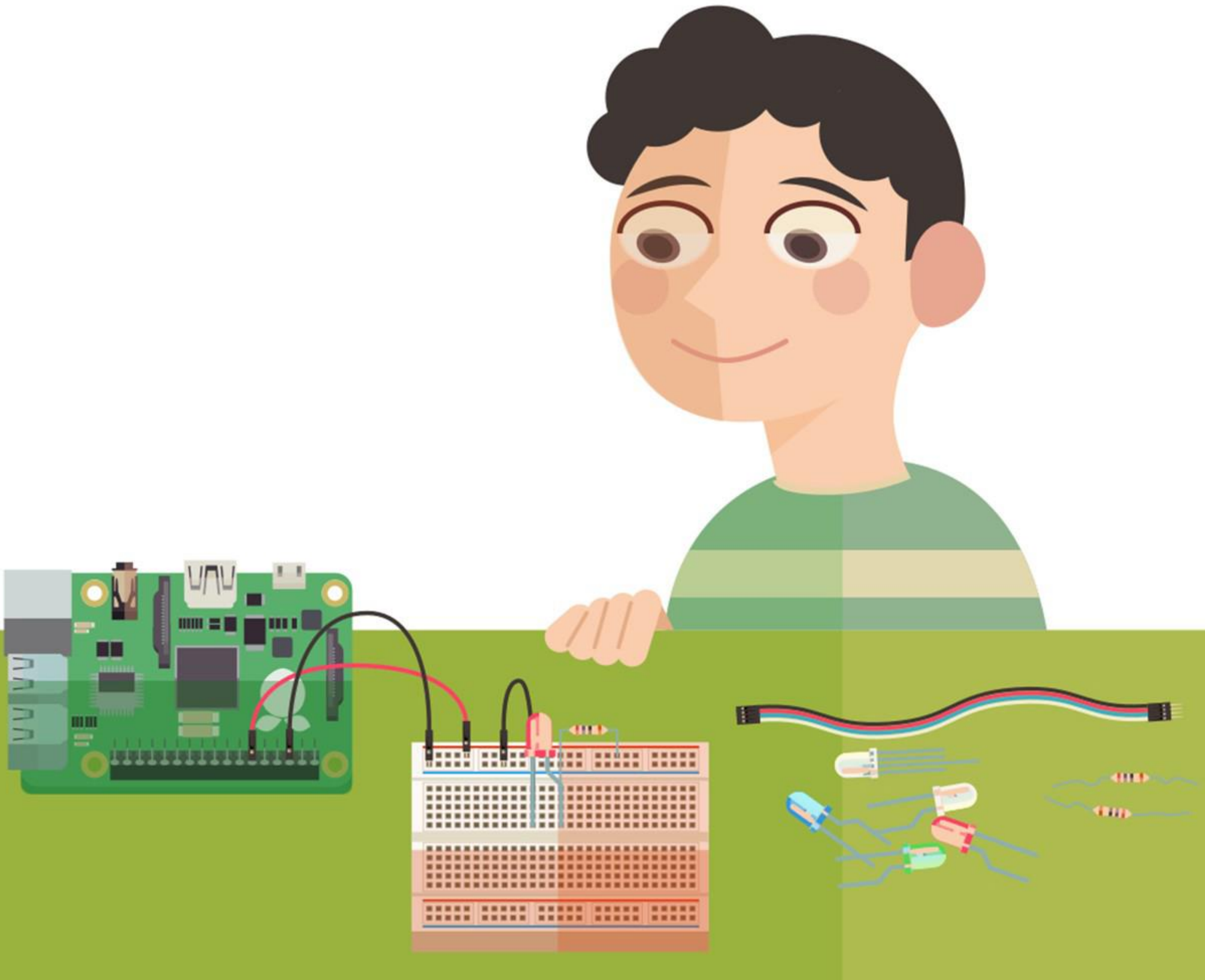
GAIA
Green Awareness In Action

PlayBook

How to launch energy saving experimentation at your school



GAIA PlayBook

How to launch energy saving experimentation at your school

GAIA - Green Awareness In Action

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1. Introduction

In this booklet we are presenting some of the core ideas, designs, tools and examples of practices that we have produced in the GAIA project. With this, we hope to offer school communities inspiration and guidance so that they can develop their own innovative educational activities for energy efficiency.

We have managed to produce this content thanks to the collaboration of thousands of students and teachers in Greece, Italy and Sweden, who participated in the educational activities of the GAIA project between 2017 and 2019.

We set out in early 2016 to design and implement methods, tools and content that would enable in-class school activities related to sustainability awareness and energy savings. Essentially, we wanted to help school communities, and especially students, understand that energy consumption is largely influenced by the sum of individual behaviours, and that if we modify those, we can achieve substantial energy savings in school buildings, as well in all buildings in which we live and work every day.

We built and installed a large-scale Internet of Things (IoT) infrastructure in 25 school buildings in Greece, Italy and Sweden, that produce data about power consumption and environmental conditions. Having these data available, we developed methods, tools and materials to make energy efficiency part of school practice.

Using these tools, teachers and students have been realizing rich teaching and learning activities, based on educational scenarios co-created by them and our team. After conducting such activities, we found that more than 75 % of the participating students believe that GAIA has had a positive influence on them, and many of their schools have actually managed to achieve tangible energy savings.

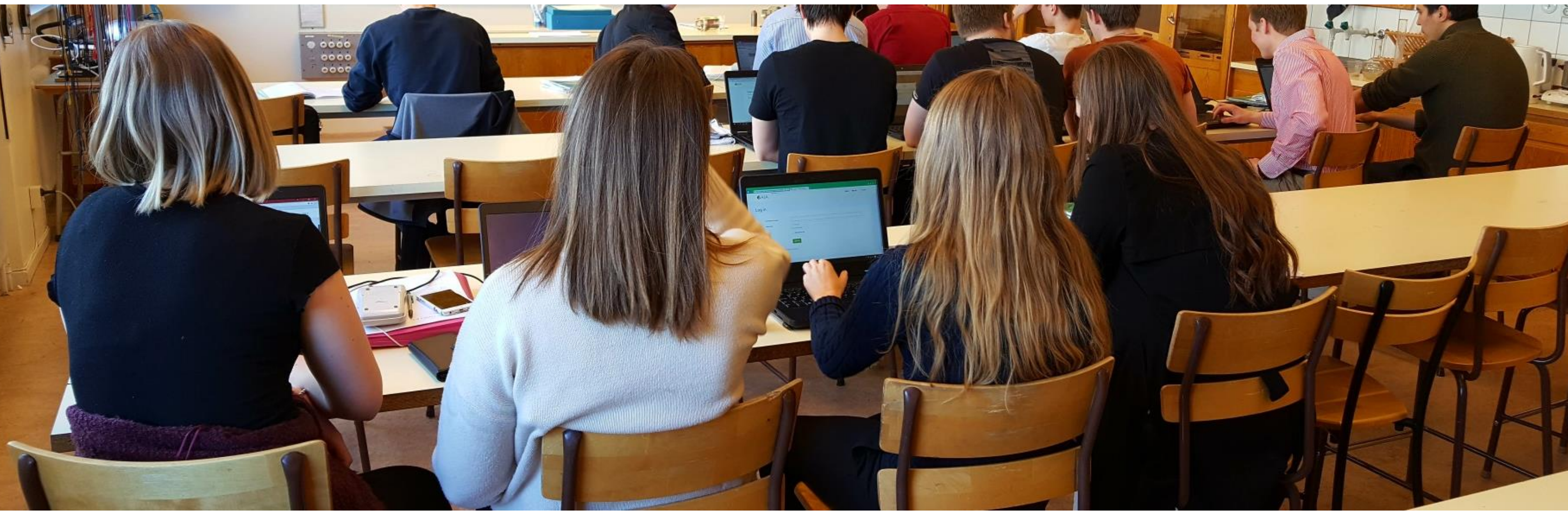
During certain periods of GAIA activities, those savings reached 15-20%, while a number of schools even managed to exceed this. In this booklet, we present some of these activities as put in practice by a number of schools, as inspiration for educators and students that would like to use our design and tools.

