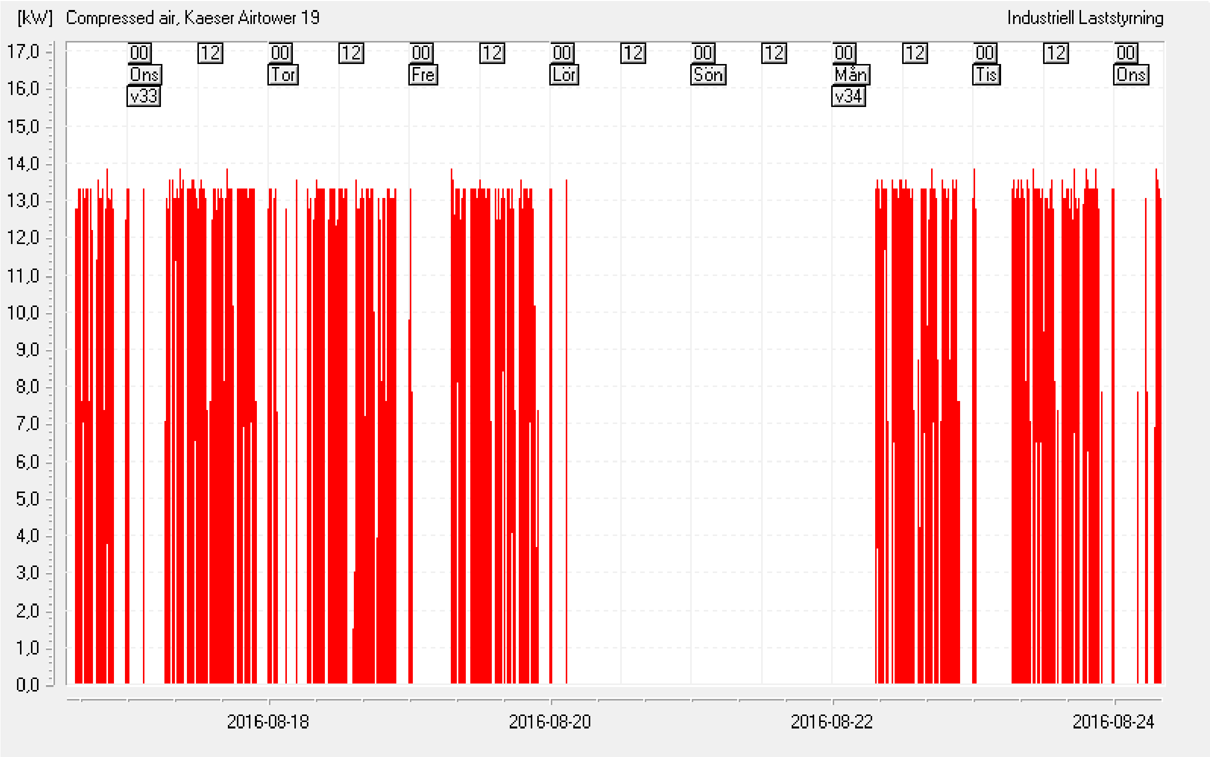
Measurement 10: Electricity central, Building 2 R3.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	2,54	0,00	19,26	54



