ACADEMILL
Energy Efficiency

EUROPEAN PROJECT SEMESTER
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PROJECT ACADEMILL

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Abstract

The following is a report for the EPS Project Academill which includes the description of the main objective of the project, requirements, research done, data and information collected through various methods, results and findings and conclusions made. The project was provided by Åbo Akademi University, Vaasa. The main objective of the project was to map the current energy situation of the university and to find a way of monitoring energy consumption as well as to provide some suggestions on how to reduce it.

The first section of the report contains the introduction of EPS, introduction of the group members, project background in detail with mission and vision of the project and scope of the project where the main aim of the project has been described in detail along with the stakeholders, approaches and deliverables.

Additionally, the report also describes the various methods and procedures used to gather data and information related with the project which includes meeting various personnel directly and through email or other means of communication and also a survey conducted within the premises of the university.

The third section of the report consists of the detail explanation on the measuring and monitoring of the energy with description of the current situation, related variables such as electricity, heating and water, and possible solutions and suggestions. This section also contains the detailed study on the various aspects such as light bulbs, computers, toilets and sensors affecting the energy consumption with the current situation and suggestions on energy saving so as to save the energy cost.

The final section of the report includes the conclusion of the project followed by the lessons learned by each group members during the whole project time period and the experiences. Also the report includes the attachments related to the project in the appendix followed by the list of references, figures and tables.

1 Chapter: Introduction

1.1 General Introduction

1.1.1 About EPS

EPS is the abbreviation for European Project Semester and stands for internationality, communication and cross culturally teamwork. The Novia UAS started with the EPS in 2010, 15 years after establishing the Project semester in Denmark. The concept of the program is to create the opportunity of gaining international experience. The background is the belief that engineers of today needs a lot of meta-skills, such as cross cultural communication, social skills, team-skills, etc. The projects are usually performed by a multi-national, multi-disciplinary team of 4 to 6 students. At the beginning of the semester, the available projects are presented. Afterwards the students can give their preferences to the EPS administrator, Roger Nylund. The final group mixes are depending from the preferences, the nationalities and the individual expertise of the students.

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1.2 Introduction to the Project

1.2.1 Project Background

The project "Academill" is an international project of the European Project Semester. It concerns the oldest University in Finland called Åbo Akademi. The University is composed of seven buildings. The project started on the 12th February and lasted for 14 working weeks. The project was completed by a group of 8 students with different nationalities and backgrounds.

The main aim of the project at the beginning was to find out the present situations concerning the electricity and water consumption monitoring in the Åbo Akademi buildings in Vaasa, and also to find a way to reduce the consumption. However, during the project, the objectives changed and the aim remained solely to find ways to reduce the energy consumption in the building. The project was requested by Timo Bäckman, director of administration of the Åbo Akademi. The reason for this project is that Mr. Bäckman does not get any information about consumption other than the bills, monthly for electricity and yearly for water.

Because of the economic crisis all over the world, the Finnish government has to find money and implement cuts in different areas. One of those areas is the education. Åbo Akademi, besides donations from single people or companies, receives a large amount of money from the Finnish government. However, in the recent years the amount of funds incoming has been smaller and will decrease even in the next years. Thus the Akademi has to find cuts in different ways. One of them is the reduction of the money paid for the energy consumption.

Åbo Akademi finds itself in an old building in Vaasa, which was previously a mill; however they do not own them. They rent the buildings from a third party and there are different things included in the rent. One of those things is the district heating, used of course to heat the building in colder months, but also to heat the water used. The Akademi however pays itself the bills for water and electricity consumption and it is the easiest way to find cuts, because renegotiating the rent might be difficult.

1.2.2 Defining the project

The requirements, available resources, project process and possible results for the project were discussed and made into a chart to define the project in proper way. This was done to ensure the proper start of the project with clear idea about what the client exactly wants and what the outcomes will be including the stakeholders of the project.

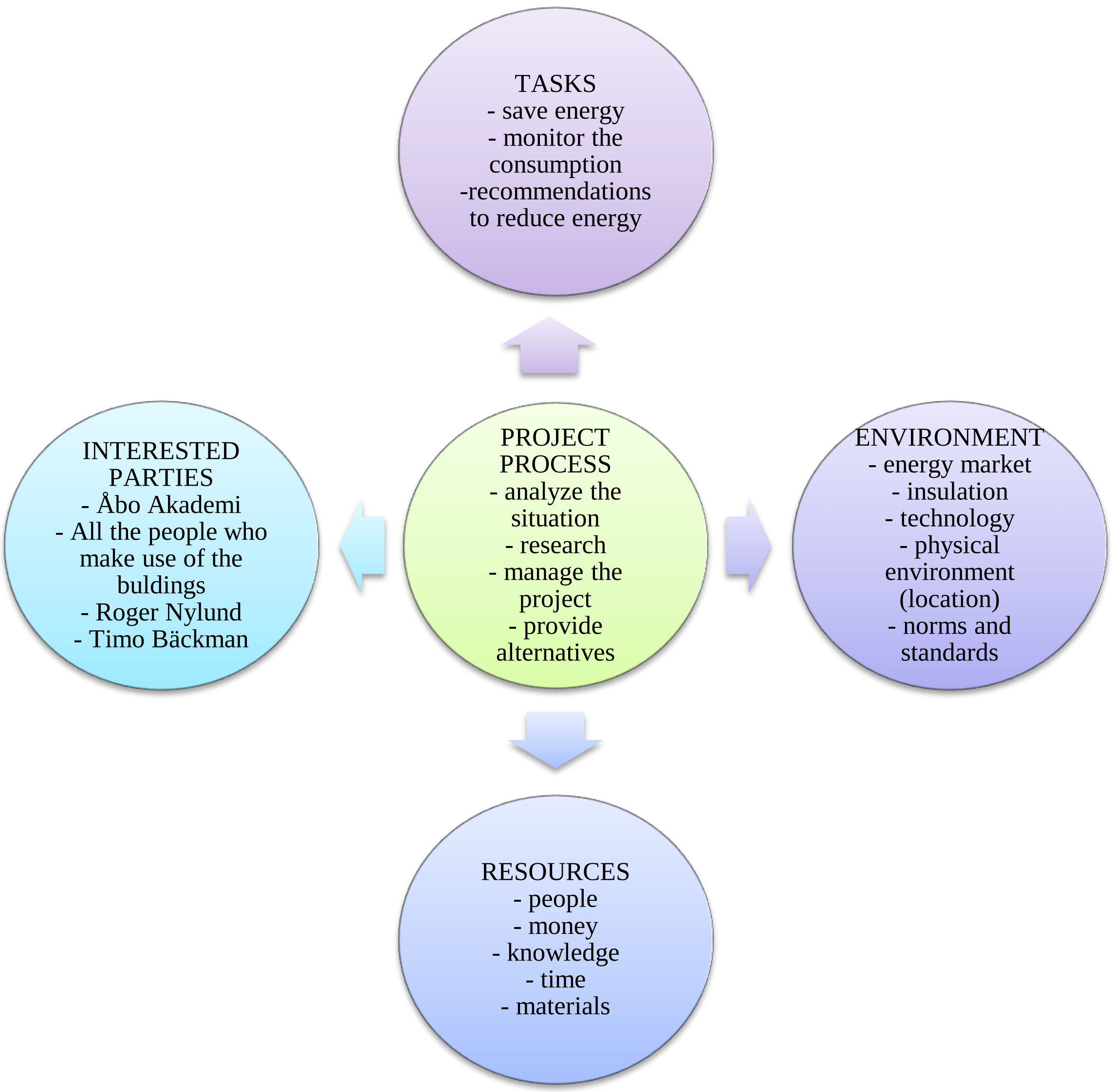

Figure 1 Diagrams showing the key factors involved in the project

1.2.3 Mission and Vision

I. Mission

The main aim of this project is to map the as if energy situation of the university buildings to present the results in graphical way if possible and to find the best solutions regarding energy efficiency to reduce the energy expense.

II. Vision

To move towards energy efficiency.

To reduce the energy cost of the university.

1.3 Scope of the Project

1.3.1 Objectives

To define the objectives better the SMART criteria was used, which is a very useful tool in project management to define specific goals and it helps to achieve it and not go off tracks. SMART is an acronym, where each letter corresponds to a certain concept. S stands for Specific, M for Measurable, A for Achievable, R for Relevant and T for Time-Bound. By using the SMART Criteria, the objectives for the team can be defined as follows.

The primary goal of the team at the beginning of the project was to find a way to deliver information about the electricity and water consumption, the only bills that are paid separately, to the director of Åbo Akademi in Vaasa, while the secondary goal was to suggest ways to lower their consumption with the help of staff and students, in order to reduce spending and save money. The information about the consumption should be continuously passed from the people who have that information to the director of Akademi after the conclusion of the project. This situation changed at some point during the project and the focus was redirected only to finding ways to reduce energy consumption, which became the primary goal of the project.

The tertiary goal, to be considered only if time and resources allow, involves the measurements heating and analyzing if the rent for the building is disproportionate. The solution for the primary goal should be ready and presented at the end of the project, which is on the 17th of May.

1.3.2 Stakeholders

There are many people involved and interested in the project, some of them will be more directly affected than the others. First of all, the main people involved in the project are the team members, who work on finding the solution to the problem and attaining the established goals. Two people who are directly involved and/or interested in the project are Roger Nylund, the EPS coordinator and also team coach, who helps the team in some cases, and Timo Bäckman, the director of administration at the Åbo Akademi in Vaasa, who wants to find ways to reduce expenses and wants to receive information about the consumption and suggestions on how it can be reduced. Other people, who are not aware of the project, but will be influenced by it, are all the people working and studying at Åbo Akademi. If the team finds a good way to reduce consumption and thus expenses, less or no staff will be laid off, based on the success of the project, students will not suffer the reduction of certain services, mainly educational. Also as stakeholders we have to consider the Caverion Company, especially Markku Enberg, who works at the Akademi, which is responsible for maintenance of ventilation and monitoring systems and monitoring itself. Also Roland Nylund, the head caretaker at Åbo, is one of the people interested in the project and its success.

1.3.3 Approach

To ensure that the project is conducted correctly and is proceeding towards success, the team used different tools and techniques, which are often used during projects, such as this one. First of all a set of rules were established, that should be respected by all team members, so the work proceeds correctly. They are a simple guideline, but very often it helps to keep the project in check. The team also established a plan for the course of the project, to help to know progress during the course of the project, if the work done is behind or ahead of schedule. To help prepare the schedule a list of tasks was prepared and a Work Breakdown Structure was developed, which in many cases is a very useful tool.

The team used a responsibility matrix to indicate responsible people and support for each task. A responsible person in case of each task was defined, but considering that the work is usually done together as a team on most tasks it was considered unnecessary to produce such a matrix. To prevent the different problems that could happen during the project, risk management tools are used, listing the causes, consequences and solution for each of them.

To structure the time allowed to the project by each member, cost management tools are used, giving a theoretical value to the work. The meetings are considered essential for the success of the team and the project itself. The team decided to meet with the team coach once a week to update him about the progress, but also seek guidance, advice and ask questions. The members themselves, however, usually meet more often, depending if the work or a task, should be done individually or by a larger group.

The official start of the European Project Semester was on February 1^{st}. However, the division of teams and the work on the project actually started on February 10^{th}. The final deadline of the project, when the final presentations will be held, is on May 17^{th}, however there are other dates and deadlines we have to consider. First of all, the mid-term presentation will be held on March 30^{th}. During that day, the team will present all of the work done until that date, how they worked, and what are preliminary solutions to the defined problem. Two days before the presentation, the team will have to hand in a report, which you are reading in this moment. According to our schedule, the work on the solutions themselves should be completed until the end of April, when we will concentrate on completing the final report, which should be delivered two days before the final presentation (May 15th), the website and prepare for the final presentation.

1.3.4 Deliverables

As stated before, the team has to produce at the end of the project a written report and a website. The report has to include several things. First of all, a general presentation of European Project Semester, of the team and team members and of the project itself is reported. The main goals, the process to achieve those goals and one or more solutions, if necessary to the presented problem, along with its analysis, technical and theoretical are described. The report will also include conclusions and personal opinions about the course of the project and its success, in terms of the European Project Semester. The website will contain similar information, but organized in a better and more "user-friendly" way, so that the reader of the website can access information about EPS, the project and the report. The final presentation serves as a "defense" of the report. Students will have to present their findings and answer to questions from the panel, consisting of stakeholders, verifying their knowledge and preparation.

To summarize the goals that were established and the team will work to achieve: find some ways, in form of suggestions with technical and financial analysis, to lower the consumption in order to reduce the costs. Those may include practical solutions, such as modifying current installations, but also including the participation of staff and students. As mentioned, reducing energy and water consumption are primary goals, which have to be included. However, heating can also be looked into, if time allows it. It has to be remembered, though, that not the whole building is in use by the Åbo Akademi. They use buildings from A to F, but only one floor from the G building. Also the studio is not used by the Akademi, so we have to remember that those are parts of the building which should be excluded from consideration. Another part that will not be taken into consideration is the environmental impact, either positive or negative, of any of the suggested changes or present situation. At the later stage of the project, the part about finding ways to monitor the energy consumption and pass the information to the responsible people at Åbo Akademi was abandoned, due to the changes described later in the report.

1.4 General description of the building

The first visit of the Åbo Akademi in Vaasa occurred on the 23rd of February and the others followed in the whole duration of the project. The main aim of those visits was to collect information about the Akademi and to get accustomed with it. The following figure presents the overall make-up of the building.

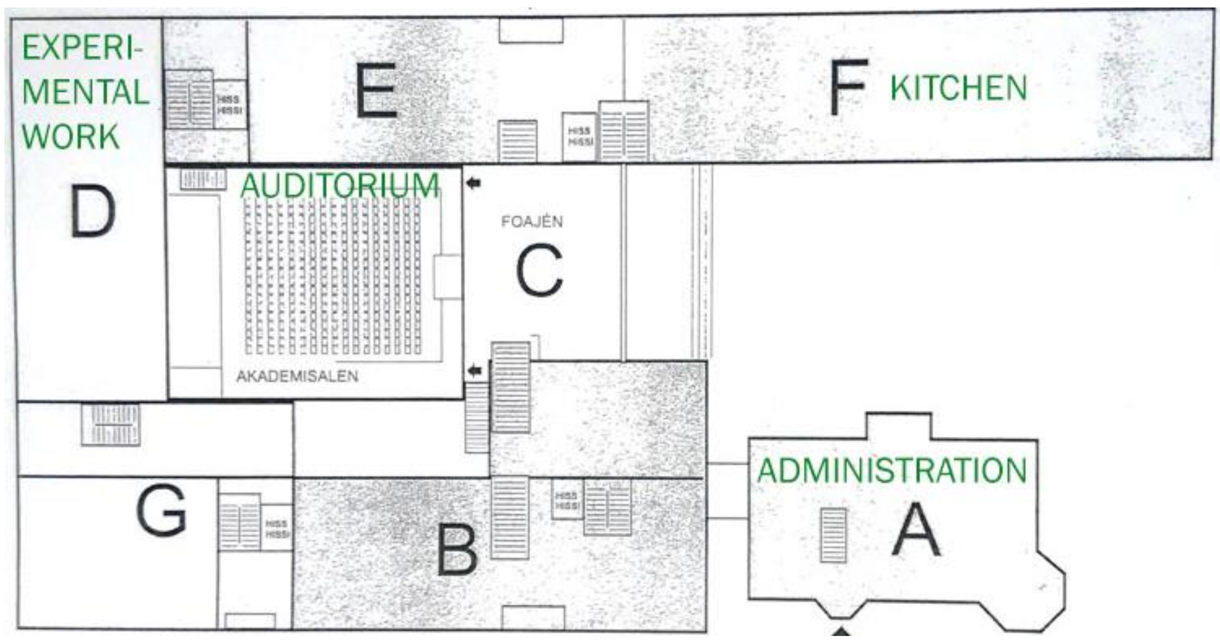

Figure 2 University buildings block plan

There are seven buildings that make up Åbo Akademi, which are situated at Rantakatu 2 in Vaasa, Finland and they are called by the alphanumerical letters from A to G. The A-building is reserved to administration and it is the oldest building of all. The B, C, D and E are used for the lectures/classes and in the D-building there are mainly laboratories or rooms where students can execute manufacturing work, such as woodworking or metalworking. The kitchen is in the F-building and it is the single biggest energy consumer. Mainly in buildings B and F there are offices of the staff, so in those buildings many of the rooms are small ones. In the G building Åbo Akademi uses only the 4th floor, where there are computer classes. The rest of the 11 floors are rented out and not in use by Åbo Akademi. The 5th floor is still used by Åbo Akademi, however it has to be excluded from the consideration since the rent will end in May and from that point will not be a part of Akademi. The biggest room, the auditorium Akademisalen is a part of the C building.

The classes and lecture rooms are equipped with electronic equipment, such as a projector, speakers, a computer and in some cases also a TV. They are also equipped with ventilation sensors, turning on the ventilation, only when the motion is detected. The main heat exchangers, electricity meters and ventilation system are in the ground floor separately. There are 3 separate ventilation systems, one in the E-F building, another one in the B building, and the last in the A building. They provide the air circulation for all the buildings.

1.4.1 Electricity

The meters showing the electricity consumption for Åbo Akademi can be found in the G building. There is one main meter, which shows the total consumption, for all the buildings of Åbo Akademi, including the ones not used by the university. There are also other meters. One for each floor of the G building, since each floor is rented to a different entity or company and it is to enable to calculate the electricity bill separately and easily. There is also a meter for the kitchen, a large consumer of electricity, and another one for the studio, in the basement of the C building. The studio is rented to someone else therefore it will be not included in the project. Once a month the meters are read and the bills are calculated for each entity that rents a part of the building. There is also a monitoring system that enables a look into the electricity consumption. However it reads off the information from the smaller meters but it does not have access to the main meter.

1.4.2 Water

Water is not included in the rent and it is paid separately. The water is billed monthly based on earlier average and at the end of the year, based on the measured consumption, Åbo either receives a return or has to pay the excess of water not predicted by the consumption. The hot water for tap uses is heated by the district heater circuit. The consumption of water is monitored by the same system that is used for the electricity monitoring, and it is easily accessible and readable by the people responsible at the Akademi.

1.4.3 Heating

As written in the aforementioned information, the heating is included in the rent. Therefore, it is not a priority for the project. However, focusing in the monitoring of the heating could bring some interesting information to the director of Åbo Akademi, who commissioned the project. In fact, if some improvement is made in the future, it could be interesting to know in order to get a proper indication of saving of energy. From another angle, it’s also interesting to detect any problem of leak of heat, in the case of a peak of consumption is taking shape.

The system of heating consists in exchanging the heat of a first circuit, which contains hot district water, to a second circuit, which contains water distributed through the whole building. During the visit to Åbo Akademi, the temperature of incoming water was 80°C, and of the outgoing was 40°C.

The ventilation is obviously affecting the heating. During the most important part of the year, the air rejected is warmer than the air aspirated. However, to reduce the losses, there are heat exchangers transferring the heat from the air going outside to the clean air going inside.

The Consumption Benchmark report for the year 2015 has been made available by the real-estate director at HS-Foundation, Jan-Erik Hinds. The total data are available for all the buildings of Åbo Akademi, without distinction of the G-building. The information provided is presented in the graph below.