We would like to thank all of the school communities that participated in the educational activities of GAIA with passion, dedication and will to contribute to a more efficient use of energy in school buildings. In this booklet, we are sharing with the rest of the world of education just a portion of the enjoyment and excitement involved in our three-year collaboration with those schools, the GAIA schools.

You can find additional information on our website:

http://gaia-project.eu

The project deliverables you can find there provide detailed technical descriptions of the developed technological tools, methodologies, activities, and their evaluation.



2. The background: The GAIA pedagogy

2.1 The learning aims and educational approach

The overall learning aim of GAIA is to utilize the infrastructure, tools and methodologies produced by the project to:

- *Raise awareness regarding the need to save energy and how this can be achieved in everyday life, primarily among the users of school buildings (students, educators, other staff), and through them, their wider communities (families, local communities).*
- *Encourage the development of behaviours in users' everyday life, which can contribute to increased energy efficiency in the school building.*

To achieve this, we have designed and implemented educational activities in pilot schools which go beyond merely informing the target audiences about energy efficiency. These activities utilize the outputs of GAIA to turn students, their teachers, and those acting as building managers into active agents collaborating with each other to monitor and shape energy use in schools. In this way, we hope to:

- *Cognitively, emotionally and socially engage users of the school building deeply with the goal of energy efficiency; and*
- *Encourage them to experiment with, and adopt, behaviours that they have themselves experienced as effective ways to save energy without compromising school life quality – and that, based on their decisions, rather than being instructed to.*

Within the school community

The core of the educational interventions we propose takes place within the school, engaging the whole school community, and aspires to improve energy-related behaviour in the school building. To this end, students and school staff in the pilot sites are motivated and facilitated to:

- *Closely monitor and understand various aspects of their own and others' habits and behaviours that affect the use of energy in their school building*
- *Based on this, make informed decisions to take action in order to increase energy efficiency, by changing their habits and behaviours, and*
- *Observe and analyze the impact of their actions in terms of saving energy, as well as in terms of comfort, functionality, and avoidance of disruption of school life.*

While the educational activities address and involve school staff too, e.g., building managers, the focus lies heavily on the students' own personal engagement with the goal and process towards energy efficiency, with rich guidance and help from the teacher, so as to maximize the chances for a long-lasting impact.

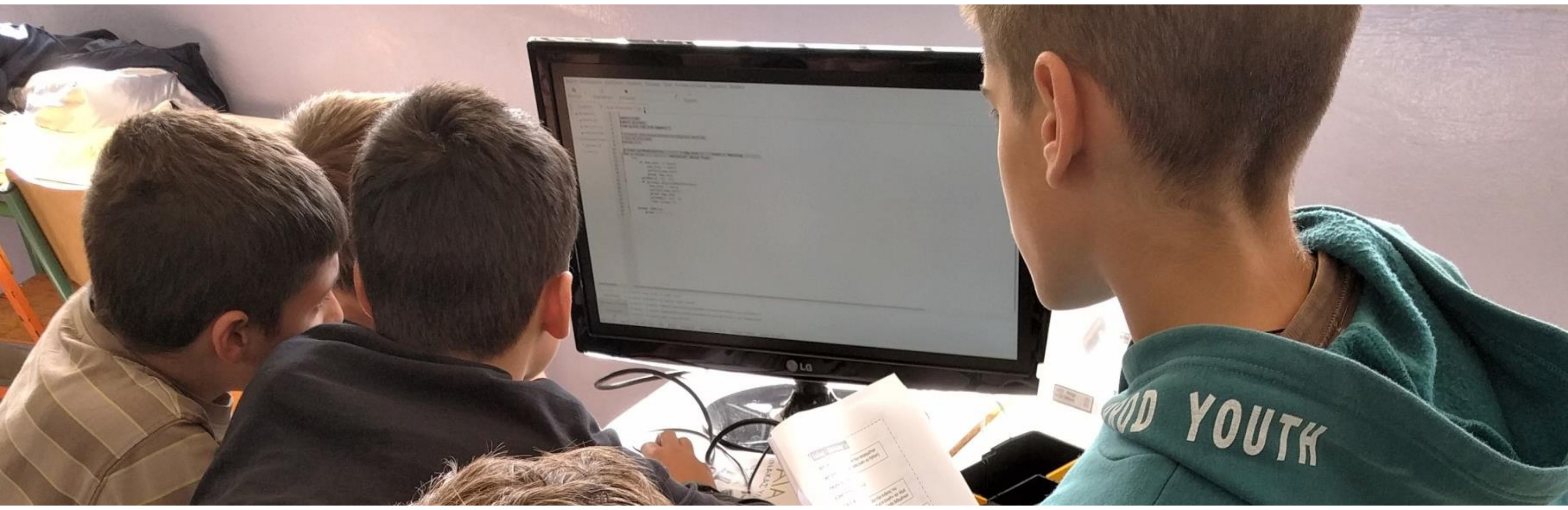
Informing and engaging the wider community

The abovementioned activities are complemented by outward-looking initiatives, aiming to spread the word for energy efficiency in the local community, involving students' families and local communities in awareness raising activities and encouraging the emergence of local initiatives informed and inspired by the mobilization of the school community for energy efficiency and its experiences and achievements.

2.2 Educational scenarios in GAIA

In order to define the envisioned educational activities in detail and introduce them to the school communities, GAIA proposes educational scenarios, i.e., activity plans and guidance describing educationally meaningful ways to use GAIA's technologies inside various educational realities.

Our educational scenarios are indicative of possibilities and options rather than being prescriptive, constituting a flexible framework for enabling an array of activities. They are a starting point for school communities to design and enact concrete activities that are relevant to their own schools and meaningful to their members, as well as applicable in their own educational realities. By entrusting the 'ownership' of the educational interventions with the school community, we put the goal of improved energy efficiency in the school building in the hands of students and school staff, as part of their own everyday life in the school.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3. The generic educational scenario

The generic educational scenario, or core GAIA scenario, is the basic description of all those necessary elements that each educational intervention in GAIA should include, and of all those open options for teachers to consider and decide how to handle based on the interests, priorities and realities in their own teaching context.

Using the generic educational scenario as their framework and guidance, teachers can generate their own context-specific scenarios of practice. The elements of the generic core educational scenario are summarized in Table 1 below and described in the subsequent sections.

Table 1: Required, desired and optional elements of the generic educational scenario of GAIA

Required	Strongly desired	Options available
Use of GAIA technologies, or similar IoT-based ones	Cycles of collaborative active learning Educational work with data from the school buildings A playful spirit in the educational activities	Steps in the learning path Time frame Levels of social engagement Adjustment to local educational characteristics Thematic coverage Educational projects and wider-frame narratives

3.1 Use of GAIA technologies

A core element in GAIA is the use of an appropriate set of the technologies comprising the GAIA solution, so as to achieve certain educational aims. The core educational scenario, as well as other context-specific scenarios derived from it, guides students, teachers and/or building managers to use all, or a selection of, the tools offered by GAIA, as summarized in Table 2.

3.2 Cycles of collaborative active learning

Preferably, learning in GAIA activities is predominantly collaborative, realized through student teamwork, students' guidance and facilitation by their teachers, and students' and/or teachers' collaboration and interaction with building managers, other school staff or community members, where and as applicable.