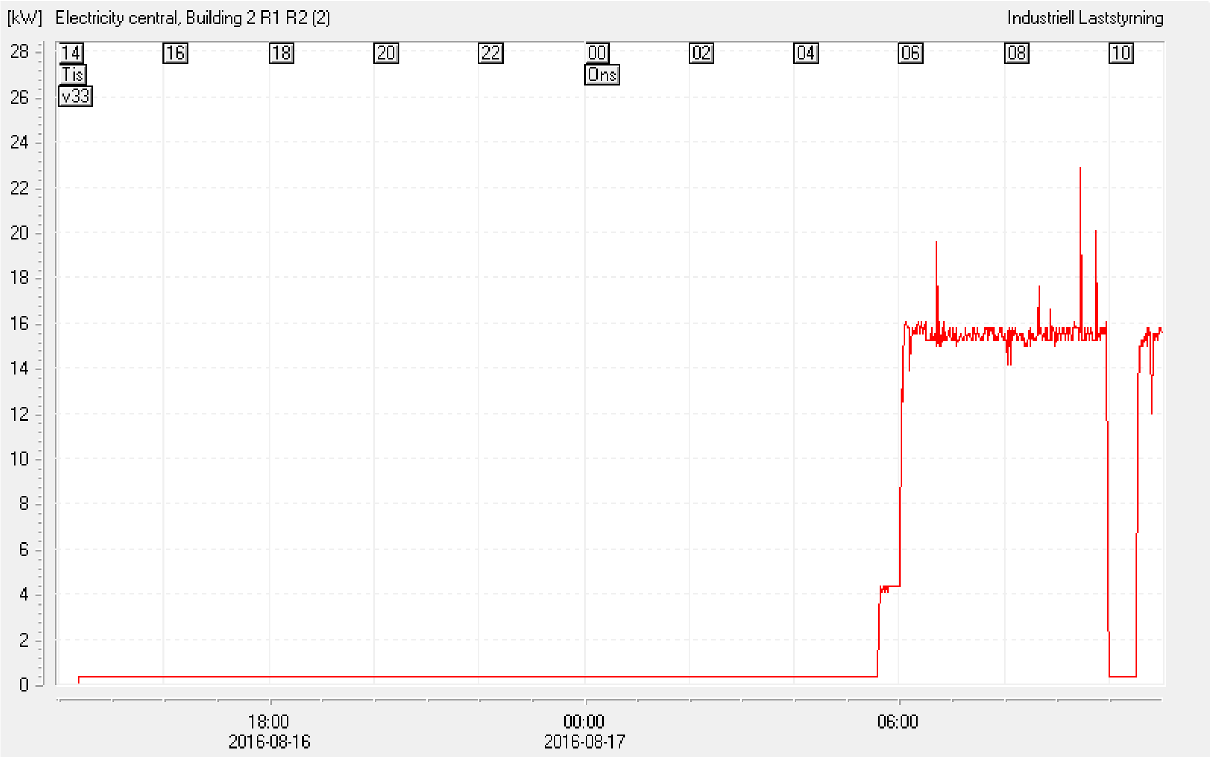
Measurement 11: Compressed air, Kaeser ASD37T.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	13,14	0,00	24,90	2 448



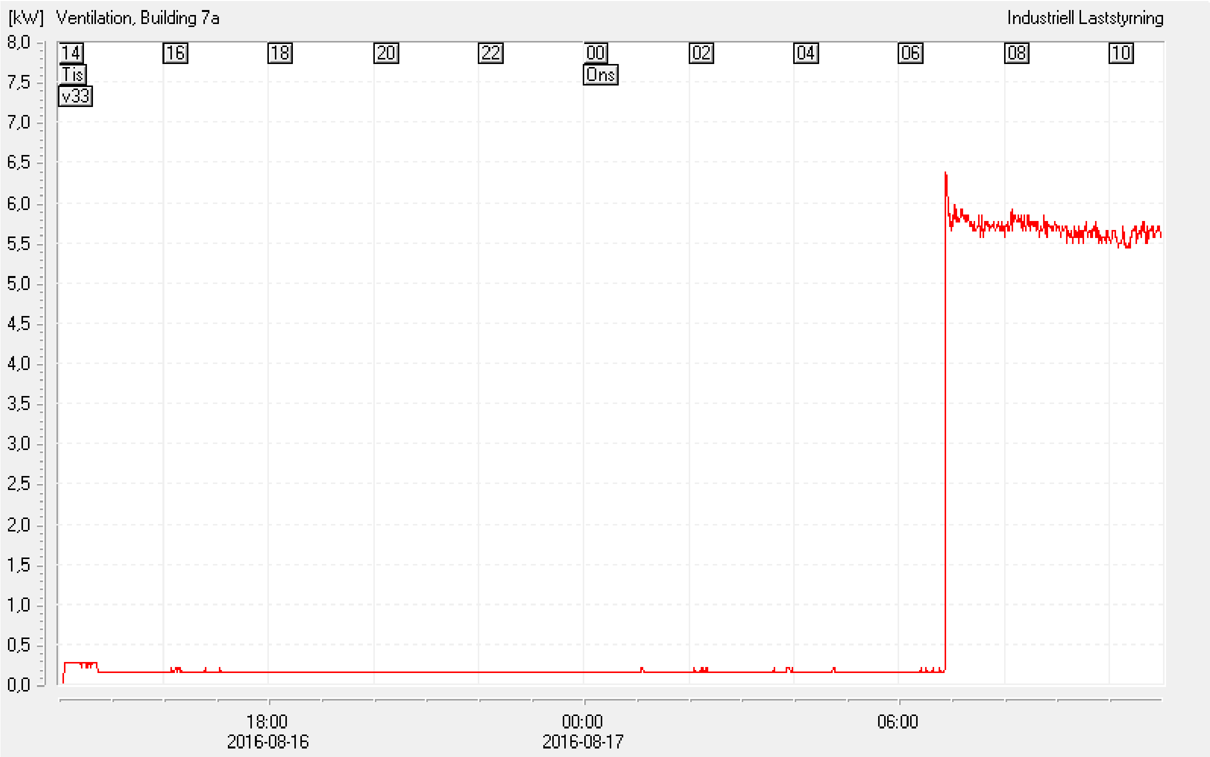
Measurement 12: Compressed air, Kaeser Airtower 19.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	2,72	0,00	13,80	506