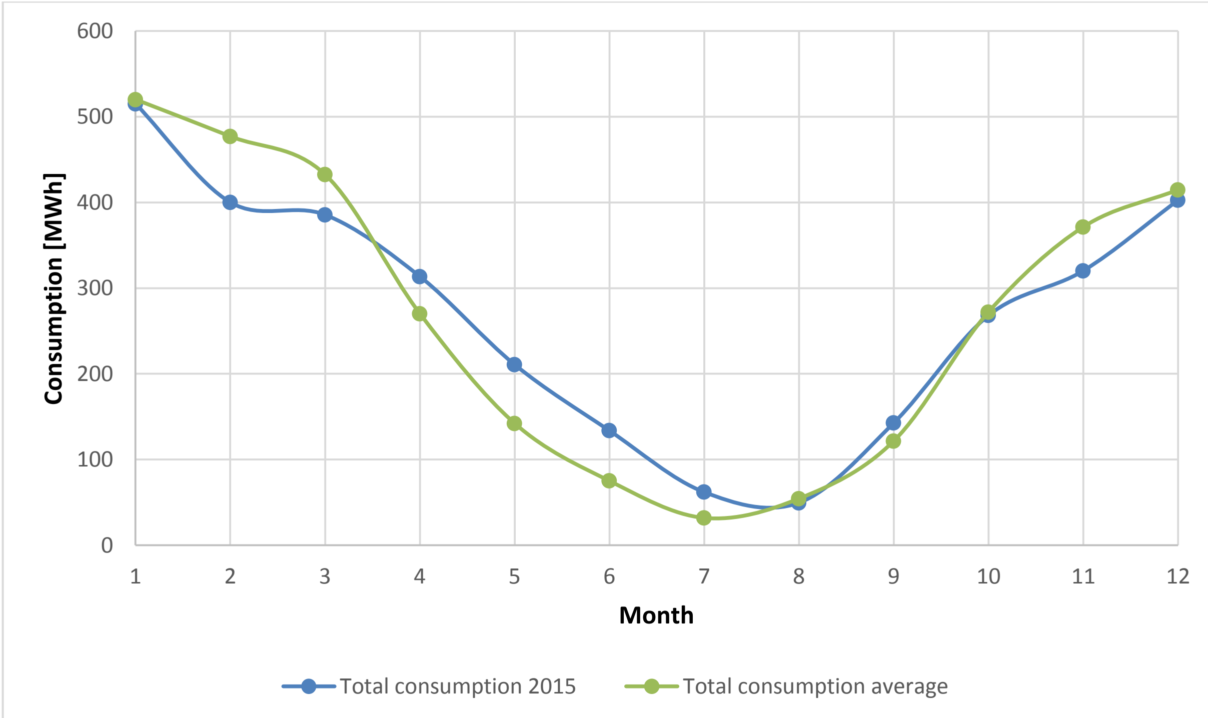

Figure 3 Heating consumption

2 Chapter: Methods

2.1 Work procedure

First of all, the collection of data had to be followed by a regular milestones planning way. Discussion between members of the team before the meeting, concerning the lack of information, or the guidelines which had to be looked deeper, lead to an agenda which was presented to the whole team. Therefore, the subject was brainstormed, and a list of question and task was raised, and responsible people for each task were chosen and alerted, knowing that they had to be sure of what they had to do, asking for clarifications if necessary. Writing the agenda was a task everybody was responsible for, at least once during the project. Usually the project manager or project secretary opened and closed the meeting. Moreover, minutes about the meeting were written, in order to summarize and to underline the main research points of the meeting. The minutes were mostly done by the secretary, although during the project it was usual that this task got done by other persons.

During the meetings with people in charge or the visits, everyone tried to get the information, asking the question raised by the given information; although one person was in charge to ask question defined before the interview. Several ways of recording the main pieces of information were used:

- Paper notes of the main facts, written by one or two previously chosen people,
- Audio or video recording,
- Photo samples of the installations.

The answers given lead to another meeting, which had to clarify and to classify the indications, underlining what was important. Those results lead to other questions. All meeting minutes were uploaded on Dropbox. E-mail correspondence was also a way to get the information, giving more time to each side of communication to bring all their ideas.

The main portal to communicate for the project members and project manager was WhatsApp. The group had an own chat which was exclusive for the project, so problems and solutions could be discussed between all group members. Collected data was distributed via Dropbox. The medium was open for all team members, the Project manager and further the Project coach. Because of his supporting but not working function he was not part of the WhatsApp group. In order to stay in touch with the Project coach, e-mails were used. This medium prevented the coach of getting for him useless information but all important problems and dates of meetings were sent to him via e-mail.

The meetings with the Project coach were tried to be held in the beginning or middle of the week. Consequently everybody could prepare over the weekend and there was enough time after the meeting to work through all discussed points till the next meeting. Furthermore having the meeting not on a Friday prevented everybody from forgetting all discussed points because of spare time activities. Also the group generally met at least twice a week although the coach would just join one meeting a week. The second meeting was to prepare and discuss further steps, update everybody with done work or upcoming problems and thinking about the next meeting. Moreover after a meeting with one of the stakeholders or technical supporters of the project, the project group had another meeting. In this meeting the just heard information was discussed and further steps initiated.

2.2 Project site visit

The first visit of the Åbo Akademi in Vaasa occurred on the 23rd of February. The aim of the first visit was to have a concrete vision of the building, trails leading to the research guidelines, and to more questions. It was the occasion to meet with the people responsible of the monitoring tools, and also with the person in charge of the administration, for future requests and authorizations.

It consisted in an explanation about the buildings which were concerned by the monitoring tasks, which have to be distinguished from the rented parts. It provided a vision about the monitoring system in the "as if" situation, although not detailed. It gave the information about the how and the where to go if some question had to be asked, depending of the request's type; therefore the line of work, human behaviors and language abilities of the concerned people. In this first step, some clues were given, that helped to redefine eventually the first mission and vision meant. All the collected data of the first meeting and visit are in the parts "study of needs", "Monitoring the energy consumption".

Some sheets about energy consumption, or maps of the building, were given during the first visit, giving an overview of the kind of information detained. And it was an important support for the following meetings.

2.3 Collection of data

The data had to be collected in the most efficient way, to be well classified and exposed through the members of the team. That is why methods and procedure of collecting the information had to be put in place. Considering the size of the project team, it has been decided to get another type of information, through a survey of students and staff. It is in some ways divergent from the client needs, but following thematically the main objectives established in the mission and vision.

2.3.1 Gather specific/ technical information

To acquire the scope of saving energy, specific information about the building and the applied techniques was needed. Therefore visiting the Åbo Akademi was a big practical and important part of the project. At these visits, the group met one of the locally responsible persons. Furthermore the group contacted companies and experts to get information about techniques and prices. To get information about the energy consumption of light and computers as well as the water use of toilettes, the data was collected through counting. This might have been the harder and time intensive work but it ensured the accuracy of calculations. Moreover the responsible persons did not have all data which could sophisticate the results of energy savings.

During the project the group made use of tests and experiments to gather information about technologies and energy consumption just like the light bulbs for example. These specific methods will be described in the appropriate parts.

2.3.1.1 Computer power experiment

To have a better idea about the actual energy consumption of the computer, measurements in the Åbo Akademi have been made on a single computer. 4 different measurements have been made to obtain approximate values of electricity consumptions, which were used as assumptions in further calculations. A computer in the office of the Åbo Akademi caretaker was taken as an example, which is an HP Elite desk 800 G1 with Samsung 225BW Syncmaster display and speakers. The measurements were made with a wattmeter placed in a socket. The power was measured for the computer in the idle mode, with some simple programs on, such as Microsoft Word, Excel and Mozilla Firefox. The results of the experiment are presented in the chapter “3.1.1 Present situation”.

2.3.1.2 Collecting information about light bulbs

The team has conducted an analysis of number of light bulbs in Åbo Akademi. The analysis was done not in every room in the building, but in most of them, especially the most crucial areas, such as classrooms and lecture rooms, corridors, common areas, but also many offices. The team chose this method because the information is more precise then estimating all bulbs by analyzing a hand full rooms. On the other hand, counting every light bulb in every area of the university would be too much to afford in comparison to the outcome. The table presenting the results of collecting information about light bulbs is presented in the following table.

Table 1 Number and power of light bulbs in Åbo Akademi

	1st floor		**2nd floor**		**3rd floor**		**4th floor**		**5th floor**		**6th floor**		**7th floor**	
	No.	Power	No.	Power	No.	Power	No.	Power	No.	Power	No.	Power	No.	Power
Fluorescent	176	7678	360	13562	170	6866	385	13866	255	7831	331	11925	246	8592
CFL	146	3358	409	6884	192	6144	417	7636	243	4442	260	4731	185	3330
Halogen	0	0	1	50	467	9999	0	0	0	0	9	326	16	605
LED	0	0	0	0	0	0	0	0	2	18	6	66	1	11

The results of the light bulb analysis can be obtained from the chapter “3.2.1 Present situation”

2.3.1.3 Light intensity experiment

One of the options considered was to remove some of the light bulbs, because of the design and the frequent placement of lights. For this reason the team has conducted an experiment with a photometer to ensure whether such an option was possible or not. There are no norms or regulations concerning the levels of light in buildings such as a university, however the International Energy Agency (light agency) the recommended levels of illumination in corridors should be 50 lux. [6]

The team has chosen a short corridor on the 3rd floor of Åbo Akademi with 4 lamps with 18W CFL light bulbs and no windows to conduct the measurements. 3 measurements have been made, in each one the light output was measured near the door at the end of the corridor, under the lamp and between the lamps. The first one was conducted at a height of 1.5m with all the lights turned on. During the second one, one of the light bulbs (the one in the middle) was removed and the measurements were conducted at the same height. The third time the light output was measured at the floor level with all the lights on. The results of the experiment are presented in chapter “3.2.1 Present situation”.

2.3.1.4 Collecting information about toilets and urinals

The information about the amount of toilets and urinals was obtained from the CAD drawings. Based on the clear quality of the building plans, the amount of toilets could be studied. This method was easier than visiting the building and saved a lot of working hours, however it is still very precise.

2.3.2 Survey

To increase the involvement of students, teachers and staff at the Akademi in the project, a survey was conducted within the academy premises. This was done also to gather the information from the students and staff and their opinion on the subject. The survey was done with randomly selected people in the academy. A list of questions was prepared by discussing with the group members for the survey and a questionnaire was prepared so that the answers could be written in the same paper along with the questions. The survey was done with either individual person or group of people. The interviewees were teachers, students and administration personal. In the end 25 people were interviewed, whereas the amount of students was predominant. All the people who were asked responded with their answers. The questionnaire with the survey answers is provided at the end of the report as an attachment.

2.3.3 Results from survey

Since the questions were very general, the answers were also very general with Yes or No. The answers from the survey shows that everyone is aware about the importance of energy saving. However, they are not very committed with energy saving especially when it is at school. But most of them try to remember to turn off the lights when leaving the rooms and toilets as much as possible. The following figure 2 shows the percentage of people who try to save energy. Almost 10 percentages say no, however this percentage are students of Åbo Akademi.

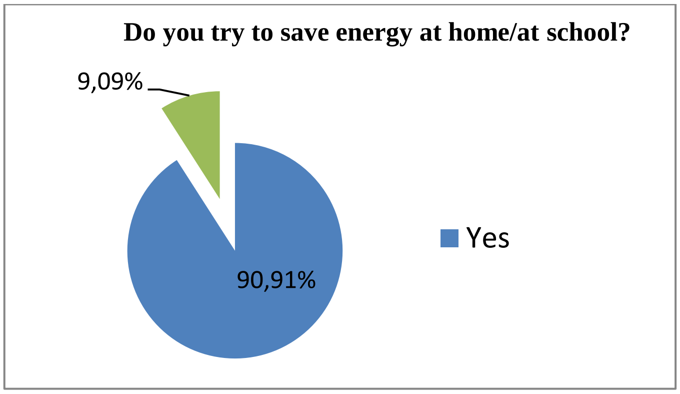

Figure 2 Chart showing the percentage of people who try to save energy

Most of the people who responded to the survey answered that the heating and air inside the rooms are comfortable but often colder, except for some rooms in D building. The air in D building has bad smell and some students have complained about sicknesses like runny nose and irritated eyes. The air inside gym area seems to be comfortable but very few people use gym. Most people prefer more natural light for studying but they are also satisfied with the present lightings.

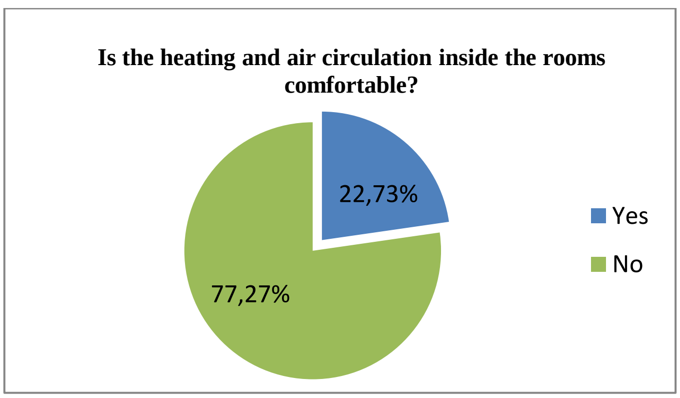

Figure 3 Chart showing the percentage of people who felt comfortable with heating and air

The school computers are mostly used about 2-3 hours per week mainly for printing. The time spent in the school by the students is about 3-6 hours per day in average depending on the class schedule. Among the people who responded the survey, few of them thought that the sensor for the lights were not necessary because it does not take much effort to just turn on and off the lights by themselves. On the other hand, some suggested that it is a good plan to have automation installed for the lights because it is hygienic when they do not have to touch the switches and also saves energy.

All the respondents from the survey were very positive towards the awareness rising programs for energy saving. The notes to turn off the lights and to close the doors provided in classrooms are good reminder for everyone to take at least one step further towards energy saving. The respondents from the survey suggested making more effort in educating people to be responsible towards the subject matter and bring some innovative ideas to encourage people to save more energy at home and at school.

3 Solutions

3.1 Computers and associated equipment

In Åbo Akademi, and generally in a normal university in 2015, there are computers in each classroom for the lecturer's use and several computer rooms at student's disposal. The employees usually have also as a main work tool a desktop computer. This part of the project has for purpose to approximate and to underline the electricity consumption of the computers and linked devices and to propose several ways to reduce it.

3.1.1 Present situation

3.1.1.1 Computer rooms

In the Akademi, there are several computer rooms available for the students. Most of the computers are in the fourth floor of the G-building. The first step is to look how many computers there are and then to approximate their consumption by looking at the model and the utilization of the PC. Furthermore, the computers have to be an indispensable help to the students that is why the programs put at the disposal for the education have to be taken into consideration.

Number of computers for each computer room[7]:

- 18 computers in room G301,
- 19 computers in room G402,
- 9 computers in room G403,
- 7 computers in room G404,
- 19 computers in room G405.

For each room, the brand of the PC and of the display has to be studied.

Table 2 Brands of computers and displays

Computers room	Brand of computers	Brand of displays
G301	Compaq 8100 Elite CMT PC with Windows 7 OS	Samsung Syncmaster 2243
G402	HP Compaq 8200 Elite MT with windows 7 OS	Samsung Syncmaster 2243
G403	Dell Optiplex 9020 computers with Windows 7 OS	Samsung Syncmaster BX 2440
G404	HP EliteDesk 800 TWR	Samsung Syncmaster 2243bw
G405	HP EliteDesk 800 TWR Gold Chassis	HP EliteDisplay E221c 21.5 inch WebCam LED backlit

To have an idea about the consumption of the models, the technical information about each brand of computer and displays studied. The essential information is presented in the table below. More details are available in the appendix. [8, 9, 10, 11, 12, 13, 14, 15]

Table 3 Number of computers and power consumption by computer room

Room	Number of computer	Power/computer [W]	Power/display [W]	Total power [W]
G301	18	47	45	1656
G402	19	35	45	1520
G403	9	50	25	675
G404	7	18	45	441
G405	19	18	27	855

3.1.1.2 Classrooms /Videoconference rooms / Staff offices

To evaluate the energy consumption of the computers, it is necessary to consider all the computers in the classrooms and also the associated devices and displays.

- 55 Computers in lecture rooms,
- 280 Staff computers in Åbo Akademi, which includes laptops and stationary computers.

To have a better idea about the actual energy consumption of the computer, measurements in the Akademi have been made on a single computer. The experiment is described in chapter "2.3.1.1 Computer power experiment". The results of the measurements were 22.5W for the computer in the idle mode and 2W in sleep mode. For the display the result was 38W and 2W for the speakers. Those results were considered as a base for all office computers in further calculations.

Table 4 Number of computer and their power consumption for offices and classrooms

Room	Number of computer	Power/computer [W]	Power/display [W]
Lecture rooms	55	~22.5	~38
Offices	280	~22.5	~38

According to the person in charge of the computer's department in Novia UAS, the new computers are equipped by new Intel technologies, having shut-wattage system in idle mode that is why some old computers consume much more than new ones.

3.1.2 Technical description

3.1.2.1 General information

To underline the consumption of the computers in the Akademi, some comparative studies were made. It is important to consider all the assumptions made to estimate the energy consumption. In the following table information about working time for a single PC, an attached display and a projector in a classroom or lecture room is presented.

Table 5 Working time assumption

	PC	Display
Hours a day	24	8
Days a week	7	5
Months a year	10	10

All calculations for computer power consumption were made for idle state; it is the state in which operating system is loaded and the default programs (those defined at startup) are running. With an exception for classrooms and offices desktops, power consumption being in active mode when basic programs are running: Microsoft Excel, Mozilla Firefox and Mozilla Thunderbird. Another exception for the computer room G403, in fact the room uses special heavy programs, therefore the power considered for calculation is the maximum power. The assumptions made for the calculations regarding power and total working hours with assumed energy consumption are presented in the following table.

Table 6 Estimation of the total energy consumption of desktops and displays in the Akademi

Computer rooms		Power[W]		Hours ON/year		
Room	**Number of computer**	**Comp.**	**Displays**	**Comp.**	**Displays**	**Energy cons. [MWh]**
G301	18	47	45	7320	1743	8
G402	19	35	45	7320	1743	6
G403	9	50	25	7320	1743	4
G404	7	18	45	7320	1743	1
G405	19	18	27	7320	1743	3
Classrooms						
55 rooms	55	22,5	38	7320	1743	13
Offices						
280 people	280	22,5	38	7320	1743	65
TOTAL						**100**

As seen in the table, the total assumed electricity consumption for all the computers with associated displays is 100MWh/year. Compared with the total consumption in Åbo Akademi for the year 2015 being 1906.379 MWh, it gives approximately 5.2%. Considering the tariff of the electricity of 2016 of €40.36/MWh, the electricity consumption of the computers and displays represents a total of €4036 each year.

3.1.2.2 Programs to turn the computers in standby mode

The standby mode or sleep mode is the state of the computer when the machine cuts the power to all the unneeded subsystems. The data necessary to respond quickly to a wake-up event involve a certain amount of power to feed the RAM memory. However, this amount of power can be neglected compared to the power consumption in active and idle mode.

The way of launching a wake-up event is usually a request via the power button. However, settings can allow the PC to respond to other wake cues, such as from keyboard or mouse. Therefore, the programmer of the standby mode settings should look thoughtfully, because in a university the power button is not the most comfortable way to launch a wake-up event.

According to the person in charge of the computer materials in Novia UAS, the desktops have to be looked at thoughtfully, especially the AC/DC power supply. In fact this piece of electronics, which is the electrical adapter, is still consuming in off and sleep mode. Fortunately, in the last models of computers, the power consumption of this part has been lowered to 1W but it could have been up to 15W for old models. Therefore, in the case of old computers, the easiest way to save energy is to replace them to new ones. The case of AC/DC converters concerns also the displays.

Working on computer consumption to save energy is and has been, in many places and particularly in Novia UAS, an important subject of work. The person in charge of the computer department provided the team with some information about this matter of consumption. For Windows PCs integrated with Microsoft Active, there are easy ways to ask the computer to switch on sleep mode: the task schedule menu or the power options in the "set preferences" system. A period of inactivity has to be taken into consideration and programmed; a certain amount of time has to pass after the last activity of the user for the task to start, because shutting down during an activity has to be avoided. In Novia, the network login system is switched from Novell to Microsoft Active. The advantage of the latter is that by applying settings to set of computers (ex: organizational unit), it is possible to use the task scheduler menu to program a short time before the computer switches to sleep mode whenever it is logged-off.

To summarize, the task scheduler menu is used for one setting when the PC is logged-off and the power options in the "set preferences" system is used for another setting when someone has logged on the PC.