While there is flexibility with respect to the length and timing of the various activities, the 'big picture' of learning in GAIA includes a set of consecutive cycles.

Starting from getting information about the facts of energy efficiency, moving to engaging in practical activities in order to gather energy-efficiency related data and experiences, and, eventually, to reflecting on the experiences, discussing the results, drawing conclusions, making decisions.

Going through the stages of this process, students gradually go deeper into understanding energy efficiency and draw closer to adopting the desired change in their everyday habits and behaviours.

Table 2: Educational uses of GAIA applications

The GAIA Building Manager Application	• *Providing users with access to data which is collected through various meters and sensors monitoring energy consumption and environmental conditions in the school building:* ➔ *Electricity consumption in the whole building and/or parts of it* ➔ *Temperature, humidity, luminosity, noise levels, presence/movement, in spaces where relevant equipment has been installed* ➔ *Weather conditions in the area of the school.* • *Allowing users to insert their own measurements of energy consumption and/or environmental conditions, e.g.:* ➔ *Fuel purchased for heating* ➔ *Readings from non-networked power meters* ➔ *Comfort levels inside classrooms*
The GAIA Challenge	• *Raising awareness and playfully sustaining students' interest in, and engagement with, longer-term educational activities, through:* ➔ *Knowledge missions, i.e. knowledge quizzes related to energy efficiency* ➔ *Action missions, i.e. playful sparking of student action in the school building aiming to increase energy efficiency* ➔ *School-safe, energy-efficiency-centred social networking among students, and competition among student groups.*
Community Engagement: Social Media, Competitions	• *Raising awareness and playfully sustaining the school community's as well as the wider community's interest in, and engagement with, project activities, through GAIA activities in the popular social media and through GAIA Competitions.*

3.3 Educational work with data from the school buildings

The educational approach of GAIA prioritizes educational activities that utilize the data collected with installed and/or other portable IoT equipment, i.e. the various meters and sensors monitoring energy consumption and environmental conditions in the school buildings. Using the GAIA Building Manager Application, users can access and use data in order to monitor and observe their school environment, engage in data-driven decision-making, implement their informed decisions, and see the impact of their action.

3.4 A playful spirit in the educational activities

An overall playful approach to learning and action taking for improved energy efficiency is strongly promoted in GAIA educational activities. The aim is to motivate and sustain long-term user –and especially student– interest in, and engagement with, the activities, and nurture the emergence of deeper understanding of energy efficiency issues, so that long-term impact on user behaviour and energy consumption can be achieved.

In the gamified online environment of GAIA Challenge, students are engaged in series of knowledge and action missions. In the knowledge missions, they are challenged to solve knowledge quizzes on various aspects of energy efficiency. Through the action missions, teachers playfully spark student action aiming to increase energy efficiency in the school building. In addition, GAIA Challenge offers a school-safe digital social networking environment for students and student groups to interact with each other on energy-efficiency related matters by sharing their experiences and achievements and competing for better scores for their group.

In the context of GAIA's, or more generally the schools', presence in social media, students as well as members of the various wider communities of the schools could participate in various community-focused engagement activities. Teachers, or others, e.g., can initiate energy-focused "treasure hunts", whereby players are asked to look up an energy-related term, find an answer to a question, complete a *certain task, or create relevant digital content such as an image or a video. Especially the last option that enables students to share content and showcase their effort, is a very practical one. By including the appropriate hashtags in their responses, can engage their friends and families to a particular activity taking place at their school. On this basis, participation in such activities can be utilized in the context of competitions between classes or schools.*

3.5 How far down the learning path

Depending on their educational objectives, the time available and other local school conditions, teachers are free to decide how far they wish to take their class on the learning path of GAIA. While they should take at least the first step, they can make further steps with their students as outlined in Table 3 below.

Table 3: The four steps in the learning path of GAIA

1st Step: Awareness Raising	*Students get informed about the need to save energy and realize that there are things they can do in everyday life, in school and beyond, to improve energy efficiency.*
2nd Step: Observation	*Students monitor and analyze energy consumption in the school building and its change over time, in order to understand it.*
3rd Step: Investigation	*Based on their findings from observation, students experiment with short-term changes in their everyday habits and behaviours that affect energy consumption in the school building. They analyze the impact of these short-term changes on energy consumption in the school building and their potential for improved energy efficiency.*
4th Step: Action	*Based on their findings from short-term investigation, students decide to take longer-term action in order to achieve greater energy-efficiency results. They observe and analyze the impact of these longer-term changes on energy consumption in the school building and their potential for improved energy efficiency, monitoring the course towards achieving their goals.*

At the most superficial, yet important, level of raising awareness, GAIA supports members of the school community to get informed about energy efficiency. This is done by providing appropriate content through the Knowledge Missions of GAIA Challenge.

Building on this foundation of awareness and at a deeper level of engagement and understanding, GAIA encourages users of the school building to engage in hands-on learning activities, in which they gather data and experiences related to their behaviour and how this can be changed to improve energy efficiency. Users may realize this at various levels of involvement, taking one or more of the steps above (Observation, Investigation, and Action). This process is enabled and enhanced through the combined use of the GAIA Challenge and the GAIA Building Manager Application.

3.6 Timeframe

Time availability, timing and balance between the various activities in a school's schedule are some of the most demanding aspects of teaching practice. For this reason, and in order to increase the chances for the realization of GAIA activities in the various contexts addressed, the educational scenarios foresee a very flexible time frame allowing for several interventions lasting from a few minutes to months, or a whole school year. Such activities can be introduced into educational settings at various degrees of integration with the everyday work of schools, ranging from one-off exceptional events to larger projects integrated within aspects of the curriculum.

Of course, increased energy efficiency and corresponding behavioural change can only be achieved and sustained in larger periods: one-off initiatives stand little chance of success other than at the level of informing and raising awareness. Therefore, we strongly encourage school communities to seek the most appropriate ways in their own circumstances to be engaged in GAIA activities for longer periods. In such a longer time span, they can flexibly pick and match any of the shorter or longer-term activities proposed, in any meaningful combination serving the larger goal of improving energy efficiency in their school buildings by developing appropriate everyday behaviours. Table 4 below offers an indicative distribution of the various levels of engagement into three timeframes.

Table 4: Distribution of different levels of engagement in different timeframes

	Raising awareness	Engaging with energy efficiency	
Short term Minutes to hours	Knowledge Missions	Observation	Investigation
Medium term Day to weeks	Knowledge Missions	Observation	Investigation
Long term Month to years	-	Action	

The teacher may more easily introduce short-term activities at any point as either they consider appropriate, according to their previous planning or even spontaneously when an opportunity arises. On the contrary, medium and long-term activities require more precise structuring and planning. The scenarios developed by the project offer an indicative time plan as guidance and support to teachers, who will of course adjust this to the realities of their classrooms.

3.7 Levels of social engagement

The educational intervention proposed by GAIA is strongly characterized by collaboration in the classroom and within the school community, as well as engagement with local communities. The extent to which each school and teacher will decide to take GAIA activities outside of the school and engage the local society, depends on the local circumstances.

Within the school, learning in GAIA activities is predominantly collaborative, realized through student teamwork, students' guidance and facilitation by their teachers, and collaboration and interaction with the building manager and/or other school staff or community members, where and as applicable. GAIA Challenge offers a school-safe digital social networking environment, which can enhance this sense of school community action for energy efficiency. Students, student groups, teachers and school staff can use this online environment to interact with each other, share their achievements, and compete for the highest score. Engagement with local communities can take several forms, ranging from awareness-raising initiatives of the school, to more active engagement of students' families and local community in GAIA-inspired actions for energy efficiency, e.g. in students' homes. This aspect can be supported effectively through social media-based activities as well.