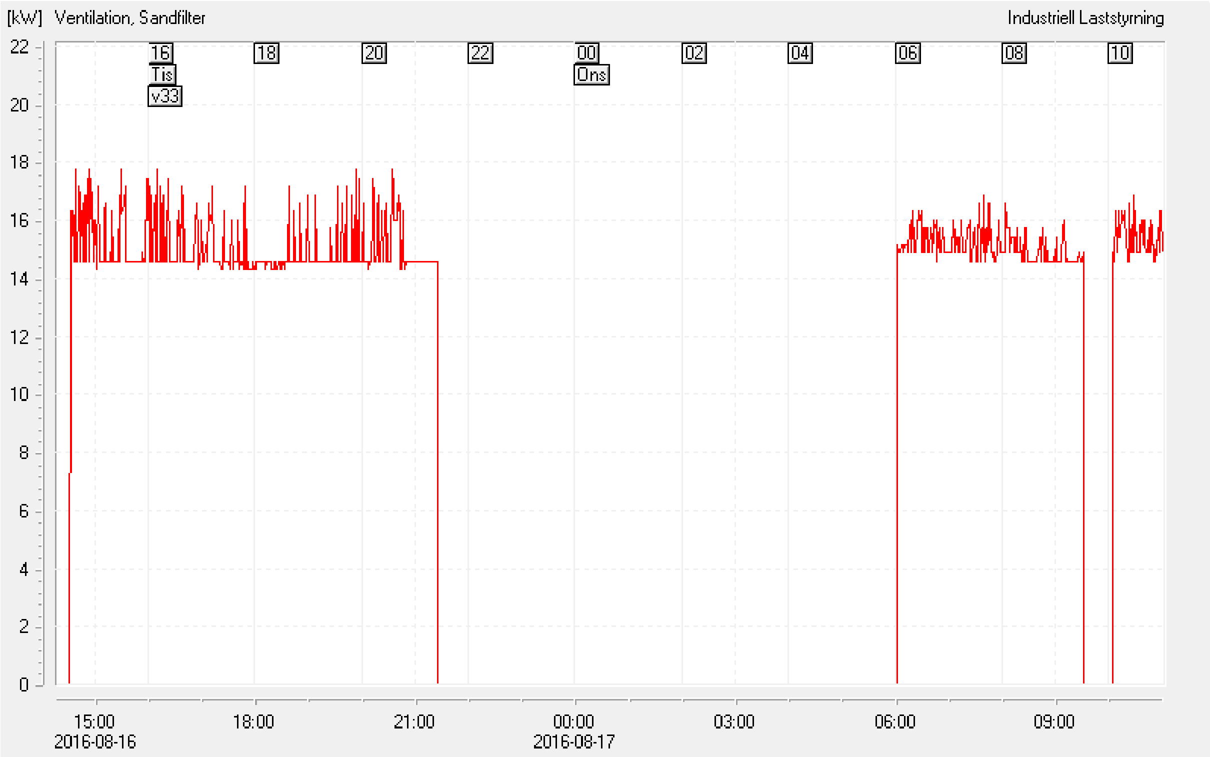
Measurement 13: Electricity central, Building 2 R1 R2 (2).

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	3,50	0,00	22,74	73



Measurement 14: Ventilation, Building 7a.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	1,22	0,00	6,36	25



Measurement 15: Ventilation, Sand filter.

Unit	Name	Ave	Min	Max	Energy (kWh)
[kW]	Power	8,23	0,00	17,68	170

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Interreg
Baltic Sea Region

EUROPEAN REGIONAL DEVELOPMENT FUND
EUROPEAN UNION

EU STRATEGY FOR THE BALTIC SEA REGION
FLAGSHIP

EFFECT4buildings