The only difficulty encountered by the staff in Novia is that when a program has been closed, log-off events are submitted by the machine. The task of setting the PCs for switching to sleep mode has to consider the correct ID number of the events.

3.1.3 Cost analysis

3.1.3.1 Savings by turning in sleep mode

The sleep mode is covered by strict regulations in many countries, such as the One Watt Initiative from 2010 in the USA. In the European Union, Regulation No. 1275/2008 forbids the RAM in sleep mode to overcome 1W. However, the experiment made in the Akademi to measure the electricity consumption in office desktop's sleep mode showed sometimes power consumption up to 2W, which may be due to some other elements of the desktop computer.[19, 20]

The assumption for the present situation is that computers are ON 24h a day, 7 days a week, 10 month a year. If a program is used to put the computers in sleep mode they would be ON 8h a day, 5 days a week, 10 month a year, like the displays, and in the remaining time, it is presumed that they are in standby mode, with a lowered consumption.

Table 7 Approximation of the energy consumption for one year with sleep mode 16h/day

Computer rooms	Power[W]			Hours ON/year		Hours Sleep /year	
Room	**Number of Comp.**	**Comp.**	**Displays**	**Comp.**	**Displays**	**Comp**	**Energy cons. [MWh]**
G301	18	47	45	1743	1743	5577	3
G402	19	35	45	1743	1743	5577	3
G403	9	50	25	1743	1743	5577	1
G404	7	18	45	1743	1743	5577	1
G405	19	18	27	1743	1743	5577	2
Classrooms							
55 rooms	55	22,5	38	1743	1743	5577	6
Offices							
280 people	280	22,5	38	1743	1743	5577	33
TOTAL	407	213	263	12201	12201	39039	49

According to the previous assumptions, and considering sleep mode power consumption up to 2W for all the computers, half of the total computer consumption (being approximately 50

MWh) can been reduced. With the tariff of €40.36/MWh, the saving represents the amount €1977.64 each year.

3.1.3.2 Savings by reducing the number of desktops

According to the data provided by the public area in the website of the Åbo Akademi, the list of programs in most of the computers could be considered as necessary but usually students can obtain them for free and use them on their personal laptops. With the exception of the computer room G403, where the computers contain different special programs that cannot be acquired by the students due to a high price.

A basic solution then could be to rely on student's own laptops. In fact, as seen later, they are more efficient, and using batteries they do not take their energy necessarily from the Akademi. Furthermore, being the property of the student, the laptop would be turned more often in off mode or in sleep mode, again for better energy efficiency. Another reason is that the computer maintenance would be student's responsibility, reducing the involvement from the staff.

Considering the assumptions for the present situation, savings approximation can be found. In the first approach, around 50% of the desktops in computer rooms are removed. The results presenting potential energy saving are presented in the following table.

Table 8 Savings removing half of the computers in computer rooms

Removed comp.		Power/ unit [W]		Hours saved/year		
Room	**Number Comp.**	**Comp.**	**Displays**	**Comp.**	**Displays**	**Energy cons. [MWh]**
G301	9	47	45	7320	1743	4
G402	10	35	45	7320	1743	3
G403	0	50	25	7320	1743	0
G404	4	18	45	7320	1743	1
G405	10	18	27	7320	1743	2
Total saved						**10**

The calculations show energy savings of approximately 10 MWh, and with the cost of €40.36/MWh, the amount of money saved could be up to €403.6 each year.

There is also a possibility of removing a different amount of computers. The following graphic shows the potential savings as a function of the percentage of removed computers. The computers in G403 containing special programs are not removed.

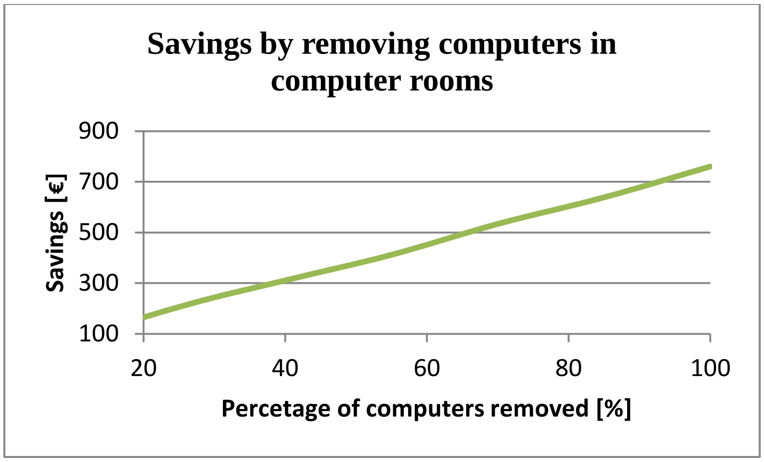

Figure 4 Savings by removing computers in computer rooms

The interval of savings correspond to 200€ each year when the computer room capacities are 20% diminished, to 800€ each year when the computer rooms are totally removed.

The working environment and linked ergonomics being more important than the desktops themselves, a possible solution is to replace all the computers by offices where the students could put their own laptops, and to let available around 20% of the actual computer rooms in order to those who really need a desktop computer, because they do not have an enough powerful laptop, for example, to use certain software.

These calculations do not consider the removal of classroom/offices computers, which represent the biggest part of the electricity consumption. Therefore, if it is possible to rely on professional laptops of the staff in the Akademi, then it is possible to consider removing all the classrooms and staff office desktops. Then, an analog graphic can be provided, considering all computer rooms, staff's offices and classrooms:

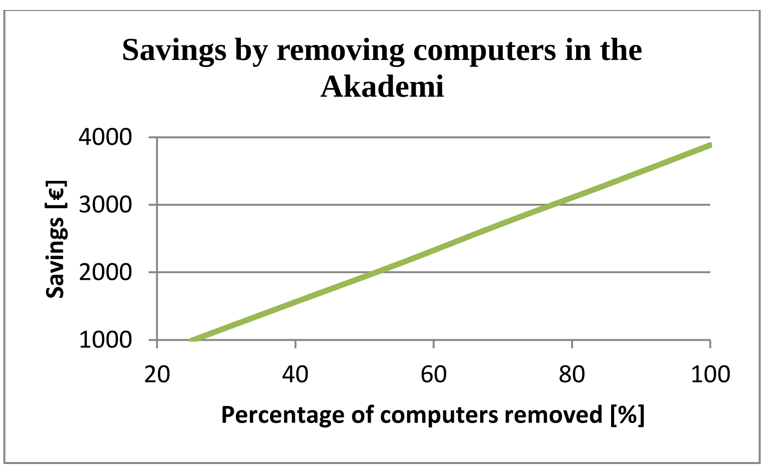

Figure 5 Savings by removing computers in Åbo Akademi

For 20% of the total number of desktops removed, approximately €1000/year could be saved. If all the desktops are removed, around €4000/year are saved. These desktop savings do not include the savings represented by less computer maintenance and neither the expenses of the electricity consumption that could be used by students/staff's laptops.

If the computers used by the students are removed, there is no problem in asking the students to bring and use their own laptops. The problem arises when the computers used by the staff are removed. The staff probably would not agree to use their own personal laptops for work, because that shifts the cost of acquiring and maintaining the device from the university to the staff. In this case the acquisition of laptops would have to be considered, along the removal of the computers. However, if in the future the computers have to be replaced, the option of acquiring laptops instead of desktop computers. The price for a single device is similar, but the consumption is much lower.

3.1.3.3 Savings with alternative devices/systems

The solution is the usage of different programs to put the computers in sleep mode, or the providing of laptops to staff and teachers in the case of the used software programs don't need a minitower. In fact, laptops usually have a power oscillating between 20 to 50 Watts, instead of 60 to 200 Watts for desktops (Tower + Display). According to the expertise of the computer's department in Novia UAS, laptops are more efficient, up to 80% less consumption for the same capacities. [21, 22]

The following scenario is considerate: all the desktops are replaced by laptops. Each laptop is brought home during the night, so it is considerate that they are consuming power only during the working hours. The laptop should not use heavy programs considering the actual programs available on desktops. Therefore the assumption is 20 W, 8 hours a day, 5 days a week and 10 month a year.

Table 9 Consumption of laptops instead of desktop computers

Computer rooms		**Power[W]**	**Hours ON/year**	
Room	**Number of Laptops**	**Laptops**	**Laptops**	**Energy cons.[MWh]**
G301	18	20	1743	0,63
G402	19	20	1743	0,66
G403	9	20	1743	0,31
G404	7	20	1743	0,24
G405	19	20	1743	0,66
Classrooms				
55 rooms	55	20	1743	1,92
Offices				
280 people	280	20	1743	9,76
TOTAL				**14,19**

Instead of a consumption of 100 MWh/year, the last assumption lead to a result of 14.2 MWh/year. Considering a price of €40.36/MWh, the savings could be up to €3462.89 each year. If the price of a laptop is considered around €500, the payback time per replaced computer seems not interesting. However, the price a laptop being approximately the same than a desktop, the recommendation would be that instead of buying a new desktop, a laptop should be preferred.

As a target of electricity savings, several projects have been made to reduce the consumption. In fact, the computers have to be in low power standby when they are not in use. In the same way that a sensor can reduce light consumption, some software can reduce the activity in an automatic way when the computer is not in use. ENTRA project coordinated in Denmark from 2012 to 2015, with a budget of more than two millions € had the objective of "Minimizing Energy Consumption of Computing to the Limit". [18]

Another possible solution is to put in place thin clients. A computer device, named the server, is managing the data. All this data constitutes the cloud information, constituting the virtual desktops. The virtual desktops are locally launched by the thin client, which has very low power consumption. For instance, in the ENIT School of engineering (France), the WYSE cloud desktop systems are installed, associated with the WYSE thin clients produced by Dell Inc. The companies promote the low consumption, amid other advantages of the system. In fact, the average power consumption is 8W, as power consuming as a normal desktop in sleep mode. The data being also in the cloud, in case of a broken computer, the data isn't lost. The cost of maintenance is also lower, because the thin clients contain fewer components, which are easier to repair. Despite the fact that the device is small, it has an USB port, and the usage is almost the same. It is also equipped with wireless technologies to connect to the cloud. However, for some special programs the capacities of this kind of devices are maybe too low for the first models, but with this kind of thin clients, the IT-department can decide to allow more capacity for particular sessions. [16, 17]

The following scenario was considered: all the desktops are replaced by virtual desktop environments. Each virtual desktop is ON during the night. Therefore the assumption is 8 W, 24 hours a day, 7 days a week and 10 month a year.[23, 24, 25]

Table 10 Consumption with virtual devices

Computer rooms		Power[W]		Hours ON/year		
Room	**Number of virtual desktops**	**Virtual desktops**	**Displays**	**Virtual desktops**	**Displays**	**Energy cons.[MWh]**
G301	18	8	38	7320	1743	2,25
G402	19	8	38	7320	1743	2,37
G403	9	8	38	7320	1743	1,12
G404	7	8	38	7320	1743	0,87
G405	19	8	38	7320	1743	2,37
Classrooms						
55 rooms	55	8	38	7320	1743	6,86
Offices						
280 people	280	8	38	7320	1743	34,94
Total						50,79

Instead of a consumption of 100 MWh/year, the last assumption lead to a result of 50.79MWh/year. Considering a price of €40.36/MWh, the savings could be up to €1986.12 each year. The software products to install the virtual desktop environment, each workstation, and the datacenter for the virtual work center have to be installed. The price differs depending of the brand and different parameters; therefore the calculation about the savings by year could be used to calculate a payback time.

The following question is naturally the one of the price of such an installation. To have an idea about the cost of this kind of virtual desktop environments, an example is presented. Wyse 5010 Cloud Desktop produced by Dell Inc. is reliable and has an interesting quality price ratio. The price of a single thin client is around €315, cheaper than the actual minitowers installed in the University. For the calculation of the total costs and potential savings several other assumptions have been made. The maintenance savings were neglected, but it has to be underlined that the maintenance costs for thin client is lower. The first assumption, according to what has been said during meetings about computers in the University, is that every 6 years the computers are changed. The price of each future PC unit is estimated around €500, which gives a difference of €185.

3.1.4 Results

Table 11 Final results for computers

Solution	Current cost/year [€]	Cost of the solution [€]	Savings/year [€]	Payback time
Sleep mode	4036	0	1978	0
Removing 50% of the computers	4036	0	400	0
Replacing by laptops	4036	203500	3460	0
Replacing by thin clients	4036	128205	14535	0

For the solutions of replacing the desktop computers by laptops or installing thin clients, the payback time was considered as €0 because the solution is not to apply now, but it is to replace by the new solution instead of buying desktops as in the as if situation. The savings/year for replacing by thin clients is the sum of the material savings and the energy savings. The material savings are due to the fact that a thin client is cheaper, the cost of the server being neglected (compared to the number of sessions in the university).

In all cases the work necessary to perform those tasks was not considered. In case of implementing the first solution, the time necessary is very short and could be performed by IT technicians working at Åbo Akademi. They already have a fixed salary and their job is to perform maintenance and solve problems regarding computers, so they would be the ones to apply the changes to the system. Removing the computers could involve selling them, which would even generate a small income, not only savings.

3.2 Light bulbs

One of the areas on which the team worked on to search for the reduction of the energy consumption is the electricity consumed by the light bulbs. In most cases, lighting accounts for a large part of the electric bills, especially in large buildings such as universities, so it is a very good idea to find some ways to reduce the consumption of electricity by lightning. Of course, some investment will be needed, because in many cases it is not possible or very difficult to turn off the lights and encouraging people using the facility might also be quite complicated. The best way to reduce electricity consumption is to change the light bulbs to much more energy efficient Light Emitting Diodes (LEDs), since the technology developments lowered their cost and enable the transition without big problems. The most energy inefficient types of light bulbs are the incandescent light bulbs. However, the investigation showed that there are not any in the university buildings. Most of the lamps in Åbo Akademi are either fluorescent or compact fluorescent. There are also some halogen lamps and only a few LEDs.

In this chapter, first a short theoretical description of different types of light bulbs will be presented, following by the description of the present situation of the light bulbs in Abo Akademi, concluding with a calculation of potential costs and savings done by implementing such solution.

3.2.1 Present situation

The total number of light bulbs counted is 4267, with 1913 fluorescent lamps, 1852 compact fluorescent lamps, 493 halogen lamps and only 9 LED lamps. The more precise presentation of collected data is in the chapter "2.3.1.2 Collecting information about light bulbs". Not for all light bulbs it was possible to find the electric power therefore some assumptions were made, based on the information from the staff and the average power of lamps used.

According to collected information, the total power for fluorescent lamps is 70320W, for CFLs 37420W, for halogens 10980W and for LEDs 95W, for a total of 11815W According to gathered information, the automatic system in the Akademi works in such a way, that the lights are on constantly from 6am to 10pm, unless turned off. That gives us 16 hours a day of constant illumination, 7 days a week. However, it was observed that the lights were off usually only in bathrooms and in many lecture rooms the lights were on, even if there was no one inside, especially in the hours, when students were still in the facility.

Table 12 Summary of present situation in Akademi

	Fluorescent	Compact fluorescent	Halogen	LED	Total
Number of lamps	1913	1852	493	9	4267
Total power (W)	70320	37420	10980	95	118815

Because of the frequent placement of light fixtures and their design, the team has considered the possibility of removing some of the light bulbs. To verify if this is possible, an experiment was conducted, which is described in chapter “2.3.1.2 Light intensity experiment”. In the following table the results of that experiment are presented.

Table 13 Results of experiment of light intensity

		Experiment 1	Experiment 2	Experiment 3
Light intensity	**Door**	126.0	x	x
	1	516.0	542.0	170.0
	1.5	91.0	123.0	148.0
	2	562.0	2.9	136.0
	2.5	92.5	29.8	149.0
	3	503.0	560	131.0
	3.5	86.5	x	135.0
	4	378.0	x	105.0

It is easy to observe that in case of one of the light bulbs removed, the light was well below the recommended levels of 50 lux, while with all the lights it is well within the limits. The variation during the first experiment, especially for the measurements under the lights and between the lamps, is due to the design of the lamps themselves. The light bulbs are placed in such a way, that the light is emitted in a cone of around 60 degrees. This causes slightly lower levels of light at higher heights and quite large variations of intensity, but is almost constant at the floor level. The experiment showed that the possibility of removing some of the light bulbs should not be considered. The only possibility considered should be to replace them.

3.2.2 Technical description

3.2.2.1 Fluorescent and compact fluorescent lamps

Fluorescent and compact fluorescent lamps, two of the most common types of light bulbs found in Åbo, have almost the same principle of working with slight differences mainly in construction. In both cases, the current running through is driven through a tube filled with argon and a small amount of mercury vapor. The current causes the gases to emit ultraviolet light, which is invisible to the human eye, and it excites the fluorescent coating, made of phosphor, on the inside of the tube. This causes the emission of light. They use the physical phenomenon of fluorescence, hence the name. This part is the same for both types of light bulbs. [27, 28, 29]

Figure 6 Fluorescent lamp

Figure 7 Compact fluorescent lamp

The main differences are in the construction. Normal fluorescent lamps have a form of long tubes, which cannot be placed into traditional socket, used also for incandescent lamps, while CFLs can be placed there. It is because of the presence of the ballast. Its function is to start the electrical discharge, which excites the mercury vapor and should be done quickly, but also control that the current does not continue to rise to the point where the tube can be burnt. The two types of lamps use different ballasts, hence the difference in construction. Traditional fluorescent lamps often use external ballast hence they cannot be put into traditional sockets, while CFLs have already a built-in ballast enabling their placement in traditional sockets.

The main advantage of fluorescent lamps is their higher efficacy compared to the incandescent light bulbs. However there are also some disadvantages. It takes some time for the bulb to become fully lit, even up to a minute, for lower quality lamps, and this process requires more electricity. Poorly designed ballasts can cause some problems, such as radio interference with other electronic devices and can overheat. Another disadvantage is the presence of mercury inside, which can cause health damage or environmental damage in case the bulb breaks. But still, good quality fluorescent lamps are much more efficient and have a longer lifespan, compared to incandescent light bulbs. [32]

3.2.2.2 Halogen lamps

Halogen light bulbs are very similar in functioning to the classical incandescent light bulbs, since they are based on the same phenomenon. A normal incandescent light bulb is made of a glass bulb filled with an inert gas, such as argon and/or nitrogen, which also prevents oxidation, a filament wire, which emits light, when heated to a temperature of more than 2000 degrees Celsius. The high temperature is the main cause of inefficiency of the incandescent lamps and they have also a short lifespan, only up to 1000 hours.

Figure 8 Halogen lamp

A halogen lamp is also based on the phenomenon of incandescence. But in this case the tungsten filament is enclosed in a much smaller quartz envelope and the gas inside is from the halogen group, hence the name. Because of the properties of halogen gasses, the possible temperature can be higher, but also the lifespan is longer and efficiency are higher than in case of traditional incandescent lamps. They are still however less efficient than fluorescent lamps or LEDs. [26, 27]

3.2.2.3 Light Emitting Diode Lamps

LED lamps have a different work principle than the other types of light bulbs. Light Emitting Diodes are semiconductor devices that produce visible light when a certain current passes through them. In their case the efficiency is higher than CFLs and especially incandescent bulbs.

Figure 9 LED Lamp

However there are different things that must be taken into account. White LEDs work slightly different than with other colors. White light produced by LED lamps is due to the fact, that they are covered or mixed with phosphor material, which changes the color of light, but that causes a slight rise in costs. LED do not emit light in all direction, therefore it affects the design of the lamps. There are some solutions to obtain light emission in all directions. LED lamps cost more than the previously mentioned types of bulbs, but their efficiency and savings are higher, because of the lower power they need to give the same amount of light and much longer lifespan of up to 50000 hours. In the table below is a simple comparison between different types of lamps present in Åbo Akademi. [30]

Table 14 Comparison between different types of light bulbs

	Halogen	**CFL**	**LED**
Lifespan in hours	2,000	9,000	50,000
Watts (equivalent 60 watts)	40	13-15	6-8
Cost per bulb	€2	€7	€10

The LED lamps can easily replace CFLs or traditional incandescent or halogen lamps. However, an important issue is encountered when fluorescent light tube has to be replaced by an LED lamp. Because of the construction of fluorescent lamps and their use of ballast it is not that easy to place LED tubes instead of them in many cases. Often it requires rewiring or other additional work and sometimes an acquisition of an additional element called Non-Shunted Rapid Start Tombstones, which costs around €2, but in this case the cost of the lamp itself is slightly lower.