3.8 Adjustment to local educational characteristics

With the core GAIA scenario, we offer guidance to teachers without being prescriptive, on the premise that each school and teacher will adjust GAIA activity to the characteristics and circumstances of their local educational settings. In addition to the options described above, other parameters to be taken into account when defining the practicalities of introducing GAIA activities in a school include the following:

- *Technological circumstances:*
  - *Availability of installed or portable IoT equipment (meters, sensors), and its kind*
  - *Availability of user devices (smartphones, tablets, computers) and internet connection for use in the activities, any restrictions in their use*
- *Educational circumstances:*
  - *Age of students involved*
  - *Number of students involved*
  - *School staff involved (how many and which teachers, person acting as building manager)*

- *Preference or not for the connection of the activities with specific curriculum subject areas (e.g. environmental education, science and more generally STEM – cf. mathematical and scientific thinking, problem solving –, cross-curricular approaches with links to social, ethical, other humanities-related aspects)*
- *Possibilities and preferences for the place of GAIA activities in the school schedule (e.g. as part of the usual teaching activities during lessons, and/or as additional activities beyond lessons such as in afternoon clubs or projects)*
- *Stability of educational circumstances, e.g. whether significant changes can be expected in the course of longer-term activities.*

3.9 Thematic coverage

Educational activities may cover one or more of the following aspects of improving energy efficiency in the school building, depending on the local circumstances and educational focus:

- *Use of lighting*
- *Use of electrical and electronic devices*
- *Use of heating or cooling*
- *Building and local characteristics (e.g. orientation, insulation, local climate)*

We propose the coverage of all four of these thematic areas in the wider timeframe of a long-term action of the school community spanning over several months.

3.10 Educational projects and wider-frame narratives

The implementation of educational projects and the use of wider-frame educational narratives addressing students as agents in purposeful missions are useful for teachers wishing to engage students in longer-term action. Some examples of educational projects that can engage students for longer periods in missions and action linked to the use of energy at school are:

Guards of the Lights: *Students become the guards of the lights in their class. For two weeks, they try to limit the use of lighting when it is not necessary. They record the time during which the lights in their class are on and the daily weather conditions affecting natural lighting, they calculate energy consumption for lighting, and decide on relevant ways to save energy. They are careful to maintain luminosity above the limit of 220 lux. After two weeks, students calculate how much electricity they have used and how much they managed to save, comparing their results with the data they get from the IoT equipment installed in their classroom, via the GAIA building manager application. They calculate the CO_2 produced to cover the energy needs of their class in order to secure proper lighting.*

Energy Labels Investigators: *Students locate electrical and electronic devices in their classroom; they study their energy labels and record their characteristics. They look in the internet for information about the meaning of the various features described in the energy labels. They observe and record power consumption during the operation of devices such as computers, the interactive whiteboard, etc., in various modes (e.g. standby, full operation, charging) and over various periods of time (minutes, in a day, in a month, in a school year).*

A Paradise for Learning - at the right temperature and levels of humidity! *Students study diagrams of relative humidity and temperature, they define the satisfactory and ideal conditions for their classroom, and record their conclusions. They then record their measurements of humidity and temperature in the classroom, determine the appropriate conditions, and decide how to intervene in order to save energy.*

A Paradise for Learning - with help from the windows! *How is temperature in the classroom affected by opening or closing the windows? How can students measure and handle noise from the outside environment and attend their lessons with the least disruption from it? What will change in the conditions of the classroom if they use the curtains of their classroom differently? They record temperature and levels of noise in the classroom with open and closed windows, and with open or closed curtains. They decide what the ideal conditions are for the lesson so that we can save energy used for the heating or cooling of the classroom.*

Choosing Orientation and Insulation! *Students build the mock-up model of a building with 2 windows in the middle of its long side. They first take the model to the schoolyard and with the help of a compass. Then, they orient the model to a different point on the horizon each time. They record the temperature inside the model and interpret the results of their experiment. Using the compass, they then find classrooms with different orientations in their school. They use the temperature data collected through the IoT equipment installed in the different classrooms, and verify the results of their experiment, suggesting possible solutions for saving energy used for heating or cooling. Respectively, they can also test the effect of the use of various heat insulating materials on the model and the school.*

4. GAIA during a whole school year

4.1 Overall schedule

In this section, we are presenting a way to realise the generic educational scenario of GAIA in the course of a school year. This timeframe is wide enough to allow us to expect more deep-rooted and stable energy efficiency results in the school community.

We are proposing an organisation of the educational activities in an overall schedule with the following characteristics:

- *Four cycles of activity span almost the whole duration of a school year*
- *There are approximately 6-7 weeks in each cycle*
- *Each cycle is dedicated mainly to one for the four thematic areas:*
  - *Use of lighting*
  - *Use of electrical and electronic devices*
  - *Use of heating or cooling*
  - *Building and local characteristics (e.g. orientation, insulation, local climate)*
- *After a theme is introduced and elaborated during a certain cycle, it remains active and is revisited during subsequent cycles.*

An example of this distribution of GAIA activities in a school year is presented Table 5.

4.2 Distribution of activities in a cycle

Further, as an indicative example, we are proposing a distribution of the various GAIA activities in a cycle as presented in Table 6 on the next page. This distribution is based on the assumption of average availability of approximately 100 minutes (two teaching hours) of time for GAIA per week.

Table 5: An example of distributing GAIA activities in a whole school year

	1st cycle October-November	**2nd cycle December-January**	**3rd cycle February-March**	**4th cycle April-May**
Use of Lighting	*Focus on the theme of lighting*	*Long-term action on the theme of lighting*		
Use of Heating		*Focus on the theme of heating*	*Long-term action on the theme of heating*	
Use of Devices			*Focus on the theme of devices*	*Long-term action on the theme of devices*
Building/local characteristics				*Focus on the theme of building characteristics*

Table 6: Indicative distribution of GAIA activities in a cycle

	Focus on the theme	Long-term action on the theme
Weeks 1-2	• *Introduction to the theme: conventional teaching* • *Play on the theme: further learning on the theme using GAIA Challenge*	
Weeks 3-4	• *Action Mission on the theme: using the GAIA Application in practical observation and investigation activities in the school building* • *Optional addition: use of the GAIA Educational Lab Kit to implement further activities on the theme*	
Week 5	• *Portfolio - Draft 1: reporting on experiences and achievements in the Action Mission, uploaded in GAIA Challenge* • *Optional addition: use of the GAIA Educational Lab Kit to implement further activities on the theme*	• *Decision on long-term action for energy efficiency* • *Continuation of use of the GAIA Application to monitor the impact*
Week 6-7	• *Community involvement: informing other members of the school community and/or the local community* • *Playful social engagement: implementing GAIA Community Engagement Games* • *Portfolio - Final: reporting on experiences and achievements in the cycle, uploaded in GAIA Challenge and social media* • *Optional addition: use of the GAIA Educational Lab Kit to implement further activities on the theme*	• *Continuation of long-term action for energy efficiency, using the GAIA Application to monitor the impact*
After the end of the cycle	*Optional: use of the GAIA Educational Lab Kit to implement further activities on the theme*	• *Continuation of long-term action for energy efficiency, using the GAIA Application to monitor the impact*

4.3 Detailed description of the activities in a cycle

(Before) Week 1: Preparations

Before the start of the 1st cycle, the following preparatory activities need to take place.

Registration with GAIA Challenge

*GAIA Challenge can be accessed at **http://gaia-challenge.com**. Students access GAIA Challenge for the first time, to create their own user accounts. Each of them will define a username and password of their choice for themselves. If they wish, that can also provide their email address, so that it is used by the system to help them if they should forget their password. They can always go to the 'My profile' area and edit their user information, and upload an image to represent themselves in the community of GAIA Challenge (their "avatar"), if they wish. The teacher uses this opportunity to discuss matters of online safety and security with students.*

*The teacher accesses the Challenge through this 'hidden' address, for teachers only: **http://gaia-challenge.com/el/user/register/teacher**. There they create their own user account with advanced rights allowing them to create and manage Mission Teams for their students. In addition, with their account the teacher will be able to access the Mission Team Management area in GAIA Challenge to get an overview of Mission Teams and each student's individual progress.*

Setting up the Mission Teams in GAIA Challenge

Students participate in the GAIA Challenge both individually, as well as members of Mission Teams. These are groups of students who work together to accomplish various energy efficiency Missions. The size of a Mission Team may vary greatly: it can be a team within a class, a whole class, an across-school team, etc. The teacher decides how to define and use *the concept of the 'Mission Team' so that it best suits their teaching purposes and local circumstances.*

Using their advanced user rights in GAIA Challenge, the teacher accesses the Mission Team Management area to create the group, i.e. the Mission Team, which the students will belong to. When the Mission Team is created in the system, the teacher receives an invitation code, which he/she gives to the students so that they can use it to join the team. The students go to the 'Join Mission Team' area in GAIA Challenge and enter the invitation code they have been given by their teacher. This automatically links them to the Mission Team the teacher has created for them and their peers.

Access to the GAIA Application

The GAIA Application Building Energy Management Application, or simply the 'GAIA Application', is the central tool for the realization of the learning activities during Action Missions and the subsequent long-term action phases. The GAIA Application can be used by teachers and students on both computers and mobile devices (tablets, smartphones).

The teacher will decide if they will use the GAIA Application themselves 'centrally', projecting their screen to show the content to their students, or if they will allow their students to become users of the Application directly. There are different levels of access rights to the Application, matched with the roles of 'student' and 'teacher' in the system. Before the start of the first Action Mission (in week 3 of the first cycle), respective accounts need to be created.

Weeks 1-2: Raising awareness

The teacher introduces the theme focused upon in the activities cycle, through any means they consider appropriate. The project can offer teaching materials and ideas. The aim is to acquaint the students with the basic and important concepts linked to the topic.

Setting out on a Knowledge Mission

Students are introduced to the relevant Knowledge Mission in GAIA Challenge. By playing this knowledge game, they will further explore the theme and go deeper into its various aspects. The thematic coverage of the available Knowledge Missions and the time required on average for the completion of each quest are presented in Table 8 on the next page.

Students can play the Challenge using a computer, a tablet, or even a smartphone with a large enough screen.

The same Mission and Quest can be played by the same player several times, and can be interrupted at any time and repeated at a later point. Students can also play the game from anywhere, not just their classroom, if there is not enough classroom time.

The teacher advises them that in case they face any problems, they can always try the 'Help' area, which provides useful information on how to use the GAIA Challenge.

Thus, the game has been designed so that it can be used very flexibly by the teacher, who will decide how often and for how long each time the students will play it in the classroom (cf. Table 7).

In cases where economizing classroom time is of priority, the teacher can also ask the students to play with some or all content of the Quests in their own time, or even in their own place and time (e.g. at home).

Table 7: Knowledge Mission in short-term or medium-term classroom activities

	Raising awareness through a Knowledge Mission
Short term	*For some time (e.g. 20-30 minutes) during a single teaching session*
Medium term	*For some time (e.g. 10-15 minutes) over a number of teaching sessions*

Table 8: Thematic coverage of Knowledge Missions and indicative time required for each quest

Theme	Knowledge Mission	Quests in the Knowledge Mission	Quest topic	Average time required
Introduction to energy efficiency and GAIA (to be covered at the beginning of the 1st cycle)	*So, what's the challenge?*	*Let's stay on this planet!*	*The need for energy efficiency*	*20-30 minutes*
		Let's GAIA!	*Let's play GAIA to learn energy efficiency*	*5-10 minutes*
Use of lighting	*Turn me off unless you need me! – I*	*Light in the dark – I*	*More energy efficiency through wiser use of the lights – First Part*	*20-30 minutes*
		Light in the dark – II	*More energy efficiency through wiser use of the lights – Second Part*	*20-30 minutes*
Use of heating or cooling	*What a school atmosphere! - I*	*Hot or cold? – I*	*More energy efficiency through wiser use of heating and/or cooling – First Part*	*20-30 minutes*
		Hot or cold? – II	*More energy efficiency through wiser use of heating and/or cooling – Second Part*	*20-30 minutes*
Use of electrical and electronic devices	*Turn me off unless you need me!- II*	*Sleeping demons – I*	*More energy efficiency through wiser use of devices – First Part*	*20-30 minutes*
		Sleeping demons – II	*More energy efficiency through wiser use of devices – Second Part*	*20-30 minutes*
Building and local characteristics (e.g. orientation, insulation, local climate)	*What a school atmosphere! - II*	*Building smartness – I*	*More energy efficiency through appropriate building and adjustment to the local climate – First Part*	*20-30 minutes*
		Building smartness – II	*More energy efficiency through appropriate building and adjustment to the local climate – Second Part*	*20-30 minutes*

Playing the Quests

In GAIA Challenge, students will land in the 'My Quest' area. There they see the Quest Map, which gives them an overview of the five Knowledge Missions and the Quests belonging to them. The Quest Map also offers a visual representation of the student's progress in the challenge: in the beginning it is completely covered by clouds, but the more quests a student plays, the more the clouds clear and the map is revealed. Nevertheless, all Knowledge Missions are available for the students to play whenever they want.

By clicking on the box corresponding to a Quest, students start playing it. This involves responding to a series of short tasks, one after the other. In each Quest, there is a variety of tasks for students to interact with, such as single and multiple-choice questions with text and images, image-based drag and drop tasks, selection and search tasks, texts with gaps to fill in, or value estimation tasks. After each response, they receive feedback from the system, in the form of a short explanation.

By playing, students score points for their Mission Team. As they can replay tasks as often as they wish, in this way may increase the score of their team, but only up to the maximum score per task and not beyond that. Additionally, for each player there are time-restricted bonus points rewarded only for the first play-through of each task. This ensures that those players who perform well in the first play-through are able to score more points than players who repeatedly play the task but did not perform well in their first attempt. Once a student has completed all tasks in a Quest, they can play the same quest again, or exit it and be brought back to the Quest Map.

When the student has completed all Quests of a Knowledge Mission, they can submit a Snapshot for this mission and in this way share their achievement with the community. To do this, they click on the Snapshot box under the respective Knowledge Mission, and they edit their submission, adding texts, images, and/or videos from YouTube or Vimeo. They can shape their Snapshot as they wish, dragging and moving around the different blocks of their con tent. They then submit the Snapshot, which will now appear in the public gallery in the 'My Community' area.

At the top of the 'My Quest' area, the student can also see their scored points, and their overall progress through the Knowledge Missions and Action Missions. At the bottom of the page, they can find the activity log, which shows their recent activities and achievements in the GAIA Challenge.

The 'My Community' area of the Challenge is devoted to showing the achievements of the different Mission Teams. There is a Mission Team leader board, where students can click to reveal more information about each Mission Team and its achievements, including its members' personal scores. There is also a gallery of all Snapshots and Portfolios submitted by the Mission Team. Students can click on them and get access to the complete submissions with all their texts, images and videos.