However, recently new LED tubes were developed which can be directly placed instead of fluorescent tubes without any additional work. Because of that the cost is higher for a single light bulb, but it saves time in replacing. Another option is installing the ballast bypass or direct wire LED fluorescent replacement tube. It allows the user to bypass the ballast entirely and run directly off of the line voltage and installation. In case of the T12 tubes there is no problem, but T8 fixture requires changing to T12 sockets with the non-shunted rapid start tombstones. This requires a simple rewiring, that should be done by a qualified electrician. There are advantages and disadvantages of both of those options. But, since the cost of LED tubes that require no additional work is usually higher by €6-€12, depending on the type of tube, its length etc., which would give a total of €11478-€22956 higher cost. That exceeds significantly the cost of hiring an electrician that would rewire the existing sockets. Therefore in the cost analysis, the cheaper option will be considered. [31]

3.2.3 Cost analysis

3.2.3.1 Work time assumptions

According to the data provided by the director of administration of Åbo Akademi, the electricity consumption in 2015 was 1906379 kWh. Calculating the consumption for the light bulbs can tell if the assumptions taken are be close to the actual situation and if they can be used in further calculations. Based on the total calculated power of light bulbs being 118815 W and the assumption of them working 16 hours a day, 7 days a week for 365 days, the electricity consumption in this case would be 693879.6 kWh, which is 36.3% of the total consumption.

Considering that not all light bulbs were counted, that number might be too high, therefore different assumptions have to be considered. If the work time of 12 hours a day is considered, the electricity consumption would be 520409.7 kWh, which is 27.3%. This is more in line with the general information about electricity consumption in university buildings.

But, since there is no information on how the lights actually work, for example during the weekends and in the summer months (June, July), where the electricity consumptions were shown to be lower, it is safer to consider another option, which is 12 hours a day, 7 days a week for 300 days a year. In this case the consumption is 427734 kWh, which is 22.4% and this value and those assumptions were considered in calculations presented in the following parts.

However, as stated before, this is simply an assumption. Based on the current state of measuring and monitoring energy consumption it is impossible to determine how much electricity is used by the lighting system and manual measurements would be simply impossible, considering the extent and the size of the data that would have to be collected to obtain correct and precise results. All the assumptions are presented in the following table. Assumption 1 considers work 16 hours a day, 7 days a week and 365 days a year, Assumption 2, 12 hours, 7 days, 365 days, and the Final Assumption is 12 hours, 7 days and 300 days.

Table 15 Assumptions for the work time

	Hours a day	Days a year	Total hours	Yearly consumption (kWh)
Assumption 1	16	365	5840	693879.6
Assumption 2	12	365	4380	520409.7
Final Assumption	12	300	3600	427734.0

3.2.3.2 Lamp cost assumptions

As far as for the cost of a single LED lamp replacing a CFL or a halogen, two possibilities can be considered. One of them is replacing the present lamps with LEDs of lower power of around 6 to 8W, an equivalent of minimum 40W and maximum 60W incandescent light bulbs. In this case the cost for a single lamp would be of around €7. The price may change for different producers and in case of acquiring a much larger amount. However, this price is for a single, good-quality 7W LED lamp. But in some areas installing 7W LEDs might not be enough.

The collected information shows that in many areas there are lamps that give a higher luminosity output, so with those lamps, there might not be enough light. The other possibility is using 12W LED lamps. In this case the price is around €12. Since the removal of lamps in the corridors was not considered, as described above, in some areas installing 7W lamps might be enough and is definitely an option to consider for the future. But, for the sake of the cost analysis, it is better continue with a safer and more secure option of considering installing 12W LED lamps. As far as LED tubes, the price considered is €12. Also in this case changes may occur, because of different lengths of the tubes, different electric power, the producer or amount of lamps acquired. In the following table is the summary of prices and power of light bulbs considered. The power for halogen, fluorescent and CFL are presented as an average, based on the analysis conducted, and the data for LED is for the replacement bulbs.

Table 16 Assumptions for the lamp cost

	Halogen	Fluorescent	CFL	LED (replacement)
Power (W)	25	36	20	12
Cost (€)	2	8	7	12

3.2.3.3 Preliminary calculations

Now that several assumptions, which are necessary to continue with the cost analysis, it is possible to proceed with more precise calculation of energy savings. Keeping in mind all the assumptions, the results of the calculations are presented in the following table. All the numbers concerning consumption and costs are for the whole year.

Table 17 Preliminary calculation regarding consumption and cost

	Fluorescent	CFL	Halogen	Led	Total
Present consumption (kWh)	251337.6	133286.4	39528.0	342.0	427734.0
Consumption with LEDs (kWh)	123962.4	80006.4	21297.6	342.0	225608.4
Present cost of electricity (€)	10143.99	5379.44	1595.35	13.80	17263.34
Cost of electricity with LEDs (€)	5003.12	3229.06	859.57	13.80	9105.55

From the table it can be observed that the cost of electricity with LED lamps installed instead of the current lamps would be lower by €8157.79, which is 47.2%, with the current prices for electricity, which are expected to rise in the following years, but due to the fact that they were not known at the moment of writing the report, the price considered for future years was the same as the price for electricity in 2016, which is €40.36/MWh.

According to that price, which was provided by the director of administration of Åbo Akademi, the savings would be €8157.79 in one year, based only on the electricity consumption, if the present light bulbs were replaced by the LED lamps. The cost of replacing all the lights with LED bulbs would be €51096, the work of an electrician not included. According to the information found, the rewiring performed by an electrician takes roughly 2 to 5 minutes, depending on the access to the wires and lamps themselves. To perform the rewiring in all Åbo Akademi to enable placement of LED tubes, it would require around 160 hours and the cost of hiring or involving an electrician can be considered €3000, roughly based on a monthly average salary of an electrician in Finland, which gives a total of €54096 to replace and install LED lamps.

Based on that, the payback time would be of almost 7 years. But considering also the lifespan of LED lamps being 10 to 12 years, Åbo Akademi would save around €27481.89 in the span of 10 years. But those calculations did not consider effective costs for the university, which include not only the price of electricity, but also the cost of acquiring the light bulbs themselves.

3.2.3.4 Final calculations

Still the cost for acquiring all the light bulbs at once might be too much, so other possibilities may be taken into consideration. One of those options is buying and installing new LED lamps, when the current CFLs, halogen or fluorescent lamps stop working. This distributes the higher costs in time and not at once. The longer lifespan of LED lamps also has to be taken into consideration. An LED lamp has a lifespan of around 50000 hours, which means that for 12 hours a day use, they would work for 10 to 12 years. That is a big difference compared to other types and in the long perspective the cost of acquiring LED lamps would be lower than acquiring CFLs, halogens or fluorescent tubes.

To perform a better comparison in the difference in costs in the time length of 10 years, few things had to be considered, such as electricity cost, the cost of acquiring the light bulbs and rewiring by an electrician. In total, for LED lamps in Åbo Akademi, the cost for 10 years would be €145151.6. For the same period of time, considering the current situation and taking into consideration the fact that due to their lifespan halogen lamps have to be changed more or less once a year (10 lamps considered in 10 years) with the price of €2, CFLs once every 2-3 years (4 lamps considered) with the price of €7 and fluorescent lamps every 4-5 years (2 lamps considered) with the price of €8, the total cost obtained was of €264957.4. That gives the total savings of €119805.9 in 10 years. Those numbers of course were calculated based on many assumptions and it is very difficult to predict exactly how much could be saved. Also the price for electricity was assumed to not be rising, which will probably not be the case. But even with those assumptions, which are probably not very far from the truth, it is evident that a transition into LED lamps could potentially save a very significant amount of money, which could be used for other purposes.

Based on the numbers above, it was difficult to find an actual payback time. For that reason, the following table was prepared to present how the total costs are rising year by year for the both cases, one with all LED lamps and one with the current lamps.

Table 18 Total costs for the next 10 years

Year	LED	Current
1	63201.56	18249.34
2	72307.12	49462.69
3	81412.67	67712.03
4	90518.23	101265.4
5	99623.78	132478.7
6	108729.3	150728.1
7	117834.9	181941.4
8	126940.4	200190.8
9	136046.0	233744.1
10	145151.6	264957.4

The current situation considers the cost of replacing halogen lamps every year, CFLs in years 2, 5, 7 and 10, and Fluorescent in years 4 and 9. The table shows that already in the 4th year, the total costs are lower in case of LED lamps, even thought that the cost in the 1st year was much higher.

3.2.4 Results

Table 19 Final results for light bulbs

Solution	Current cost (10 years)[€]	Cost of the solution (10 years) [€]	Savings/year on average [€]	Payback time
Replacing light bulbs	264957.4	145151.6	11980.6	Less than 4 years

As shown in the table above, it is recommendable to replace all the current light bulbs with LED lamps. Not only it is beneficial for the environment, but especially financially, which was the main area of concern for Åbo Akademi. If a decision is made to transition into LED lighting, the potential savings could be €119805.9 in 10 years, according to the calculation performed.

3.3 Toilets and urinals

Åbo Akademi is a big university, so to satisfy the needs of people there, a lot of toilets are installed in the buildings. Nowadays, aside from economical cost, it is important to try to reduce water consumption to respect the environment and make a responsible consumption of it. Humans have an obligation to protect this resource and to become aware of the risks that would cause scarcity. Climate change is coming in silence and it is necessary to save water as much as possible.

Improvements on water consumption can be done on the building without affecting comfort of the people that work or study there, with just small changes. The idea considered was to replace half of the toilets for men and conventional urinals with waterless urinals. That will provide big savings in water. The savings could be thousands of hundreds liters per year and hundreds kilos of CO_2 for each replaced toilet.

In this chapter, first the present situation of toilets at Åbo Akademi will be presented, following a theoretical description of the chosen toilet, concluding with a calculation of potential costs and savings done by implementing such solution.

3.3.1 Present situation

According to the CAD drawings, the actual numbers of toilets at Åbo Akademi can be seen in the given table below:

Table 20 Present toilet situation

Floor nº	For women	For man	For invalids	Unisex	Urinal
1	2	1	1	1	1
2	7	7	1	12	
3	3	3	2	4	
4	7	6	3	3	1
5	7	6	3	1	1
6	5	4	2	5	1
7	5	4	2	2	1

For the calculation, placement of 4 urinals for 2nd floor, 2 urinals for 3th floor, 3 urinals for 4th floor, 3 urinals for 5th floor, 2 urinals for 6th floor and 2 urinals for 7th floor were taken into consideration. In total the calculation for 16 replacements from toilets to waterless urinals and 5 conventional urinals to waterless urinals was done. There will be no changes done for the ladies' toilets.

3.3.2 Technical description

One of the proposed solutions was based on installing waterless toilets from the brand URIMAT. They are manufactured without a rinsing channel or rims on the urinal bowl using durable high-tech polycarbonate material and non-porous. The polished ceramic ensures deposit reduction on the urinal surface and prevents the formation of bacteria and odours. Urine is drained off into the odour trap and passes through the vertical membrane into the waste pipe. The membrane closes when the flow of liquid ceases, therefore ensuring waste pipe gases and odours are retained within the waste pipe network. [33]

Urimat urinals provide a lot of benefits for the customer and for the environment, mostly because of the fact that they do not use water for flushing. That reduces the costs of maintenance and has less environmental impact. [34]

Some arguments to install Urimats are:

- No water consumption
- No solidification of urine
- No chemicals
- CO2 reduction (at least 175 grams per m3 water)
- No flushing systems necessary
- Carbon-neutral manufacturing
- System design and patented worldwide
- Microbiological cleaning system
- Possible advertising revenue
- Materials long life
- 100% recyclable
- Saving minimum 100,000 liters of drinking water a year per urinal = 17.5 kg less CO2

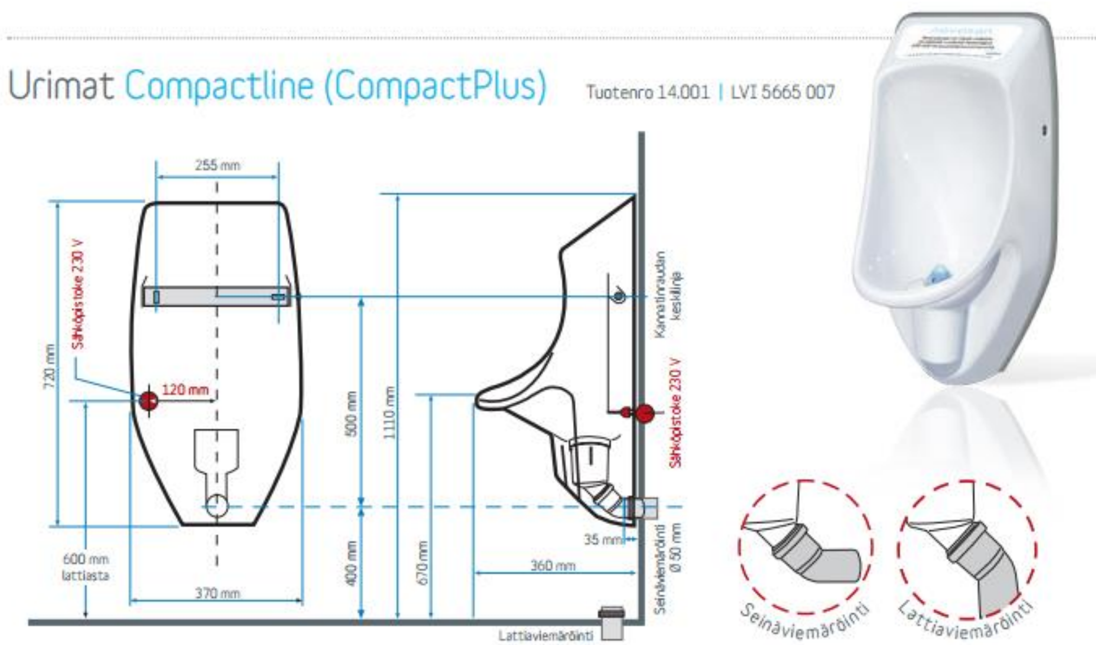

Figure 10 URIMAT Compactplus

Urimat Compactplus is the chosen urinal, it is the cheapest model and the most functional because of the plumping system, all other models have a 90-degree pipe.

The installation of the pipe will be at 45º because the urine gets a lot more speed from the urinal than from the 90-degree pipe and because the urinal is not flushed, it is better that urine goes further right from the urinal pipe. And then the whole plumbing system will lead the urine further.

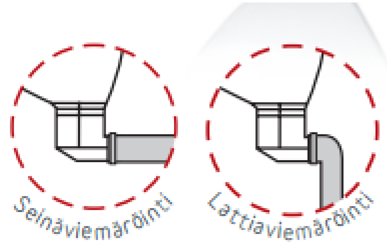

Table 21 90 degrees pipe

The specifications of the proposed model are the following:

Table 22 URIMAT Compactplus specifications

Weight	3.45 Kg
Color	Sanitary White
Bowl Material	Polycarbonate
Width	370 mm
Height	720 mm
Depth	360 mm
Static Advertising Display	Yes
Backlit Static Advertising Display	No
Digital Advertising Display	No
Power Supply Required	No
Recommended Rim Height from FFL	620 mm
Centre of Concealed Waste Height from FFL	350 mm

Instead of using water, the Urimat MB ActiveTrap is used. It needs to be changed every 3 months and its function is to collect the urine and channel it into the waste pipe without flushing, while at the same time sealing in any odours.

When ActiveTrap is replaced the toilet should be cleaned with MB ActiveCleaner. It is not strictly necessary but MB-ActiveCleaner eliminates the bad odours caused when organic matter decompose, it contains micro-organisms that penetrate the pores (joins) and destroy any odours caused by organic residues deposited there, leaving a pleasant and lasting freshness.

Figure 11 MB Active Cleaner

Fluids are channeled via a vertical membrane straight into the sewage system. Above the membrane there is a microbiological cleaning block which prevents build-up of deposits both inside the odour seal unit and in the waste pipe. As soon as fluids stop flowing through the membrane, it automatically forms an airtight seal.

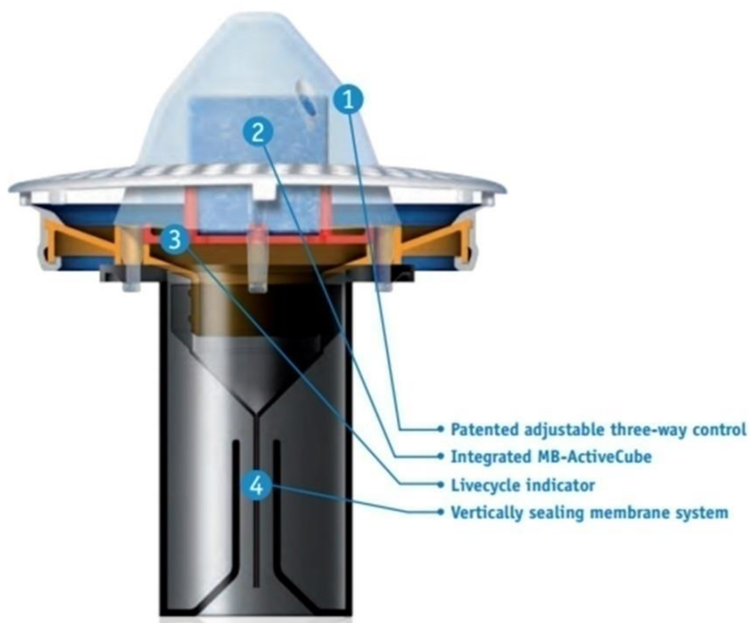

Figure 12 Urimat MB ActiveTrap

1. **Patented three-way control-** The cover of the integrated MB-ActiveCube has three settings which regulate the efficiency of the block, thereby controlling its effective service life.
2. **The integrated MB-ActiveCube-** It improves hygiene, reduces deposits and prevents the inside of the odour trap and the waste pipe becoming encrusted with organic matter, urine deposits and fats.
3. **Lifecycle indicator-** After the MB-ActiveCube has dissolved, the red surface beneath the transparent cover signals that the odour trap has to be replaced

4. **Vertically sealing membrane system-** The vertical membrane technology guarantees that odours are completely sealed away and is able to withstand both negative and positive pressures. It is impossible for gases from the sewage system to escape.

One advantage of the model CompactPlus is the advertisement display. It could be used to attract sponsors for further income, which would reduce the costs of investment. The cost for a single urinal, according to the seller, is €654.72 including taxes.

3.3.3 Cost Analysis

3.3.3.1 Saving calculations

If an estimation of use of each toilet is done with 100 times per day on average, following figures can be obtained:

Table 23 Usage per toilet estimation

Water and sewer rate [m3]	Water discharges [Uses/day]	Water flow [Liters/use]	Open days of building in a year
6,20	100	6	250

With this data the final result of the savings in water can be obtained about 930 euros per year, and the potential savings of 150,000 liters per year. [36]

In consideration to the maintenance cost, if an estimation is done with buildings being open for 500 days every 2 years (69.44%) the consumption for an ordinary toilet will be about 300,000 liters in 50000 uses. The water cost will be around 920 euros during this time period and 0 euros for Urimat, the maintenance cost will be about 150 euros for normal urinals and the only thing that needs to be changed in Urimat is the MB-active trap, which costs 33euros each (every 3 months), which sum up to 264 euros in two years.

The chemical products to clean the normal urinals cost about 39 euros for two years whereas there is a cost of 65.50 for 4L of ActiveCleaner Urimat. A big difference can be seen in savings with the use of Urimat.

For conventional urinals, considering an average water flow of 1.5 L/use, water saving costs can be of 232.5€/year and potential savings of 37.500 liters/year.