Weeks 3-4: Observation and investigation in an Action Mission

After the introduction to the theme in the previous weeks, the focus of the learning activities now shifts to practical observation and investigation in the school building, which the teacher orchestrates in the form of an Action Mission. During the Action Mission, students apply in practice the knowledge they have gained on the theme focused upon. They work with data from the school buildings in order to observe how energy is used in them; they experiment with changes in everyday habits and behaviours, and monitor their impact on energy consumption.

In the observation phase: *Guided and facilitated by the teacher, students monitor and analyze the energy consumed for a particular purpose (lighting, heating, cooling, the use of certain devices, etc.) in the school building, as well as the conditions within the school building and the weather conditions outside. Their aim is to start understanding how energy can be used more efficiently for this particular purpose, without disrupting functional and pleasant living in the school building.*

In the investigation phase: *Investigation builds on, and extends the observation activities above. Based on their findings from observation, students experiment with short-term changes in their everyday habits and behaviours that affect the energy consumed for that particular purpose. They analyze the impact of these short-term changes on energy consumption and their potential for improved energy efficiency in the school building.*

Timeframe

The timeframe is again very flexible. The teacher will decide how long and how often students will be engaged in the observation and investigation activities, depending on the teaching settings and local circumstances. Generally, investigation requires more time than observation (cf. Table 9).

Table 9: Action Mission in short-term or medium-term activities

	Inquiry: Engaging with energy efficiency through an Action Mission	
	Observation	**Investigation**
Short term Minutes to hours	As part of a teaching session (e.g. a 15-30 minute activity)	A whole teaching session or a few hours within a day
Medium term Day to weeks	Distributed instances in a time frame of several hours or days	Distributed instances in a time frame of several days or weeks

Week 3	Week 4
Observation	Investigation

It is recommended to use the whole or part of Week 3 largely for observation activities, and at least Week 4 for investigation activities. Starting investigation activities during the first week will create a slightly wider timeframe that will allow for deeper investigation activities. However, this loose indicative division needs to be adjusted to the time availability and the characteristics of each educational setting.

Working with data from the school buildings: from illustration to inquiry

The availability of data from the school buildings allows the teacher to realize a wide range of practical learning activities. The minimum possibility is to demonstrate data to the students, as a form of illustration, so that pupils gain first-hand experience of energy consumption and the various aspects of the energy efficiency problem. This can be useful if the purpose is to provide a basis for introducing concepts, discussing, and thinking about energy efficiency. This is a useful starting point, which can be used in teaching even before the start of the Action Mission.

However, GAIA offers unique opportunities for students' more active and open-ended involvement in inquiry-based learning moving far beyond the illustration paradigm. In such activities, the teacher takes students to observation and investigation voyages in which they make decisions about why and how to observe or investigate. Table 10 below presents what students ask and do in the three phases: a) Illustration, b) Observation, c) Investigation.

The schematic representation of a proposed inquiry-based learning process in Figure 1 on the next page can be of use for teachers developing relevant lesson plans for the Action Mission phase. Further, the data that students may observe and investigate per thematic area are summarized in Table 11.

Table 10: Inquiry-based learning in an Action Mission

	Inquiry: Engaging with energy efficiency using data from school buildings	
Weeks 1-2	**Week 3**	**Week 4**
Illustration	**Observation**	**Investigation**
What do we need to know about energy efficiency?	How is energy used in the school building? Is it wasted? How can it be used more efficiently?	What effect do certain changes in everyday habits and behaviours have on energy consumption in the school building? How effective can these changes be in our efforts for energy efficiency?
Students develop basic knowledge and understanding of energy efficiency.	Students explore, describe, sort and classify, note similarities and differences in the data, in order to identify and explain important features of the energy efficiency problem.	Students make a hypothesis, plan the collection of evidence, collect evidence, analyze and interpret it, draw conclusions, communicate their conclusions and reflect on them and the inquiry process.

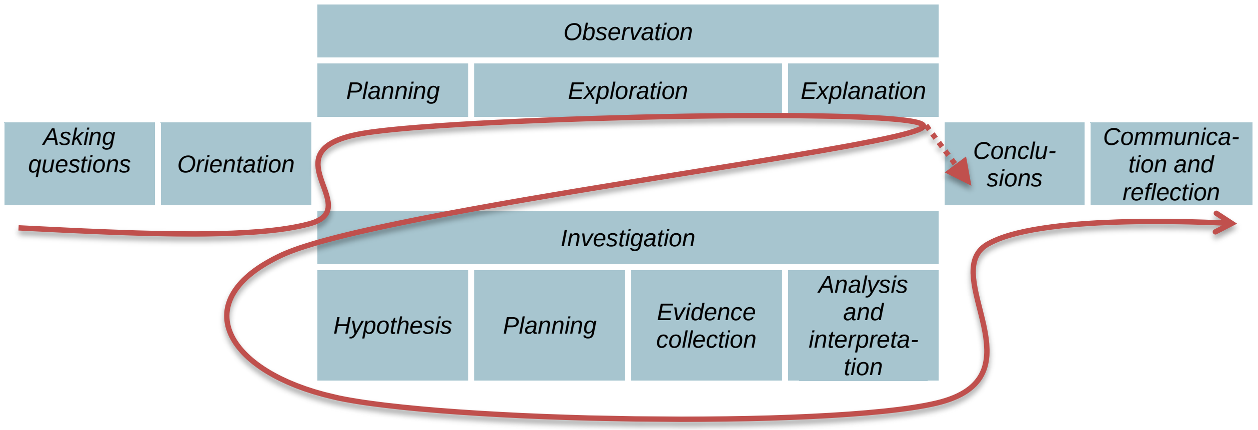


Figure 1: Proposed inquiry-based learning process in an Action Mission

Table 11: Data to observe and investigate per thematic area

Theme:	***Use of lighting***	***Use of heating or cooling***	***Use of electrical & electronic devices***	***Building and local characteristics***
Data from installed equipment				
Electricity consumption	*X*	*(X)*	*X*	*X*
Luminosity	*X*			*X*
Presence/movement	*X*			
Temperature		*X*		*X*
Relative humidity		*X*		*X*
Noise levels		*(X)*		*X*
CO, CO_2		*(X)*		*X*
Weather conditions	*X*	*X*		*X*
Measurements from other equipment (participatory sensing)				
Electricity consumption: readings from power meter	*X*	*(X)*	*X*	*X*
Fuel consumption: readings from fuel meter		*X*		*X*
Fuel consumption: quantity purchased		*X*		*X*
User comfort level: light	*X*			*X*
User comfort level: sense of heat or cold		*X*		*X*
Luminosity	*X*			*X*
Temperature		*X*		*X*

Steps to follow in the data-based observation and investigation activities

The teacher adjusts the teaching approach to the availability of equipment and data.

Teacher and students define the space observed: a classroom, a group of classrooms, or the whole building? Their own school building, or that of another school (too)?

Step 1: Defining the physical space observed and establishing the availability of data

Teacher and students discuss the installed equipment and what it records, and/or what other measurements *they can also make to understand how energy is used in the school.*

Even if there are no installed meters and sensors in their own school, the teacher and students can still do data-based activities. They can:

- *Work with the data from other schools*
- *Collect and record data themselves.*

In the former case, another school can be chosen as a case study. In the latter case, students are guided by the teacher to use portable equipment to make relevant measurements and submit them to the system of GAIA. Even in cases in which automatic metering and measurements are available, it may be considered pedagogically useful to engage students in participatory sensing practices such as, for example, submitting readings from the power meter, in order to foster students' awareness and personal involvement.

Such user-inserted measurements can be of different kinds, such as:

- *metrics of energy consumption (e.g. electricity used in a given period, oil bought, or gas used for heating in a given period),*
- *temperature,*
- *level of user comfort, e.g. by defining and using a scale of integers from 1 to 5 (e.g. how comfortable we feel with the available right in a given room, or how comfortable we feel in terms of our sense of heat or cold in a given room),*
- *other values that are interesting in the local context (e.g. how much paper is used for photocopies in a given period).*

Step 2: Observing and comparing values

Students can observe:

- *Current values and their fluctuations during the observation window*
- *Change of the values over longer periods of time (day, months, seasons, years) (using historical data for the school building)*
- *'Building condition now':*
  - *Overall building consumption*
  - *Building summary (Floor Plan)*

They can make comparisons within the same building (their own building or other building observed):

- *Values from the same sensor/meter in different timeframes (cf. differences between times of the day, day and night, winter and summer, workdays and weekends/holidays, etc.)*
- *Values from different sensors/meters in the same timeframe (cf. differences between parts of the building with different needs, different uses, different characteristics, etc.)*

Alternatively, they can make comparisons between different buildings (their own building with another, two other buildings):

- *Total building measurements*
- *Specific sensor values (same kind of measurement in the two different environments of the two schools)*

In all observations and comparisons, they choose the appropriate granularity: "Per 5 minutes", "Per Hour", "Per Day", "Per Month".

Step 3: Observing behaviours and habits affecting energy use

Students observe and record everyday habits and behaviours that have an impact on energy consumption:

- *Turning on/off the lights*
- *Turning on/off the heating/air-conditioner*
- *Opening/closing the windows*
- *Opening/closing the curtains/shades*
- *Turning on/off the fans*
- *Turning on/off other devices (e.g. PCs, projector)*

Students match the observed behaviours with patterns in the data.

Step 4: Investigating the impact of behavioural changes on energy consumption

Based on their findings from observation, students experiment with short-term changes in their everyday habits and behaviours that affect the energy consumed for a certain purpose.

They observe and analyze the impact of these short-term changes on energy consumption for that purpose. They also consider the impact of the investigated changes on the level of comfort and convenience of the users of the school building: if habits and behaviours change, is that likely to disrupt functional and pleasant living in the school building? What are the chances of them being accepted and adopted? How can people be helped to adopt them?

They calculate the potential for improved energy efficiency in the school building, if the investigated changes in everyday behaviours and habits are adopted in the long term.

Things to investigate include:

- *Changes in the use of lighting in the course of a day, linked to the variation in natural light or the needs for lighting during different activities*
- *Use of different kinds of lighting technologies*

- *Changes in the timing and duration of the use of heating and/or cooling*
- *Changes in the timing and duration of ventilation of the room (opening the windows, use of fans)*
- *Changes in the timing and duration of the use of window curtains, blinds, etc.*

In short-term investigational activities (e.g. a teaching session or a few hours within a day) will involve aspects of energy consumption that can be observed and investigated in such a short time span, such as:

- *the consumption of energy by an electrical heater or cooler,*
- *the consumption of energy by certain lighting devices,*
- *the effect on room conditions of certain ventilation or sun-blocking practices, etc.*

In medium-term investigation activities, observations and experiments may be distributed over a number of days or weeks, so that they can take account of patterns emerging only over longer periods. E.g. referring to energy consumption in different times of the day over a week, or in periods of normal operation compared to weekends, or allow comparisons linked to the weather, etc. The use of historical data further widens the time window for the investigation, e.g. allowing for comparisons linked to seasonal variation of natural light, temperature, etc.

Part of the investigation can be 'what if' scenarios and calculations, such as of the equivalent of certain energy uses in CO_2 emissions, e.g.:

- *What would be the saving in energy used for heating if we reduced inside temperature by 2oC on a cold winter day, and on a warmer winter day?*
- *What would be the saving in energy used for lighting if we reduced the time of use of the lights by x minutes, or if we changed the lighting technology?*

Using the GAIA Challenge for the 'Action Mission'

The teacher can create a 'footprint' of the Action Mission in the game environment of GAIA Challenge, with which students are already familiar.

Apart from the five Knowledge Missions, GAIA Challenge also includes Action Missions. Action Missions are by default hidden on the Quest Map, and can be activated by the teacher for a particular Mission Team. Then, the Action Mission shows up on the Quest Map for the next 14 days for the students of the Mission Team. During that time, Mission Team members can play with the Action Mission in GAIA Challenge. After this 14-day period is over, the Action Mission is automatically closed and cannot be reopened for this team.

Using their advanced user rights in GAIA Challenge, the teacher accesses the Mission Team Management area to start the Action Mission. They carefully select the time for this, as the Action Mission can only be started once for every Mission Team. After the activation by the teacher, the Action Mission appears on the quest map of the students participating in this particular Mission Team, for the next 14 days.

Working with the GAIA Application during the Action Mission

To conduct the data-based learning activities, teacher and students use the GAIA Application Building Energy Management Application, or, in short, the 'GAIA Application'.

Visiting the Sensors page in the Application, they can view the current values of all sensors and meters of their building. By clicking on a sensor, they view its history in a chart presenting the last recorded values.

The GAIA Application can be used by teachers and students on both computers and mobile devices (tablets, smartphones). In addition, it has been designed for access by both students and teachers, at a different level of access rights for each group. The teacher will decide if they will use the GAIA Application themselves 'centrally' and project their screen (or even use printouts) to show the content to their students, or if they will allow their students to become users of the Application directly.

Participatory sensing

Teacher and students can use the relevant area of the GAIA Application to upload measurements they wish to keep track of. User-inserted values appear in the Application as 'virtual sensors'. With their teacher account, in the Sensors page the teacher can to add a virtual sensor for their school, name it appropriately, and link it to a corresponding category. After this virtual sensor has been added, the teacher, as well the students through their own accounts, can upload values to the system for this virtual sensor.

They can add these values using a computer, or mobile devices (smartphones, tablets) with the Participatory Sensing app offered by GAIA. They simply select one of the virtual sensors that have been created for their school, they type in their measurement, and they save it. In addition, they can also use the Auto Gathering function of the app to add *values that are automatically provided by their device, such as luminosity measurements.*

Working with diagrams

By default, the Application presents the available data of the buildings through diagrams. Teacher and students view the recorded data in the form of charts, where the x-axis represents time and the y-axis the chosen measurement.

Teacher and students can choose to view the data in a bar chart or a linear chart. Placing the mouse on the chart, they can view the exact value for a specific time. Next to the chart, the system also presents the daily and monthly average values.

The chart presents the last 48 recorded values. Using the relevant features of the Application, teacher and students can set a specific timeframe for which they want to view the values, and thus alter granularity: "Per 5 minutes", "Per Hour", "Per Day", "Per Month". They can also zoom in an area of the chart.

Teacher and students can save the diagram locally on their computer in the form of an image. In this way, they can print it, or use it as content for their Portfolios and other reports.

Working with numerical data

In addition to presenting the data in charts, the Application also offers the possibility to download the data in the form of lists of numerical values. This offers additional possibilities for mathematics, science, or even IT learning activities.

Making comparisons

Making comparisons between data from different contexts is central to the data-based learning activities. Teacher and students can use the Application to draw comparisons of one or more of the following types:

- *Within the same building (typically, their school building)*
  - *Values from the same sensor/meter in different time frames*
  - *Values from different sensors/meters in a given time frame*
- *Between different buildings*
  - *Total building measurements*

In the Application, students and teachers are facilitated to draw such comparisons through combinational charts of the chosen measurements.