Table 24 Assumption for costs in 250 days

	€ COST / 250 DAYS			
	Water cost [€]	**Maintenance [€]**	**Cleaning products [€]**	**TOTAL [€]**
Average toilet	920	150	39	1109€
Urimat	0	264	65.50	329.5€
Conventional urinal	230	150	39	419€

So in 250 days it is possible to save 779.5 euros each toilet and 89.5 for each urinal.

As mentioned previously, the price for a single Urimat CompactPlus is €654.72. But the costs are significantly lower if more units are acquired. For 21 urinals, the price for a single one is €430 including taxes, which gives the difference of almost €225. Therefore the total cost for 21 urinals would be €9030.

Following is the table presenting how much can be saved in 250 days, if 5 conventional urinals and 16 toilets are replaced with Urimat CompactPlus. This however does not include installation costs, just cost of using and acquiring new urinals

Table 25 Savings and payback time (without installation costs)

Saving for toilets	Savings for urinals	Total savings	Payback time
12472.0€	447.5€	12919.5€	175 days

It can be extracted from the table that the payback time is 175 days, which is less than half a year. However to find more precise information about actual savings, installation and replacement costs have been also considered.

3.3.3.2 Installation costs

3.3.3.2.1 Urinals

Installing time for one urinal is about 1-2 hours. It is very easy to install, but it is important to clean the plumbing system from dirt. There is going to be some urine stone in the system, so it is necessary to clean it either with water using high pressure or with a mechanical system.

The company Urimat in Finland charges 320€ for the installation of the first urinal and then 190€ per urinal. Therefore the costs of replacing old urinals and installing new ones would be €1339.2. It includes everything from cleaning the pipes to recycling the old urinals.

Furthermore it is possible to get a deal with an external company to install them at a fixed price. Installing 5 Urimats requires 6-8 hour of work, which represents a total cost of €500-

€700 for the installation. The following table presents the two options, installing the urinals with Urimat or with an external company, and the payback time.

Table 26 Installation cost for the urinals in place of conventional urinals

	Installation cost [€]	Urinals cost [€]	Total cost [€]	Savings/250 days [€]	Payback time [years]
Urimat	1339.2	2150	3489,2	447.5	5.34
External	600	2150	2750	447.5	4.21

3.3.3.2.2 Toilets

The time for replacement of the toilet for the Urimat, depending on the floor and on the room itself, can vary, but in all cases it will take more time than for urinals. The problem with the installations of the urinals instead of the toilets is that some modifications have to be done; removing the tubes or closing the water on them; replacing tiles and other different problems can arise too.

The company Urimat charges €400 for the first replacement and then €250 for each next one. In that price the water pipe removal is included. It is always more safe to remove the water pipes for good, not to just close them, especially if they come from the floor. In the case of unexpected problems, some extra work can be charged for. It makes a total price of €5146 in total. With an external company, considering 3-4 hours of work of each toilet, the cost would be around 3900€ in total.

Like it is said before the price for replacing the toilet is different from the urinals and it involves many factors to get a fixed price, for that reason the following table can be very helpful to decide and to get budgets from different companies.

Table 27 Installation cost for urinals in place of toilets

	Installation cost [€]	Urinals cost [€]	Total cost [€]	Savings/250 days [€]	Payback time [years]
Urimat	5146	6880	12026	12472.0	0.66
External	3900	6880	10780	12472.0	0.59

3.3.4 Results

Two different scenarios were considered to complete the final results. The first scenario was the CompactPlus model, which brings the possibility of adverting revenue, and the installation made with Urimat. The second scenario considered was the same model and the installation made by an external company by fixed price per hour.

Table 28 Final results for urinals

Solutions	Current cost[€]	Cost of the solution [€]	Savings/250 days [€]	Payback time [years]
Urinals - Urimat	2095	3489,2	447.5	5.34
Urinals – external	2095	2750	447.5	4.21
Toilets - Urimat	17744	12026	12472.0	0.66
Toilets - external	17744	10780	12472.0	0.59
Total - Urimat	19839	15515,2	12919.5	0.82
Total - External	19839	13530	12919.5	0.72

The installation of the urinals with Urimat is the better option in a long term, because of their experience with the Urimat urinals there is a much higher chance that the installation will be done correctly and there will be no problems, which can arise if an external company is hired. Considering a small difference in payback time, it is recommended to involve Urimat for the installation. The urinal can be ordered from one of these 3 companies Onninen, LVI-Dahl or Ahlsell. [39, 40, 41]

The replacement of the toilets and urinals is a good solution for Åbo Akademi. Each year a large amount of water can be saved, but the proposed model gives a possibility of advertising revenue, so it is even possible to earn some money, increasing the possible savings and reducing the payback time. Moreover, with these urinals replacements it is going to be saved about 472,5kg of CO_2a year, which would help to fight the climate change.

3.4 Occupancy sensors

During the initial visits to Åbo Akademi, it was noticed that the lights in the building are on for long periods of time, even after the last person in the area has left. The automatic system controlling the lights is setup in such a way, that they are on from 6 am to 10 pm, each day of the week, causing a large wastage. One of the proposition is to install motion activated light switches, so called occupancy sensors, in the corridors of the floors, toilets facilities, and some of the rooms in the Åbo Akademi building to control the lights and turn them off if no motion is detected. If someone walks into the area, then the lights will switch back on in that area.

In this part of the report, the present situation regarding the lights will be presented, followed by a technical description of existing and proposed occupancy sensor technologies, and finally a cost analysis of potential savings will be done and commented.

3.4.1 Present situation

Åbo Akademi is a building into blocks A, B, C, D, E, F and G, which are made up with classrooms, offices for the personnel, auditoriums, toilet facilities, a restaurant and others. The building has a variety of light fixtures, from halogen light fixtures, fluorescent and compact fluorescent with only a few LED lamps. The table presenting the number of light bulbs and their total power, in Åbo Akademi divided floor by floor and by type of lamps is in chapter "2.3.1.2 Collecting information about light bulbs".

A big budget is involved in installing occupancy sensors to existing lighting system especially with the case of Åbo Akademi where there is a very large number of lighting fixtures and they are using the traditional method to switch on and off the light bulbs resulting in a non-efficient usage of the energy, causing higher electricity bills. To reduce the one-time big cost for the entire lighting system covering all floors, it can be decided to concentrate on some areas that are probable to waste more electricity, and then implement the correct type of occupancy sensor.

It has been noticed that people do not remember to turn off the lights or in some cases they simply do not care. In some of the rooms or areas, where printers or photocopy machines are present, the lights are always on, even when there is nobody going there to take the printed paper or do a photocopy. Most corridors also have their lights on while there is nobody there and no one passes through it very often.

The main areas of concern should be classrooms, toilets and urinal facilities, the main restaurant that has a lot of lights, the corridors, the store rooms and some of the stairwells that are not much in use but the lights are always on, thus causing a lot of wasted energy. Because of the difficulties in getting more accurate results in the energy gained and wasted in all of these areas together, after the implementation of the lighting control sensors, the analyzed case included sample areas in the building and based on that calculation was made to present potential savings and payback time for Åbo Akademi.

3.4.2 Technical description

Occupancy sensors can be described as devices used to detect the movement of individuals within an area. They are also known as automatic lighting controls. They have the capability to switch on and off the lights, depending on whether the location that is being observed is occupied or not, the period of the day and the illumination level of the room or area. [44]

The occupancy sensors consist of motion detectors, as well as controllable switches, electronic control and power supply. Most of the units that are embedded in it detect motion within its parameters by sensing infrared radiation. This leads to a shift in the frequency of the reflected ultrasonic waves or in some cases, a combination of both. After the sensor has been able to determine the motion, the electronic control performs a function of sending the signal to the relay which ultimately opens the power circuit, inherently turning the lights on or off. The technology of occupancy sensors is also used in the vacancy sensors. They require however some manual activity from the user to turn the lights on, but can also be applied and useful in many cases.

The following table presents the potential savings for different types of areas and spaces with occupancy sensors applied, according to the U.S. Environmental Protection Agency. [42]

Table 29 Savings potential with sensors according to EPA

Space Type	Savings Potential
Private office	13–50%
Conference room	22–65%
Classroom	40–46%
Restrooms	30–90%
Corridors	30–80%
Store areas (including warehouses)	45–80%

3.4.2.1 Passive Infrared (PIR) Occupancy Sensors

The PIR, which is the Passive Infrared Sensor, is a type of sensor which uses the technology of infrared light which is direct line of sight, in order to detect within the observed area the presence of any activities. In other words, they detect the difference between the heat that has been emitted from an individual who is in motion and the one that is emitted from the background, in the event that the person is moving across the sensor's switching zone. In principle, the more switching zones that the sensor has, the higher the chance that it has to detect small movements.

Figure 13 Example of wall mounted PIR sensor

There is one significant drawback to this sensor and it lies in the fact that their capability to sense small movement diminishes at the distance of 4.5m. This has led to making it suitable for small areas that are enclosed with no partitions. Installation of these sensors' field is seen as a requisite and needs a good adjustment which should not be directed towards an open door, where it may pick random people using the door way or just passing close by. PIRs are limited when the sight lines are obstructed and are regularly used in connection with other sensor technologies such as ultrasonic and microphonics. [43]

3.4.2.2 Ultrasonic Occupancy Sensors

Ultrasonic sensors emit a high-frequency signal that is undetectable by humans and animals. This signal bounces off objects, surfaces and people in a space. It then returns to the sensor, which interprets change in the frequency as motion. While these sensors do not require a line of sight and can sense movement around corners and objects, they may be prone to false triggering if placed too close to an HVAC (Heating, Ventilation, Air Conditioning) vent. Ultrasonic sensors are highly sensitive to small movements up to 7.5 m. They typically offer a larger coverage area than PIR sensors, but should not be mounted in high ceiling applications (over 4 meters). [45]

Figure 14 Example of a ceiling mounted ultrasonic occupancy sensor

3.4.2.3 Dual Technology Sensors

Dual technology sensors use both ultrasonic technologies and PIR for maximum coverage, as well as reliability with fewer false triggers. These sensors basically activate lights only in the event that both technologies involved have detected movements and because either of them is virtually enough to hold the lights on. In this case, the sensors are known to reduce the possibility of false on and off triggers. [45]

Figure 15 Example of ceiling mounted Dual Technology sensor

3.4.2.4 High Bay Sensors

Even though occupancy censors are generally cost effective, it can be seen to apply most in warehouse isles. This is due to the fact that such areas are known not to be occupied on regular basis. When it comes to warehouses with high intensity discharge light sources for instance, the lighting can be switched to lower levels. However they cannot or should not be turned off completely. High intensity sources of light in their nature need time to cool and warm back up to give a maximum output of light. This is a process which takes quite a long time and is not always practical, especially for those that have the need to perform duties that are in need of space. [46]

Figure 16 Example of high bay sensor

High or low occupancy control can invariably switch its lighting from full output of light to up to about a third of output when the area in question is relatively unoccupied. In the situation whereby the sensor detects the activity being done, the level of light and the power is restored almost immediately to full.

3.4.2.5 Vacancy Sensor

Vacancy sensors are a quite commonly used technology with occupancy sensors. They do not turn on the lights automatically. They need to be turned on manually when the occupant enters the space. However, the light is turned off automatically in the event that the occupant vacates the premises or when there is no activity within a certain period of time. Such sensors are known to guarantee the highest level of energy saving, due to the fact that the lights are not inclined to automatically turn on.

3.4.2.6 Sensor for the University

Having the basic knowledge about occupancy and vacancy sensors, as providing control over the lighting system, it is necessary to make a right choice for the analyzed areas of Akademi. The occupancy sensor automatically turns on light when motion is detected and off when the room is unoccupied or after a set period of time adjustable during the installation. They provide convenience of hands free switching which can be great for rooms where occupants might have their hands full and when reaching for light switch could be difficult. These could be suitable for store rooms, lecture halls, the exams halls, some of the offices, even the toilet facilities where people do not usually like using clean hands to off the lights. Vacancy sensors are known to be highly effective in areas that are relatively enclosed and where the access to the sensors is very easy. These types of sensors are very good for corridors and staircases, as people do not stay there permanently and usually only pass through.

There are large number of factors that have to be considered, based on the type of technology and type of placement, when installing sensors. When it comes to the type of placement, there are four main types of mountings: wall-switch, ceiling-mount, wall-mount and fixtures-mount.

The wall-switch is very useful when it comes to replace the existing traditional light switches to the ones controlled by sensors. This type of technology comes with two possibilities of use, as occupancy sensors and manual on/off switching in a single device. The ceiling-mount is a type that can provide 180° or 360° coverage area. The wall-mount is described as good for places that have regular shape or those with varying ceiling height, as well as narrow hallway and high-bay corridor applications. For detection in spaces outside the field of view of other occupancy sensors, adjustable swivel neck rotates 80° vertically and 60° horizontally to allow wall or ceiling mount installation. The last type is the fixtures-mount that, as the name implies, is mounted to the light fixture and are good for high ceiling spaces, task lighting areas, general work spaces and offices.

While it comes to the type of technology used, passive infrared, ultrasonic, etc. there are also many factors to be considered when the installation of sensors is considered. The size and shape of the needing coverage should be in line with the range of the sensor selected, as well as mounting height of the sensors. This can vary for different technologies and products, so it should be thoroughly. The placement of furniture or other obstructions should not block the sight, especially in case of the PIR sensors. In some cases airflow can be falsely register the motion. Also the HVAC ducts, IR cameras, incandescent or halogen light bulbs or other heat sources can disturb sensor’s activity.

3.4.3 Cost analysis

Due to the difficulty of calculating possible savings in all of the Åbo Akademi buildings, some different areas were chosen, that could serve as an example and a measure for other parts of the building. The chosen areas were a part of restaurant; stairwells in buildings B, E and G; an exam room; rooms D0302, 0303, 0304, 0305, 0306, 0307; a corridor in B building (0322); two toilets in B building (0320, 0321). The information about the electrical power of the lighting fixtures in those areas is presented in the following table.

Table 30 Electrical power of light fixtures in studied areas

	Restaurant	Stairwells	Exam room	Rooms D building	Corridor B building	Toilets B building	Total
Electrical power (kW)	3.98	1.48	0.6	5.38	0.22	0.12	11.78

Having this data, it was possible to calculate the electricity consumption in a year and the effective cost. The work time considered was of 12 hours a day, 300 days a year, which gives 3600h/year in total, the same assumption taken in the chapter “3.2 Light bulbs”, and the price is €40.36/kWh. The final consumption and cost are presented in the following table.

Table 31 Consumption and cost without sensors

Work time [h]	Total power [kW]	Total consumption [kWh]	Cost [€]
3600	11.78	42408	1696.32

The table above presents the costs for electricity without implemented sensors. This cost can be much lower if occupancy sensors are implemented. While the total power, of course, remained the same, the work time of the lights would be much lower. In this case the work time considered was of 1800 hours in a year, which is half of the original working hours. It was difficult to predict how much time could be reduced, because of the lack of the actual information about the use of studied areas. Based on the savings potential provided by the US Environmental Protection Agency, the average potential savings should be approximately 50% for analyzed areas, which gives 1800 hours mentioned above. The result for the reduced working time is presented in the table below.

Table 32 Consumption and cost with sensors

Work time [h]	Total power [kW]	Total consumption [kWh]	Cost [€]
1800	11.78	21204	848.16

Reducing the working time by 50%, with the use of sensors, reduces the cost for electricity by 50% also, which is €848.16. Although the area considered is just a small part of Academill, it shows that the potential savings, by implementing occupancy sensors can be large.

To consider the actual savings, the cost of buying and installing the sensors has to be considered. To fully cover the areas studied, 29 sensors need to be installed and placed in proper points, with a total cost for one being €60, according to an electrical contractor in Vaasa, which includes the cost of the sensor itself and the labor cost for installing such a sensor. The cost is an average price, regardless of the type of sensor used. This gives a total cost of €1740 for acquiring and installing the sensors.

3.4.4 Results

Table 33 Final results

Solution	Current cost [€]	Solution cost [€]	Savings/year [€]	Payback time [years]
Occupancy sensors	1696.32	1740	848.16	2.05

In the table above, the final results of conducted studies and analysis are presented. As seen, the payback time would be of a little above 2 years. This is not a very long time, considering the potential savings, which in the studied case are of €848.16. But it has to be remembered, that not all the areas of Åbo Akademi were studied, and if the occupancy sensors would be applied in most of the areas, the yearly savings would be much higher.

3.5 Energy awareness campaign

From the survey it can be concluded that there is lack of awareness about the energy issue within the university population and those who do know about the environmental and social impacts of energy use often have an apathetic attitude towards it. There is often a lack of commitment to save energy from large users, coupled with low awareness levels and apathy.

It is important for the students and staff to become aware of the energy consumption and that they are responsible for it. Simple changes in an individual´s behavior can quickly lead to significant energy savings, but such changes will only happen if the people are aware of the energy consumption and that they have the power to control. Everyone knows that saving energy is a good thing, but most people will only be motivated when it can be demonstrated how much energy is being wasted by their activities and just how much potential there is for them to improve.

Therefore, most of the energy waste can be avoided by energy awareness. This will ensure long-term benefits for people, the university and the environment.

3.5.1 Objectives

The objective of the energy awareness campaign is to guide and to encourage people who make use of the buildings of Åbo Akademi appropriately, in order to achieve huge cuts in energy consumption. The campaign will get people to use energy more responsibly through influencing the actions of staff and students. The energy saving campaign itself will need to have definite and clear communication and marketing objectives. People need to know the results of their efforts.

3.5.2 Implementing an awareness program

To make energy awareness part of any organization, there are four essential steps.

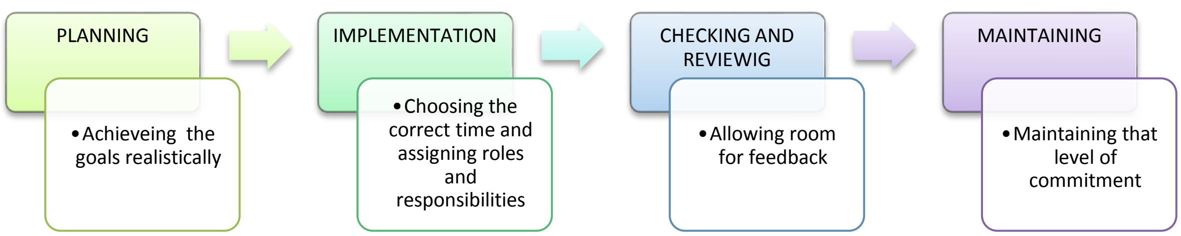

Figure 17 Energy awareness campaign steps

3.5.2.1 Planning

Good planning is fundamental to the success of an energy awareness program. In order to succeed in the mission of the project the steps of the planning have to be methodically analyzed. Here are the main points to consider:

- Support and resources

It is necessary to secure a budget and have the time allocation into account.

- Current situation

Knowing university´s energy consumption and identifying where and how most of the energy is being wasted is important before starting. Finally, research on the awareness level of the staff on the energy waste should be done. The survey was conducted on 22 March 2016 to the staff and students of Åbo Akademi to acquire this information.

- Target audience and goal setting

The study should be done to know who should be targeted and on which level, financial, environmental, motivational, etc., to base the campaign and messaging and above all to identify how people can contribute to save energy.

In order to get this we have to find the way to encourage the people. In the following table there are some motivations which can be used for Åbo Akademi.

Table 34 List of motivations and explanations

MOTIVATION	EXPLANATION
Improved reliability	Using equipment efficiently and correctly for them to work better and longer, resulting in cost savings, less equipment "downtime" and fewer demands on maintenance staff.
Environmental aspect	Making people aware of the positive effect that their actions can have on their local and global environments. Saving energy is one of the simplest 'green' actions. For some, environmental issues are significant. By making the link between energy use and the environment, people can appreciate that they can make a difference.
Improved comfort	Better control of heating and lighting leads to a more comfortable working environment. This may have potential health benefits and may result in greater productivity.
Moral	Having better working conditions as a direct result of being energy efficient has a positive effect on the attitude of most people.
Saving at home	Although staff may not always respond to energy awareness at work, most will be interested in saving energy at home, including vehicles. People are motivated by self-interest; so persuading them that the methods used to save energy at work can be applied at home and reduce energy cost.
Competition	Some individuals respond to the challenge of competition. Competitions can be set between sites, buildings or departments regarding energy savings i.e. to see who can make the greatest savings.
Recognition	Recognizing the actions and successes which staff makes with energy savings will encourage them to make further suggestions.

- Messages and communication channels

People are constantly bombarded with promotional messages. Being aware of promotional overload, people tend to look at subjects or issues that interest them and ignore the rest. The messages and slogans should be punchy and varied to interest different people.

To achieve the objectives some recommendations should be followed: creating content suitable for different audiences, selecting relevant motivational themes, using appropriate language and selecting the right communication channels.

3.5.3 Ways of communication

There are a lot of channels of communication available. To choose the correct way to communicate is necessary to identify each target. In the University, wall planners can be used for freshman, videos for academic purpose and through internet or email to students and staff.

The communications mix is then chosen to achieve maximum reach thus targeting audience as large as possible. Some examples of channels of communication which can be applied in a University are mentioned in the following table.

Table 35 Key communicatio routes

KEY COMMUNICATION ROUTES	
E-mails	Sending emails as direct form of communication, but avoiding overload.
Presentations and/or training	Providing dedicated presentation or longer-term training on energy saving can be an ideal opportunity for getting the message across.
Posters	Putting the posters to remind people to save energy but they must be renewed at regular intervals.
Staff newsletters	Using staff communications where available, to inform people and report successes.
Meetings	Putting energy on the agenda.
Walkabouts	Walking round the office at regular intervals to establish good practice.
Stickers	Encouraging people to think about saving energy at the point of use, e.g. on photocopiers, printers.
Word of mouth	Generating messages to stimulate interest and getting people talking.
Displays	Using part of an existing notice board or creating a dedicated one about energy saving, or to inform on how the campaign is going.
Competition	Creating competitions between teams, different buildings etc. or setting them up to design a poster or quizzes as a part of university activities.
Internal communications	Including the energy saving slogan or message in memos, minutes or other standard internal communications.
Letters	Sending letters about the initiative to a home address will attract attention.
Payslips	Adding energy saving messages to payslips is a good way of attracting attention.
Energy literature	Creating leaflets, booklets or newsletters to show people how they can save energy.
Suggestion schemes	Providing the means by which people can suggest energy saving ideas and offer rewards.
External input	Inviting experts to talk about energy saving and environmental issues.

3.5.4 Channels of communication used

3.5.4.1 E-mail

E-mail messages should be relevant and interesting to increase effectiveness. The e-mail should be concise and pertinent and it is better to use graphics and color to catch the attention of the reader. In the same way, it is important not to overload recipients with too many messages because it can cause a negative reaction. Therefore a rule can be made to send one email at the beginning of each semester to the staff and students of Åbo Akademi on energy awareness.

An example of an e-mail that could be sent is provided below.

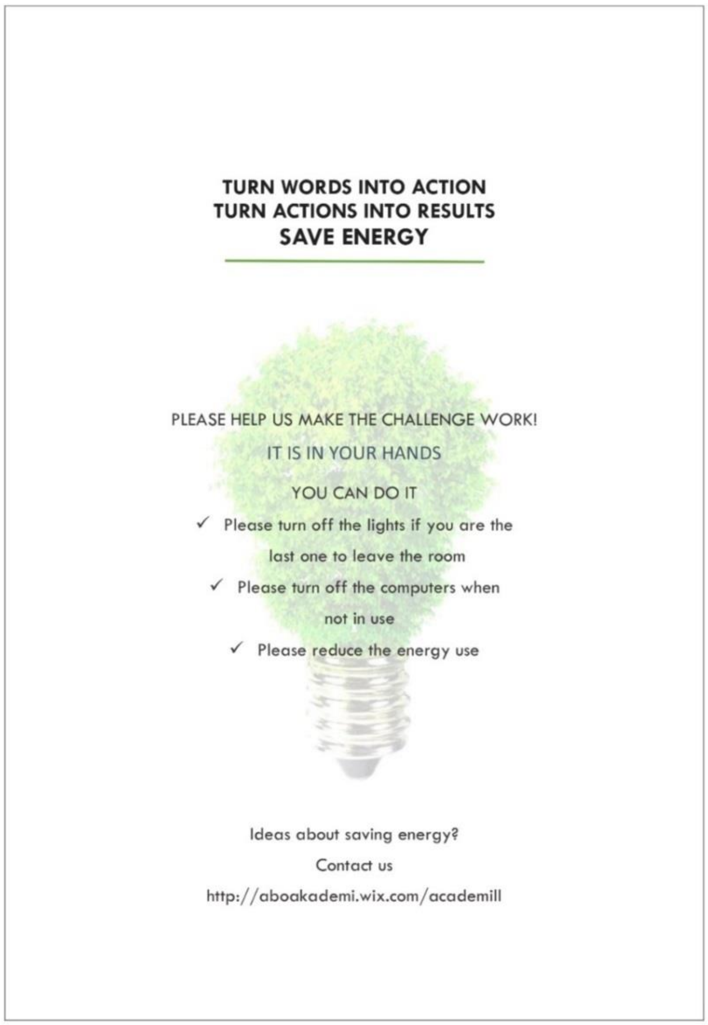

Figure 18 Example of an email

3.5.4.2 Posters

A poster usually suggests action that can take place now. The message must be short so that the lettering can be bold and large and can be seen at a distance. Posters can also generate word-of-mouth communication. To achieve better results it is important to remember following things:

- Focusing on a different issue for each poster
- Using images; internet search engines will guide to royalty-free images
- Replacing them regularly, e.g. monthly, as they have a limited shelf-life
- Using effective campaign poster with better quality.
- Placing posters at point-of-use and at eye-level for example placing them in public areas where everyone can see and not placing them in windows as this will cut out natural light.

An example of a poster that can be used is provided below.

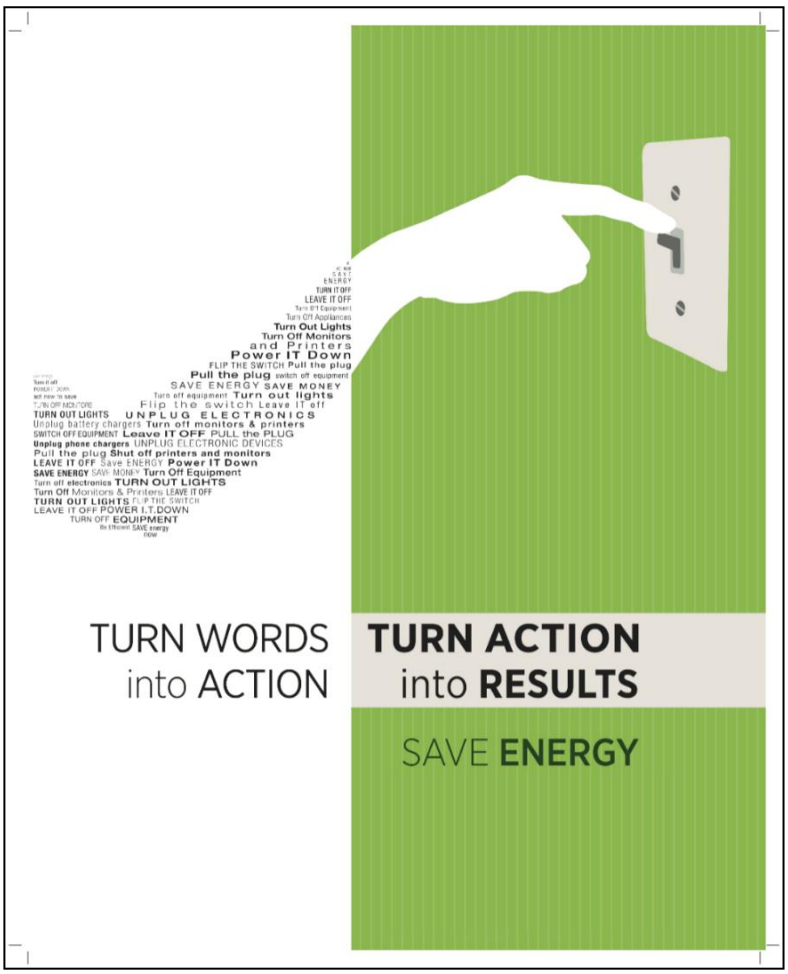

Figure 19 Example of a poster

3.5.4.3 Stickers

Like posters, stickers can be used to target different equipment or individuals. Some recommendations are mentioned in the following list.

- Using stickers at point of use, on or near equipment, e.g. photocopiers, printers, computers, lights, machines etc. and labeling equipment with colors.
- Labeling those light switches which should be switched off first, i.e. rows of lights beside windows.
- Labeling equipment with high energy use.
- Adding an explanation in the images because a simple image can convey a command but without an explanation, it may simply be ignored.

Some examples of stickers are provided below:

Figure 20 Example 1 of sticker

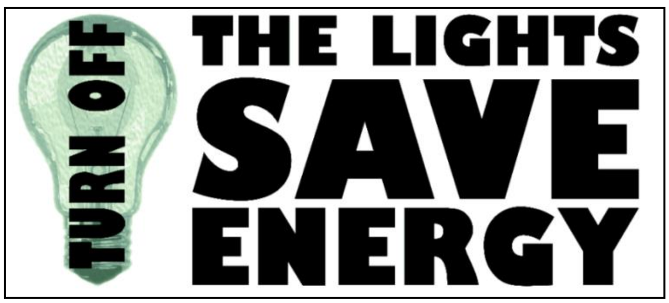

Figure 21 Example 2 of sticker

Figure 22 Example 3 of sticker

3.6 Meters and Monitoring System

In consequence of an offer of the energy provider, the solution of installing meters and a new monitoring system have been abandoned. The energy provider extend that the Åbo Akademi can have the data of energy consumption of each building for 200€ per year. This offer will probably not help to save energy based on the less specific data. However the Åbo Akademi does not have the budget to install new meters therefore this offer has a good money value.

This chapter should contain solutions of getting more information about the energy consumption. It shows different kinds of meter solutions and possible monitoring programs. It was not considered necessary to concentrate anymore on this part, so the work got halted on the May 1st and all the data and information acquired until this date can be obtained out of the appendix 1 and 2.

4 Conclusion

To sum up reducing the energy consumption requires hard work linked with big investments, but is not impossible and can bring great results. Sometimes it requires installing new equipment or replacing the old one, but also involvement from all the people working and studying at the University is necessary. To summarize all the solutions analyzed and studied by the team:

Table 36 Final results

Solution	Current cost[€]	Solution cost [€]	Savings/year [€]	Payback time [years]
Sleep mode	4036	0	1977.64	0
Removing computers	4036	0	403.6	0
Replacing by laptops	4036	0	3462.89	0
Virtual desktop	4036		3795.89	
Replacing light bulbs	264957.4	145151.6	11980.6	<4
Total Urimat	19839	15515.2	12919.5	0.82
Total External	19839	13530	12919.5	0.72
Occupancy sensors	1696.32	1740	848.16	2.05

The table above shows all the possible solutions to save energy in the university. It can be seen that saving energy is linked with big investments, however by time the investment is always returned and savings are possible, in some cases smaller, in others larger.

Not all the solutions can be implemented together. For example it is necessary to consider in which cases it will more profitable to install sensors and in which to replace the lightbulbs. Implementing both solutions is also possible, but the cost will be higher, savings lower and the payback probably lower.

All the solutions have to be analyzed to consider advantages and disadvantages to ensure that the best solution is chosen, from the financial point of view, but also considering the comfort and satisfaction of all the workers and students at the University.

In conclusion, the team considered the project a success. The main goal established before the start was reached and all the difficulties and obstacles were overcome. The analysis conducted and the work performed lead to the final results, which present in a satisfying way the potential benefits for Åbo Akademi.

5 Appendix

5.1 Appendix 1: Meter Solutions

Reducing the consumption of electricity and water is an important part of reducing cost of maintenance of a company or, as in this case, a public institution, such as university. In many cases, electricity bill makes up a large part of monthly expenses by an institution. For that reason, it is very important to find ways to obtain maximum efficiency at lowest cost possible. There are some elements that cannot be removed, eliminated or reduced, but there are also many that can be taken into consideration. While electricity is often the main area of concern, in this project also water consumption must be taken into consideration, since they are both paid separately by Åbo Akademi, and there are different ways to reduce their usage. In this part of the project some possible solutions will be presented with examples of financial impact, if possible.

5.1.1 Present situation

There are seven buildings that make up Åbo Akademi, called by the alphanumerical letters from A to G. The consumption is only evaluated by the main meter, which is cleared to zero each month. Then, the other meters, connected with the separate floors, give the subtraction information.

The meters showing the electricity consumption for Åbo Akademi can be found in the G building. There is one main meter, which shows the total consumption, for all the buildings of HS-foundation in this area. There are also other meters, one for each floor of the G building, since the floors are rented to a different entity or company and it is to enable to calculate the electricity bill separately and easily. There is also a meter for the kitchen, a large consumer of electricity, and another one for the studio, in the basement of the C building. The studio is rented to someone else therefore it will be not included in the project. Once a month the meters are read and the bills are calculated for each entity that rents a part of the building. There is also a monitoring system that enables a look into the electricity consumption.

Figure 23 Meters of electricity consumption

5.1.1.1 Current electrical meters

ISKRA – MT32AT4-1B-K / Landis+Gyr – E450

The current measuring of consumption for the floors of the G building, are electric meters of the company "ISKRA". They are basic electrical meters connected to the main wire of every floor. The electrical devices to measure the total consumption of the G building and of the total university are newer products. Produced from the Switzer Company "Landis + Gyr" the E450 is a good performing meter. The meters send their data to the current monitoring program. The data can be checked by the responsible person in the technical office of the building. [50, 51]

5.1.2 Technical description

Knowledge of energy consumption is the first step to manage savings and discover energy loses. A comprehensive monitoring system will help us to achieve high energy savings from the start, and without specifying costly investments.

Energy monitoring is strongly connected to Energy management. It is the act of collecting energy data. Nowadays the measuring of energy and consumption data is very important in due to the problems in buildings such as energy leaks. Therefore, Energy monitoring is divided in two types, real time and interval measurement.

5.1.2.1 Real-time meters:

This type of measuring is collecting data from electric, water or gas sources in real- time. This means to quantify the energy consumption data in very short intervals. These intervals are between 1 second and 15 minutes. The collected data is instantly sent to the cloud so it can be reviewed and analyzed. The short intervals make it able to see current data, which gives the opportunity to react to sudden energy loses or energy leaks like water leaks. However real time data should be handled very carefully because sudden changes in energy consumption based on real-time data possibly avoid damage.

5.1.2.2 Interval meters:

Likewise the interval meters can provide data from electric, water or gas consumption. The data is sent to a platform or other tool where it can be analyzed. In opposite to the real-time meters, they measure data in wide intervals. The timeframe is from 15 to 60 minutes. With this technique it is possible to analyze a more comprising overview of the energy consumption. The disadvantage is the inaccuracy of analyzing because of the missing data in between the intervals. Recapitulating it is to say that the interval meters provide data to insight into energy consumption, but it provides far less information than a real-time system.

5.1.2.3 Installing new meters

To install meters, they have to be plug in the main wires of the area which want to be measured. These wires are often connected to a breaker or switchbox. Therefore the first step is to locate these boxes. In the Åbo Akademi the main wire is dived into the different buildings. In building D the wire passes a breaker box from floor 1 to 6. In floor 6 the breaker box also connects floor 7. Building E and F are quiet similar. Both start in the second floor and have their breaker boxes on every floor. The administration building A has two boxes for three floors and the B house has 7 floors with two boxes each. The wires in the B floors are split into the left and right side of the building therefore the data of building B can be split in a part with kitchen and without.

To sum up the Åbo Akademi has 34 breaker boxes which are installed in a cupboard. The cupboard contains enough space to install a meter there. The following meter is an example meter from “Enermet”.

5.1.2.4 Enermet E600

The E600 meter is an integrated electricity meter, designed for reliable and efficient metering in small and medium size commercial and industrial sites. The meter opens up new opportunities for cost efficient energy management. Support of wired and wireless communications guarantees compatibility with different manufacturer´s metering systems. The device is easy to install and during the installation process, the meter`s self-diagnostics starts to check the operations. In consequence you get immediate plain text feedback on the display, if something went wrong. The E600 meter is shown in the picture below. It is a modern device and would perfectly fit with the current monitoring system.

Figure 24 Enermet E600

5.1.2.5 Iskra Wx30x/Wx10x/EC1-80

The company Iskra is also producing active energy meters. They have a couple of devices which could fix in the University. The Wx10x series for example, is a energy meter used for measuring energy by using direct connection in three-phase systems. Furthermore the measurement of apparent energy is possible. The products can be equipped with a serial communication which enables data transmission to a network or energy management program. Furthermore the EC1-80 application is interesting equipment, mostly used to measure single-phase systems just like in Residential, Utility and Industrial applications. Throughout the interface it is possible to check the consumption. With a communication adaption to a monitoring program, it is possible to analyze the energy-consumption to reduce the running cost to a minimum for buildings like the Åbo Akademi. This device is a good solution if the University does not want to connect to the current monitoring system based on budget reasons.

5.2 Appendix 2: Monitoring

Monitoring is the second most important thing if the target is saving energy. You cannot save what you do not measure, but you cannot identify the measurements without monitoring them. Of course, monitoring can be manual by just reading the measurements from the meters and writing them down. However the more precisely the monitoring is, the more energy can be saved. Therefore the following chapter will provide monitoring solutions which work precisely but are easy to use and intuitive.

5.2.1 Current situation

At the present time the Åbo Akademi is in possession of a monitoring system of “Hurricane electric” which is in co-working with the company Schneider electrics. The system is connected to the current installed meters. This includes the heating, water, electrical and ventilation system. Currently the program has a problem with transforming the data to an excel file, which might be the problem why the director of administration do not get the information about the known energy consumption.

5.2.2 Solution – new monitoring System

5.2.2.1 Schneider Electric

The company “Schneider Electric” provides a lot of electrical technologies and energy management systems. Some of their main products are their monitoring systems. They provide two kind of monitoring systems for large buildings. Both systems cover service benefits just like mobility and a clear view of the energy status. The listed prices are annual.

The first one is called “Copilot Improve energy” and with a price of 5250€ the cheapest product. It follows the main energy consumptions and recognizes trends in the usage. Furthermore it is possible to add energy targets to the program. The management system will tell you when you are about to reach the target, or miss it. Moreover the company will help to analyze the consumption with reports and recommendations. [49]

The second management system is called "Copilot Improve Energy & Operation for large buildings". As the name says, the program satisfied the same tasks like the system mentioned above, and a number of tasks more. The added tasks are supervising and maintaining efficiently the connected equipment, just like lighting or ventilation and boilers. Moreover the user gets maintenance reminder on assets and schedule tasks from web portal and mobile app. However this management system costs 6950€ which makes it more expensive then the first one.

It is to mention that Schneider Electric gives customers the possibility to get a trial system of "Copilot improves energy".

5.2.2.2 ENISEF

Enisef also offers a monitoring tool which provides different ways to measure the energy consumption and compare it from other years or months. One advantage is that Enisef allows buying or just rent metering equipment, which is simple and inexpensive to install. [52]

Overall, Enisef provides technical support from expert staff.

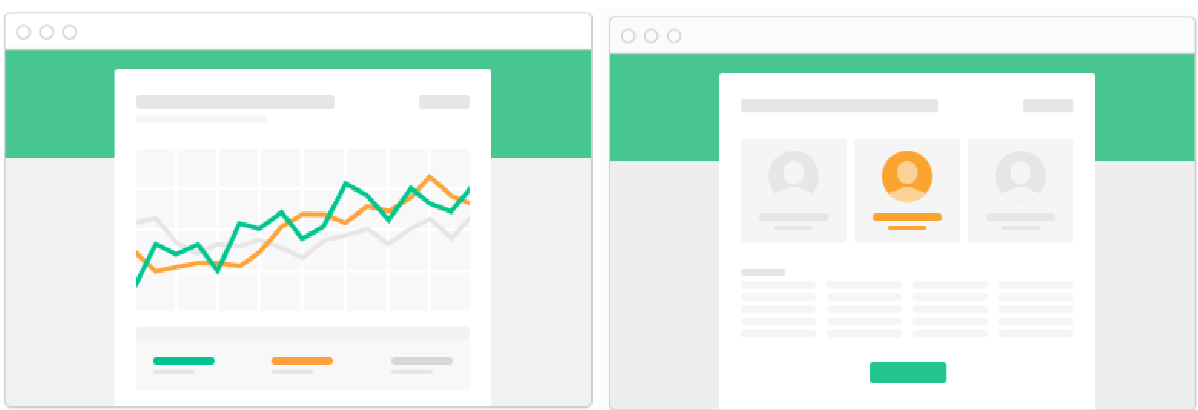

Figure 25 Enisef monitoring system

5.2.2.3 EMON

This solution is an all-inclusive solution based on the technique. The problem could be the company support, which is not available. Otherwise the system is easy to handle and to install which should be no problem for the technician of Åbo Akademi. Emon system has the capacity to monitor electrical energy use/generation, temperature and humidity. This energy monitor could be one of the best low-cost and most complete options. The system is made up of five main units. [53]

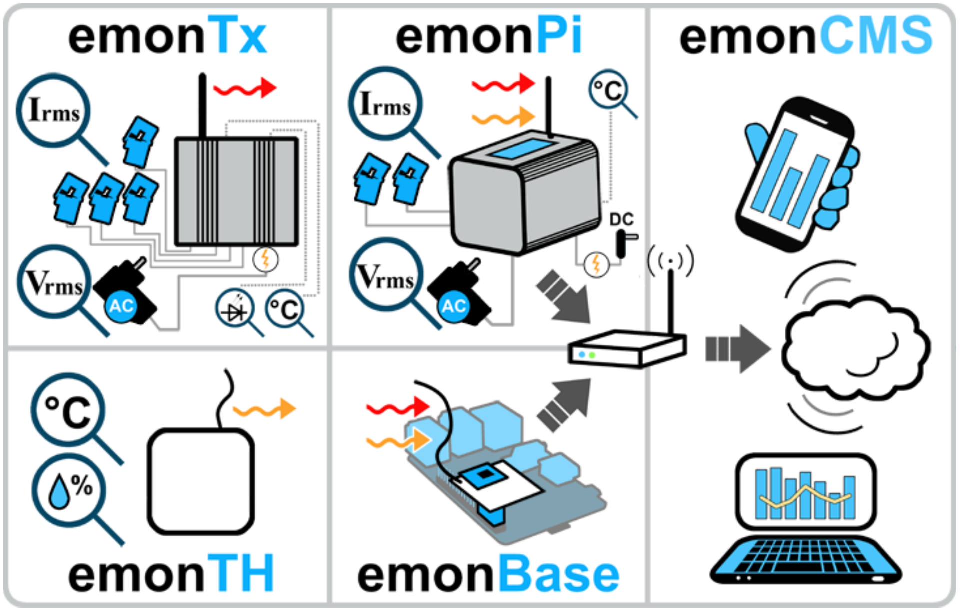

Figure 26 Emon monitoring system

- EmonPi. It is based energy monitoring unit making for a simple installation where Ethernet or WiFi is available at the meter location.
- EmonTx. Is a remote sensor node. Data is transmitted to an emonPi or an emonBase via a low power 433MHz radio. The emonTx can monitor up to four single-phase AC circuits using clip-on CT sensors.
- EmonTH. A long battery-life, easy to deploy, wireless room temperature and humidity sensor node designed for monitoring a building's thermal performance.
- EmonBase. An internet gateway that relays readings received via a 433 Mhz radio link from emonTx/emonTH sensor nodes to emonCMS. It is a low cost Linux computer. The emonBase can run a web server in conjunction with emonCMS for writing data to an SD card, and can be configured to simultaneously forward data to a remote server.
- EmonCMS. A web application for processing, storing and visualizing energy and environment data. EmonCMS can be installed on a server of your choice.

5.3 Appendix3: Project Management Tasks

5.3.1 Work Breakdown Structure

Work breakdown structure is a technique used in project management which divides the project tasks into smaller and manageable tasks. WBS was done in the beginning of the project to split the tasks in simpler manner to facilitate resource allocation and division of the individual responsibilities. WBS was done before the time duration for the different activities were estimated. WBS can be taken as a monitoring tool to check the work progress of the project until the end. Since the WBS is made in hierarchical manner so it guides the tasks procedures and progress in managed way. A readable size WBS structure is attached at the end of the report as an appendix number 5.

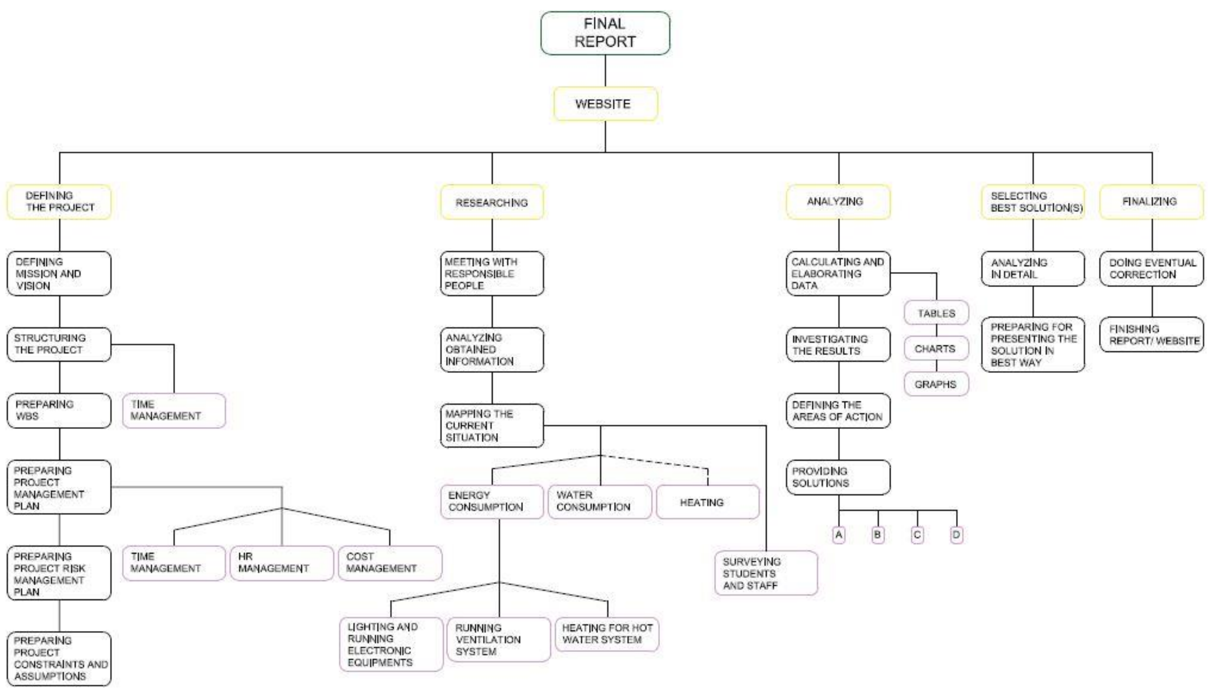

Figure 27 Work Breakdown Structure

5.3.2 Time Management

Time is a very valuable resource which should not be wasted. Especially when the time period for a project is limited then time should be spent very efficiently to achieve the goal on time. Time management plan helps in preventing the possible delays due to various reasons and aids risk management and cost management as well since time is also money. Preparing the work schedule helps in time management for project manager, group members as well as the project as a whole.

Various steps were taken to ensure that proper time management was done throughout the project period. The different steps taken for time management are briefly described below:

- First of all, the project was broken down into main tasks involved in order to complete the project until the final delivery of the product. Then those main tasks were further broken down into sub tasks, as best as possible which can be handled easily, forming a tree structure which is also known as WBS.

- The tasks from WBS were then listed in sequential order to make sure the tasks were carried out efficiently. This ensures that all the necessary previous tasks were completed before executing the following tasks. The interdependencies of each activity were considered during this step.

- Then the type of resources required for each tasks were defined. Responsible person for each tasks were selected.

- Time and effort required for each task were estimated based on the EPS schedule. The weekends, holidays and the trip days for group members were taken into consideration.

- Lastly, the tasks divided in WBS were listed, with the milestones for the project and the durations required to complete each task, to produce a time schedule (Gantt chart) for the project. The chart also included the person responsible for each task. Gantt chart was produced using MS Excel program. The critical path for the project was also determined as it is a crucial part to determine the total project duration.

Each task was monitored using the Gantt chart that they were finished on time in order to accomplish the goal of the project on time. The schedule was updated according to the changes that happened during the project progress. The tasks in the Gantt chart can be seen in the table below along with the responsible person for the task. The complete Gantt chart is also attached at the end of the report as an appendix number 6.

5.3.3 Human Resource Management (HR)

The project team members are the most important resource for the project. Depending on the type and subject matter of the project different expertise are required in order to complete the different tasks in the schedule. Managing the available human resource is very important in order to distribute the work to the team member efficiently to obtain the best results. HR management involves the process that organizes, manages and leads the project team towards its goal. It helps in distributing the workforce according to the nature of the work and its requirements in optimal way. It helps in monitoring and controlling the workforce being used excess unnecessarily and less where necessary. HR management can also be considered as a part of quality management.

The project was done by eight group members. The roles and responsibilities for each member were defined while preparing the work schedule. In order to distribute the work load among the group members efficiently, various inputs were made. Doing the Belbin test was the first step to check the compatibility of each group members with various working posts. However, this was not used as a base for the distribution of the tasks because the education background for each group members was different. So the tasks suitable with the study background were given to each member as their responsibilities. The project manager and the secretary for the project were chosen unanimously. Specific working posts were not provided for other group members as the tasks required involvement of more than one member. A responsibility matrix was constructed to define the main tasks for one or more responsible member.

S.N.	Responsible person ⇨ / Tasks ⇩	Maksymilian Chwirot (Chairma)	Laia Melero (Secretary)	Ismael Bravo	Prabina Deshar	Tomas Kienzl	Thibault Védrine	Charlotte Apegnikou Adjovi	Kahgni Kpodar
1	Defining the project	S	**R**	S	S	S	S	S	S
2	Researching	S	S	S	S	**R**	**R**	S	S
3	Collecting data	**R**	S	S	S	S	**R**	S	S
4	Analysing data	S	**R**	**R**	S	**R**	S	S	S
5	Preparing the solutions	S	S	**R**	**R**	S	S	**R**	S
6	Mid-term presentation and report evaluation	**R**	**R**	S	S	S	S	S	S
7	Choosing the best solution	S	S	S	**R**	S	**R**	**R**	S
8	Working on the chosen solution	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
9	Writing the final report	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
10	Preparing the website	S	S	**R**	S	S	S	S	**R**
11	Preparing the final presentation	S	S	S	S	**R**	S	S	**R**
12	Finalising the project	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Figure 28 Responsibility matrix

Assigning the task to each member allowed the use of skill and knowledge in right task at right time. The tasks which required more attention were done collectively and all the decisions related to the project were made by discussing with all the group members.

5.3.4 Risk Management

Identifying the risks which might affect the progress of the project towards its goal is very important project management task. Various possible risk factors were discussed among the group members and a risk matrix was made. The risks were graded from 1-5 with the probability and impact in the matrix. There was no fatal risk identified which might put the project in grave danger.

Impact	Remote 1	Unlikely 2	Possible 3	Likely 4	Highly Likely 5
Fatality 5					
Severe 4		>Unclear objectives	>Communication with data provider; >Lack of enough information; >Lack of coordination;	>Time management	
Major 3			>Communication with group members; >Lack of commitment; >Delayed information; >Work distribution	>Tardiness; >Documentation problems	
Minor 2			>Lack of motivation; >Sickness; >Technical problems	>Language problem; >Group members on trip	>Different time schedule
Superficial 1					
	Probability				

Figure 29 Risk matrix

In order to a better reaction to the risks or to prevent them, it's necessary, for each of them, to study the causes, consequences, and solutions of each one; at least for the most important of them.

<u>Impact 4, Probability2 >Unclear objectives</u>

- Causes: Misunderstanding of the subject between the members of the group, lack of information about the project.
- Consequences: Delay of the tasks/deliverables, wrong way taken, redefining objectives, loss of motivation from members.
- Solutions: Good communication between members and clients, same goal: be willing to work and co-operate, making sure that everybody is motivated, and asking the client if he agrees with the mission and vision presented by the team.

<u>Impact 4, Probability3 >Lack of enough information from data provider;</u>

- Causes: Misunderstandings/misinterpretations of the questions by the data provider. Misunderstanding/misinterpretations of the answers by the team members. Brief answers. No answers at all. Lack of knowledge. Lack of access to the needed information.
- Consequences: Redefining the project objective, lack of deliverables, wrong solutions, delaying the project. Decreasing of motivation and ambition caused by a lack of trust between both sides (client/team workers).
- Solutions: Increasing the relationship between the data provider and the team workers. Talking clearly with the responsible people about the requirements and possibilities. Finding a better source of information.

Impact 4, Probability3 >Lack of coordination;

- Causes: Unclear goals, bad leadership, using different platforms to communicate between members; not assigning the members in their field of tasks where they are more productive.
- Consequences: Unnecessary work, delay on the project, conflicts.
- Solutions: Creating efficient communication channels, developing a work plan, defining the roles of each member, knowing what everyone can bring to the group, marking common objectives, having an overview of the work to be performed.

Impact 3, probability 3 >Bad communication within group members;

- Causes: Bad communication network, inaccessibility to the chosen tools, language skills.
- Consequences: Lack of motivation of some team members, delay of the project, conflict, decision of working in irrelevant tasks.
- Solutions: Making sure that everyone accesses to the communication tools

Impact 3, probability 3 >Lack of commitment;

- Causes: Lack of confidence, lack of consideration from the other members/tutors, disapproval of other members, bad language skill, incoherent background, fear of failure/being wrong, delaying the team on tasks.
- Consequences: Being rejected by the group, loss of motivation, loss of creativity, difficult to start because of hesitation on taking responsibility.
- Solutions: Making the team members know each other, making them do some activities together, acquiring knowledge about the field of the project “by his/her own”, and showing interest to all the tasks within the project.

Impact 3, probability 3 >Delayed information;

- Causes: Business of the data provider or in holidays/ Misunderstanding the questions which are not clear. Bad choice of the ways of communication.
- Consequences: Delayed tasks/answers/work, lack of motivation, loss of trust.

- Solutions: Trying to suppose the worst scenario, working on other task in parallel, being able to use several ways of communication.

Impact 3, probability 3 >Bad work distribution;

- Causes: Wrong selection of the project manager, bad responsibility matrix, lack of motivation from the person in charge, lack of knowledge, lack of team cohesion, supposition about the tasks, bad WBS.
- Consequences: Delay of the project, uncomfortable feelings/ lack of motivation/trust.
- Solutions: Knowing the background and personality of each member and what they can bring to the group, making a good WBS, improving the Gantt chart, changing the responsibilities in case of mistakes.

Impact 2, probability 3 >Lack of motivation;

- Causes: Cultural shock, depression, too much parties, bad field of work, bad project, misunderstandings/absence of tutors, uncomfortable within the group, lack of short term goals, too much big tasks, not enough meetings, milestones.
- Consequences: Delay on the task, miss of knowledge, absenteeism, bad mood, avoidance of the work, no communication within the group.
- Solutions: Breaking down the big tasks into smaller pieces, scheduling milestones, learning and trying to share/dialog with others, giving specific work in a coherent field of background, and giving responsibilities.

Impact 2, probability 3 > Sickness;

- Causes: Team members don’t practice any sports, bad nutrition, bad lifestyle, bad adaption on the climate, isolation.
- Consequences: Lack of motivation, absenteeism, depression, rejection within the group, delays in the tasks, lack of imagination, creativity, problems to carry out the project.
- Solutions : Eating well, asking question to the team members about their lifestyle, trying to advise them, wearing appropriately regarding the climate, making sport: *"Anima sana in corpore sano"*

Impact 2, probability 3 > Technical problems;

- Causes: lack of knowledge, human error, old/bad quality device, limited precision of measurements, software/hardware problems.
- Consequences: Delay on the project, lack of motivation, wrong calculation, loss of data, wrong solutions.
- Solutions: Saving the data in several places, verifying the quality of the device, employing relevant software/hardware.

Impact 4, probability 4 >Wrong time management;

- Causes: Misevaluation/misunderstanding of the project, deliverables, tasks, lack of skill from team members, bad WBS or responsibility matrix, lack of milestones, delay from the data provider, absence of data.
- Consequences: Delay of the project, lack of deliverables, loss of motivation, and loss of efficiency.
- Solutions: Acquiring knowledge about time management, choosing a person in charge of the time management, following the comparison between theoretical expectation and reality, taking measures if unexpected facts.

Impact 3, probability 4 >Tardiness;

- Causes: Bad communication between data provider and team members, tardiness in bureaucracy, group members on trip, sickness, technical problems, lack of information, bad work distribution, lack of commitment, unclear objectives, delayed information, misunderstanding within the team.
- Consequences: Delay of the project, less deliverables/solutions, shorter time to work on other tasks, stress and anxiety within the group, large amount of work at the end, botched work.
- Solutions: Discipline at delivery time, commitment since the beginning between the group and with each data provider, realistic objectives for each task, good distribution of work and responsibility within the tasks.

Impact 3, probability 4 >Lack of documentation;

- Causes: Lack of discipline in writing the minutes, the agenda, the time involving, bad synchronization between members, lack of trust from the data providers, lack of knowledge.
- Consequences: Delay of the project, less deliverables/solutions, stress and anxiety within the group, botched work.
- Solutions: Having good rules of communication; giving a serious and credible image of the team and the importance of the objectives, working repartition and task of investigation.

Impact 2, probability 4 >Language problem;

- Causes: Bad language skills from team members, or data provider.
- Consequences: problems of communication, lack of documentation.
- Solutions: Finding someone to translate, improving the linguistic skills.

Impact 2, probability 4 >Group members on trip;

- Causes: Thirst of discovering Finland, adventurous spirit.
- Consequences: Delay in the tasks and therefore in the project; more work for team members left, tensions within the group.

- Solutions: Each team member has to be responsible his/her work schedule, asking team before to book the trips, booking trips according to the milestones/report presentation.

Impact 2, probability 5 >Different time schedule;

- Causes: Incompatibility between each member's schedules other project/lectures to follow (part time students).
- Consequences: Problems of communication, tensions within the group, delay in the project, students missing the meetings, delay of the meetings, lack of motivation, lack time of work for the project.
- Solutions: Finding the best period of gathering (listing for each members the availability), being flexible as much as possible for the team.

5.3.5 Quality Management

As a part of project management various steps were taken in order to maintain the quality of the project till the end.

Proper task schedule was made in the beginning of the project to make sure that the project is finished on time. Similarly, each group members were given responsibilities and were encouraged to finish the tasks on time. All the group members helped each other if there were any problems. All the decisions made and information acquired via different sources were passed to all group members using different means of communication. Communication with each group members and related parties was done as efficiently and regularly as possible. Meetings were held regularly with supervisor to report the work progress and get further suggestions. All the work done was documented properly including the minutes from each meeting.

Rules regarding the methods of communication and sharing information, meeting norms, work norms and conflict management for the project were made. This was done to encourage and motivate the group members to work efficiently. This also helped in creating safer environment to work for people coming from different cultural background. Few rules are provided below:

PROJECT ACADEMILL – RULES

METHODS OF COMMUNICATION AND SHARING INFORMATION

- *All opinions of each member are valued equally and should be heard and respected by the others.*
- *Everyone should feel free and welcome to express their issues concerning all aspects of the project during meetings or other conversation, in order for the whole team to listen and be aware of such problems, and take them into consideration.*
- *There will be different methods of communication as suggested by group members.*

- *Each member is obliged to check the messages sent via means of communication mentioned above daily, in order to be always updated on the developments, eventual changes or organized meetings.*
- *The whole team should be aware of all activities done individually and the progress.*
- *All work done by each member should be uploaded in common drop box folder as soon as possible for other members to read it and consult it, if necessary.*
- *The team caretaker, Roger Nylund, will be informed of the developments of the project during weekly meetings and in case of emergency via e-mail.*

MEETING NORMS

- *There should be at least two weekly meetings organized to discuss progress and pressing issues. Once a week with the supervisor, to update him on the progress of the team, and the second one with just team members to discuss anything that is necessary for the completion of the project.*
- *In case of every meeting an agenda, describing the topics which should be discussed during a meeting, and minutes, which describe what was discussed and decided during the meeting, should be prepared. An agenda should be done one day before the meeting and send to every participant of the meeting for them to consult it and prepare for the meeting. Minutes should be done one day after the meeting and also sent to everybody and uploaded to Dropbox. The person preparing agenda and minutes will change after each meeting.*
- *The punctuality should be respected, especially in case of the meetings with the supervisor. In case of lateness all members should be informed, as soon as possible.*

WORK NORMS

- *Every team member should dedicate as much time as possible in order to complete his\hers task.*
- *Each assignment should be reviewed by the team during meetings. More complex and important tasks should be reviewed also by the supervisor.*
- *The team requires full collaboration and communication of each of the team members. If a member does not commit himself/herself to the execution of the project or doesn't perform the task assigned before the deadline and doesn't inform or contact the group in any way, he/she should be confronted about it during a meeting. If such behavior would repeat the supervisor will be contacted.*

MANAGING CONFLICT

- *Before a decision concerning the project is made, all team members should agree and it should have a 100% approval.*
- *In case of disagreements, the differences shall be resolved personally, during meetings, preferably with an impartial mediator overseeing the discussion. During the dispute, all parties will have the chance to express their opinions and concerns with calm and composure, with the other paying attention.*
- *Any type of feedback, positive or negative, is welcome, as long as it is logical and meaningful. Unsubstantiated critique is not welcome. The feedback should be presented in front of the rest of the group, for them to give feedback as well.*

5.3.6 Cost management

A detailed calculation was done in order to estimate the added value of the Project Academill. First of all, an analysis of the possible costs (profitability) was done and also when they could occur (cash-flow) was estimated. Since in this project, the main purpose was only to provide service for the project, the main resources used were time and knowledge.

Usually the projects are paid according to progress and a payment schedule agreed prior to the start of the project. In order to keep track of the progress in relation to the costs, Earned Value Analysis was used.

The calendar showing the meeting date and group work days are provided below:

Figure 30 Calendar for February

ENERGY WEEK

MARCH

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
29/02	01/03 Meeting with the tutor Roger Nylund EPS room / 2h 45min	02	03 Team meeting Computer room F4215 / 3h	04	05	06
07	08 Team work EPS room / 6h	09	10 Team meeting EPS room / 1h 15 min	11	12	13
14 Meeting with Roger, Markku and Timo Åbo Akademi / 2h 30 min	15	16	17 Team meeting EPS room / 1h	18	19	20
21 Team work EPS room / 6h	22 Team work EPS room / 6h	23 Team work EPS room / 6h	24 Skype with Monitoring Expert EPS room / 1h	25	26	27
28	29	30 MIDTERM PRESENTATION	31	01/04	02	03

Figure 31 Calendar for March

APRIL

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
28/03	29	30	31 Team meeting EPS room / 3h	01/04	02	03
04	05 Meeting with Roland. Åbo Akademi / 2h Team meeting EPS room / 2h	06 Team meeting EPS room / 1h 30min	07 Team meeting EPS room / 2h	08	09	10
11 Team meeting EPS room / 2h 30min	12	13 Meeting with the tutor Roger Nylund EPS room / 1h	14 Team meeting EPS room / 3h	15	16	17
18 Meeting with Henrik/Markku and Roger Åbo Akademi/ 4h	19 Meeting with the tutor Roger Nylund EPS room / 1h	20	21 Meeting with Roland Åbo Akademi / 2h	22	23	24
25	26 Meeting with the tutor Roger Nylund EPS room / 1h	27 Meeting with Timo Bäckman Åbo Akademi / 1h 30 min	28	29	30	01/05

Figure 32 Calendar for April

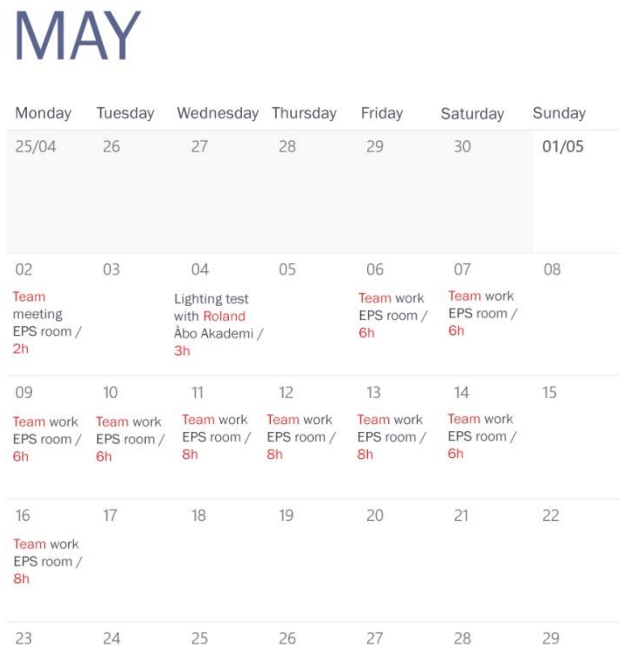

Figure 33 Calendar for May

The total hours spent in group for project tasks and for meetings are provided in the table below. The table also describes the details of the task.

Table 37 Work hours for various tasks

TASK	DETAILED	TIME	COST
1. **Team meetings**	Collect the information, decide the solutions.	23h 45min	€475
2. **Tutor meetings**	Follow-up the tasks.	8h 45min	€175
3. **Expert meetings**	Guided visits, getting information of the current situation.	21h 30 min	€430
4. **Team work**	Research, elaborate the report.	86h	€1,720
5. **Classes, PM & Teambuilding**	Lectures and preparation for project work	45h	€900
6. **Individual work**	Work on each task of the project.	See figure 32 below	-

The cost calculation for each individual member and the whole project with the assumptions made are shown in the figure below:

Assumptions	
Total work hours per week	30
Total working week	15
Work Rate per hour in Euros €	20
Working hours per day	6
Number of group members	8
Total theoretical cost for one person	9000
Total theoretical hours during project	450
Total theoretical cost for the group	72000
Total working days with holidays subtracted	68
Total hours of the project	408
Total hours spent in group	185
Total cost for one person	8160
Total cost for the group	65280

Team member name	Total hours (individual)	Total hours (teamwork +individual)	Percentage of worked hours (%)	Individual cost	Cost percentage
Max	140	325	34.31	6500	79.66
Isma	132	280	32.35	5600	68.63
Laia	138	286	33.82	5720	70.10
Thibault	106.75	273.25	26.16	5465	66.97
Charlotte	57	242	13.97	4840	59.31
Kangni	80.5	210	19.73	4200	51.47
Tomas	95.5	225	23.41	4500	55.15
Prabina	90	219.5	22.06	4390	53.80
			Total cost	41215	
			Savings	24065	

Figure 34 Cost calculations

In case of this project, an assumption of the cost for 1 work hour to be20€ for all the tasks involved was made. The total theoretical cost of the project for working 15 weeks and 30 hours per week summed up to 72000€. However after subtracting the obvious holidays, the total cost of the project summed up to 65280€. The total cost for 8 group members at the end of the project was calculated to be 41215€ which means the project was completed with less budget than expected with the savings of 24065€.

The cost of the project was affected by the individual working hours. The individual working hours for all the group members differed because of different reasons. One of the reasons was that there were two part-time workers among the group (Prabina & Tomas) and the other reason was that two group members joined the group late than others (Carlos & Charlotte). One of other reasons was that the group was big with 8 members. The group was supposed to be of maximum 6 members with total of 2448 working hours (408 hours per member), but because of 2 members added to the group the required individual working hour was decreased to 306. Also the working hours depended greatly on the working methods of each member. Hours spent on group meetings were also different for each members because in some cases not all members attended them, because either it was not necessary (in few cases) or unavailability (e.g. Part-time members, trips, sickness). Some percentage of hours from the total team work hours were subtracted for few members in such cases.

The detail about the working hour comparison between each group members is shown in the graph below:

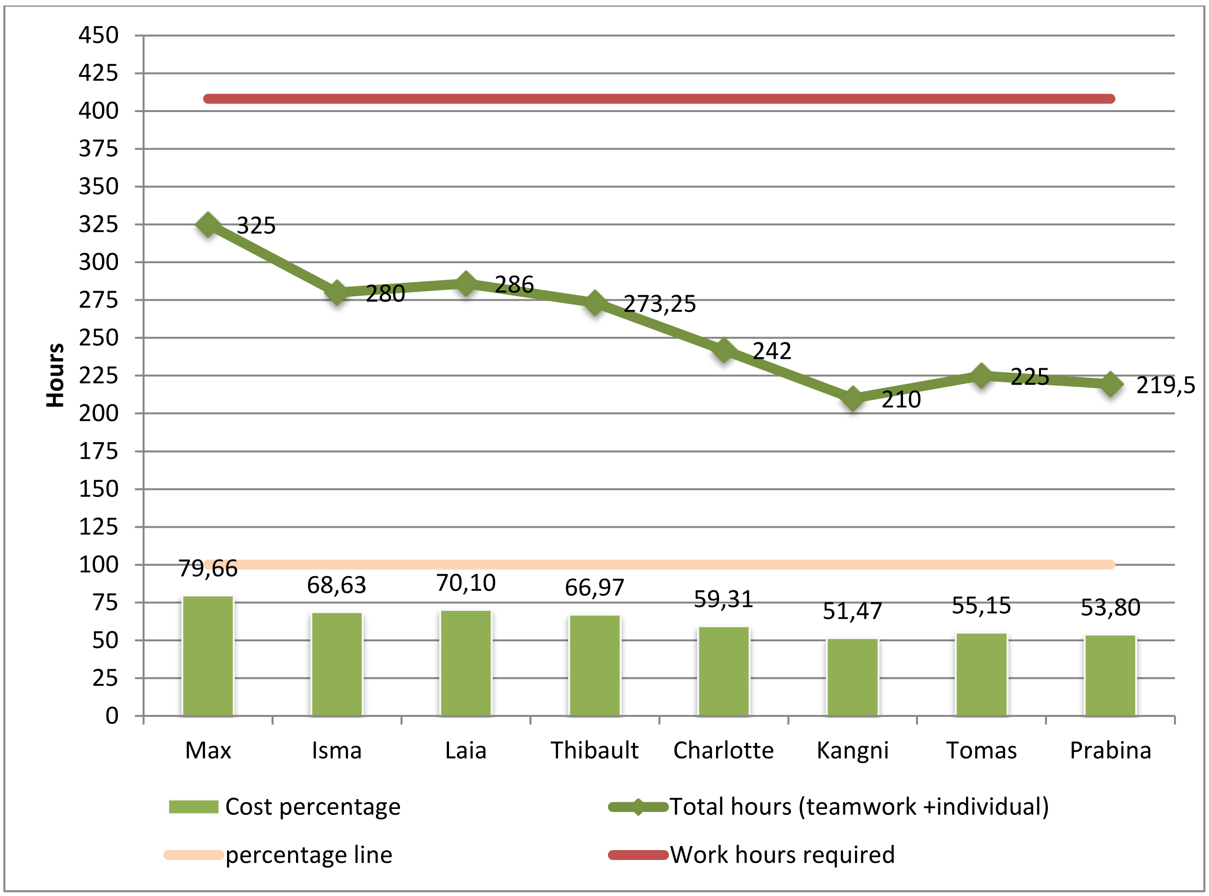

Figure 35 Graph showing the level of individual working hours compared to required hours and the percentage of the cost.

The thick red line is the required hour level for each member which is 408 hours. The thick green plotting with data levels shows the total hours spent by each group member. Similarly the light red line is the 100% level. The bars with the level shows the percentage of the cost with the cost of 8160€ per member.

5.4 Appendix 4: Corporative Identity

5.4.1 Brand

Figure 36 Final logo

ACADEMILL is the name of an international project of the European Project Semester. This project concerns the oldest University in Finland, Vaasa called Åbo Akademi. The University is composed of four buildings.

The main objective of the project is to evaluate and monitor the main sources of energy consumption. Furthermore, come upon alternative solutions to reduce the energy consumption in order to save money. Moreover the solution will have environmental impacts. ACADEMILL search to offer a simple, clean and close image. Our visual communication style has to help to disclose the compromise we have with our customers.

5.4.2 Construction and application

To get a solid image of the Project an image type was created by assembling an icon or symbol with text. In this image type, the text and the symbol are clearly differentiated and to use it separately. The image type is the union of a logotype and isotype. The image type is composed by one graphic part (image) and one typographic part (text), both connected by the same concept but they can operate separately. The commercial name of the project is ACADEMILL, which is determined by the university who have ordered the task of this project, Åbo Akademi. Accompanying the name of the brand, in order to add an identifier to describe concisely the main objective of the project, is "Energy Efficiency". The symbol comes as a simple element of curved shape. The combination of gearwheels and the small plant represent the connection between engineering and environment. Moreover, the co-operating gearwheels symbolize the correct and constant operating of the team.

5.4.3 Protection Area

Figure 37 Protection area of the logo

It has established a protection area round the logotype. This area has to be exempt of graphic elements which could interfere with its perception and lecture. The construction of the protection area has been determined by the measure of X=20mm to any use of the logotype. Anyway, whenever possible it is preferable to increase this protection space in order to separate clearly the logotype of the rest of elements of the page.

5.4.4 Minimum Size

It has been established a minimum size of offset reproduction of 40mm wide and 50mm for the screen printing. This is the minimum size to not compromise quality and message of the logo.

5.4.5 Color

IMAGE

Green
PANTONE 368 C
R:126 / G:188 / B:44
C:50 / M:7 / Y:96 / K:1

Red
PANTONE 7621 C
R:170 / G:0 / B:29
C:22/ M:99 / Y:97 / K:12

FONT

Grey
PANTONE 877 C
R:128 / G:128 / B:128
C:48 / M:37 / Y:37 / K:18

The main colour of the name of the Project ACADEMILL is grey. This colour is solid and stable, creating a sense of calm and compromise. For the big gearwheel green tone was used with the purpose of grasping the concept of save energy and also the close relation to the environment. One of the consequences for this project was to respect the environmental and contribute to improve the current situation. In the same way, the word “Efficiency” is a part of the identifier of the project and green tone was used to stress our compromise with the environment. Eventually, for the small gearwheel red tone was used in order to follow the same template as Åbo Akademi.

5.4.6 Typography

Franklin Gothic Medium Cond:

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
0 1 2 3 4 5 6 7 8 9

The main typography of ACADEMILL is “Franklin Gothic Medium Cond”, because it is a type of “Sans Serif” font. The font is lineal, clear and simple; even so it contributes a modern image. Furthermore it transmits security, severity and compromises as a value.

5.4.7 Chromatic application

Figure 38 Chromatic application

GREY SCALE

Figure 39 Logo – grey scale

5.5 Appendix 5: Computer specifications

G301, Compaq 8100 Elite CMT PC with Windows 7 OS:

QuickSpecs HP Compaq 8100 Elite PC

Standard Features and Configurable Components (availability may vary by country)

3 Technical telephone support applies only to HP configured, HP and HP qualified third party hardware and software. Toll-free calling and 24 x 7 support may not be available in some countries.

Power Supply	Small Form Factor	Convertible Minitower
Standard Efficiency	240W active PFC	320W active PFC
High Efficiency*	240W active PFC 87/89/85% efficient at 20/50/100% load	320W active PFC 87/89/85% efficient at 20/50/100% load
Operating Voltage Range	90 – 264 VAC	90 – 264 VAC

Figure 40 HP Compaq 8100 Elite PC specifications

- Convertible Minitower Energy Consumption (typically configured) 230 VAC
- Normal Operation 47.0125 W
- Sleep (Energy Star low power mode) 3.7250 W
- Off 0.8895W

G403,Dell Optiplex 9020 computers with Windows 7 OS

Feature	9020 MT/SFF/USFF Technical Specification			
Processors[4]	Intel® 4th generation Core™ i7/i5 Quad Core, Core™ i3 Dual Core and Pentium® Dual Core			
Chipset	Intel® Q87 Express Chipset			
Chassis		Minitower (MT)	Small Form Factor (SFF)	Ultra Small Form Factor (USFF)
	Dimensions (H x W x D) Inches/(cm)	14.2 x 6.9 x 16.4 / (36.0 x 17.5 x 41.7)	11.4 x 3.7 x 12.3 / (29.0 x 9.3 x 31.2)	9.3 x 2.6 x 9.4 / (23.7 x 6.5 x 24.0)
	Min. Weight (lbs/ kg)	20.68 / 9.4	13.2 /6.0	7.26 / 3.3
	Number of Bays	2 internal 3.5" 2 external 5.25"	1 internal 3.5" 1 external 5.25" (slimline)	1 internal 2.5" 1 external 5.25" (slimline)
	Expansion Slots	1 full height PCIe x16 1 full height PCIe x16 (wired x 4) 1 full height PCIe x1 1 full height PCI	1 half height PCIe x16 1 half height PCIe x16 (wired x 4)	1 miniPCIe connector
	Power Supply[8] Unit (PSU)	Standard 290W PSU Active PFC or optional 290W up to 90% Efficient PSU (80 PLUS Gold); Active PFC	Standard 255W PSU Active PFC or optional 255W up to 90% Efficient PSU (80 PLUS Gold); Active PFC	200W up to 90% Efficient PSU (80 PLUS Gold); Active PFC

Figure 41 Dell Optiplex 9020 specifications

- Normal:10.2 W
- Standby: 1.3 W
- Max:57.0 W

G402, HP Compaq 8200 Elite MT with windows 7 OS:

- Microtower Energy Consumption (typically configured) 230 VAC
- Normal Operation 34.7426 W
- Sleep (Energy Star low power mode) 2.5323 W
- Off 1.0106W

G404, HP EliteDesk 800 TWR **and** G405, HP EliteDesk 800 TWR Gold Chassis :

HP EliteDesk 800 G1 Tower PC - Specifications

Power supply specifications

Power supply specifications

Specification	Description
Standard efficiency	320 W active PFC
High efficiency[1]	**Integrated graphics:** • 320 W active PFC • 87/90/87% efficient at 20/50/100% load
Operating voltage range	90 - 264 V ac
Rated voltage range	100 - 240 V ac
Rated line frequency	50/60 Hz
Operating line frequency range	47 - 63 Hz
Rated input current	5.5 A
Rated input current with energy	5.5 A
Current leakage (NFPA 99)	< 450=> 275 µA
Power supply fan	92 mm variable speed
Power cord length	1.83 m (6 ft)

Figure 42 HP EliteDesk 800 G1 Tower PC specifications

- TOWER Normal Operation (Short idle) 17.92 W
- Normal Operation (Long idle) 16.28 W
- Sleep 1.58 W
- Off 0.60 W

G301, G402, G404: Samsung Syncmaster 2243

- AC 120/230 V
- Frequency Required50/60 Hz
- Power Consumption Operational 45 Watt

G403, Samsung Syncmaster BX 2440

- Power consumption 25 W

G405, HP EliteDisplay E221c 21.5 inch

- Power Supply Internal Input
- Power 90 - 265 VAC at 45 - 63 Hz
- Typical Power Consumption 27 W

5.6 Appendix 6: Work Break Down Structure

5.7 Appendix 7: Gantt Chart

5.8 Appendix 8: Survey questionnaire with answers

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