Working with the floor plan

The Application includes the Floor Plan feature, which can offer additional teaching opportunities. The Floor Plan page depicts the top view of all areas of the building that are being monitored. Clicking on it, teacher and students can see the sensors located in the chosen area and their measurements, and thus have a summary view of the status of the building on a "realistic" depiction of its floor plan. Note, though, that the Floor Plan represents an abstraction rather than an accurate map of the building.

In addition, using the feature available for editing the Floor Plan, teacher and students can experiment with different arrangements that may serve them better in their projects. Note that the arranged view of the Floor Plan is saved locally, and therefore different computers may have different depictions of the plan.

Week 5: Reporting on Action Mission and deciding on long-term action

In this phase, having just completed the Action Mission, students report on it and tis the results in a Portfolio, and. Based on their experiences and findings, decide on relevant long-term action for energy efficiency.

Reporting through a Portfolio

Students share their experiences and achievements in the Action Mission by developing a report and having a Portfolio uploaded by the teacher in GAIA Challenge. During the Action Mission, students of the Mission Team have worked collaboratively to collect and generate content for this Portfolio. When the Action Mission is completed, students author the Portfolio in a first version, in which they report on their experiences, achievements and findings in the preceding two weeks of the Action Mission. They can use texts, images, and videos from YouTube or Vimeo, in different combinations. When it is finished, the teacher uses the content prepared by the students to submit the portfolio for the Mission Team. The teacher can do this using their GAIA Challenge teacher account with advanced user rights allowing them to access the Mission Team Management area to submit.

Deciding on long-term action

Based on their experiences from the Action Mission, students decide to take long-term action to improve energy efficiency in a wider timeframe, i.e. during several weeks or months.

Through discussion, students realize that to achieve noticeable results on the energy consumption of the school building their action requires longer-term engagement over several months. The timeframe of a school year, or of a substantial part of it, is useful for setting an ambitious target and motivating the school *community to work towards achieving it under various weather conditions during the different seasons.*

Long-term action builds on and extends the observation and investigation activities conducted during the Action Mission. While preparing towards their decision for certain action, and then as they start implementing it, students continue doing data-based activities expanding on what they have already done during the Action Mission. During the action phase, they continue observing and analyzing the impact of the longer-term changes in everyday school behaviours and habits on energy consumption, monitoring their course towards achieving their goals.

Students' reporting to the school (e.g. the building manager, or the head teacher) on energy use for a certain purpose and action required to improve energy efficiency can also be an engaging practice. Just indicative examples include students asking the manager, based on the analyzed data, to change the threshold value of the thermostat for heating or cooling, to change the kind of bulbs used, to use timers, to make changes in the use of the building to exploit better its orientation and other characteristics, etc.

Regular monitoring through alerts and notifications

Long-term engagement in action can be further fuelled by automatic notifications sent to teachers and students by the GAIA platform based on the data gathered through the monitoring infrastructure, e.g. when:

- *temperatures recorded in the building indicate excessive use of heating or cooling*
- *lights are on in rooms where no motion is detected*
- *data gathered indicate that all lights are on while just half of them, maybe natural light alone, would suffice to provide proper lighting conditions, etc.*

The Application offers the possibility of defining rules that generate automatic notifications when certain values are observed in the data from the school building. This offers a very useful element for the long-term action projects of the students.

The students can ask a user with managerial rights (e.g. the building manager) to define an alert rule on the measurements of particular sensors. This rule will generate notifications, which the building manager will be able to see in the corresponding page in the Application. In addition, students can also have a rule defined, which will send notifications to the email of the teacher, or any other email address.

Students name, describe the rule, and define the message to appear when the rule is activated. They choose the relevant sensor and they use operators (<, >, or =) to formulate a rule involving a threshold value. E.g., when the humidity in the room is higher than 35, the message "Open windows" will appear.

Weeks 6-7 and beyond: Community involvement and playful social engagement

Throughout the education path of GAIA, in the context of social networking and mild competition among classes and schools in the GAIA Challenge, students share their experiences and achievements in the activities, and teachers share news on the progress and completion of the activities and its results. In this final phase of the activity cycle, community involvement and social engagement become the focus, in parallel to the long-term action that has started.

Informing the school community

Students collaborate to produce materials and organize events within the school to inform the other members of the school community.

Informing the wider local community

Students collaborate to produce materials and organize an event addressing the local community. For example, they propose and organize synergies with their families and the rest of the local community, taking action not only in the school building, but also at home and in their local area.

GAIA community engagement games

Teacher and students design and set up a GAIA community engagement game in popular social media, aiming to raise awareness and playfully sustain the wider community's interest in, and engagement with, energy saving activities.

Final version of the Portfolio

Students prepare and submit their final report on their experiences and achievements overall in the cycle, in the form of the final updated version of the Portfolio, which the teacher eventually uploads in GAIA Challenge and social media.

After the end of the cycle: continuing long-term action

The long-term action for energy efficiency taken by the students is continued after the end of the cycle of activities, using the GAIA Application to monitor the impact.

5. GAIA methodology for activities in shorter timeframes

In this section, we describe the methodology we propose to school communities that wish to integrate GAIA energy saving activities into daily school life in timeframes considerably shorter than the whole-school-year framework we presented in the previous section. This methodology, the "GAIA methodology", is relevant to schools with installed IoT infrastructure in their buildings, which is used to monitor power consumption and other environmental parameters, as proposed by GAIA. The design of this methodology follows the overall philosophy of GAIA, but is not limited to the use of the specific hardware and software produced by our project.

In general, in order to change the behaviour of students and teachers in terms of energy consumption and achieve sustainable results, we utilize a loop-based approach focused around three pillars: raising awareness, supporting action, and fostering engagement. In the context of GAIA methodology, this is realized by following a series of simple steps, in which students and teachers successively study their environment, monitor the current situation and detect potential issues, devise a strategy to achieve energy savings and act, and then monitor and review the results of their actions.

This methodology, in general, is an attempt at combining a set of specific guidelines with certain flexibility in terms of choosing the energy domain to focus on, as well as the means to implement a strategy towards energy savings. Overall, the educational domain has many constraints on implementing innovative activities that are not in some way tied to other teaching and specific learning outcomes. In this sense, having a well-defined set of tools that provide clear and concise data, and integrating these data within a learning activity can lead to very interesting results.

We now continue with the basic steps of our proposed methodology: awareness, observation, experimentation and action. A final step suggests staying focused and monitoring progress.

5.1 Steps of GAIA in practice

Step 1 – Awareness and Preparatory steps

This step can be done either in parallel with Step 2, or before Step 2. Schools create a general profile or their building and locate the points where energy is consumed:

- *Lighting inside the building, classrooms and corridors, as well as outside the building*
- *Heating and air-conditioning*
- *Electrical appliances, e.g. water heating devices, ovens and refrigerator*
- *Equipment used for teaching purposes like PCs, lab equipment, smart boards, printers, etc.*

The timetable of the school regarding the following aspects is also noted down:

- *Days and hours in which the building is used.*
- *Classrooms used in the building and classrooms monitored by GAIA.*
- *Number of students and educators occupying the building overall and the classrooms monitored by GAIA.*

This step is useful in understanding the potential points of energy consumption in the buildings, and their relative contribution in the energy consumption of the building compared to each other.

Step 2 – Observation and establishing a baseline for energy consumption

This step involves monitoring the energy consumption of the school building for a time period that is not directly affected by class hours. This will help to identify what the energy consumption of the building is when no class activities take place in it. The following are some examples of options to consider on how to establish this baseline:

- *Days when there is activity inside the school building but no classes take place inside classrooms, e.g. on excursion days*
- *Weekends and national holidays*
- *When the school building is used by other communities after class hours.*

This is an important step in understanding what part of the energy consumption can be thought of as non-flexible, and which cannot be easily affected by the students and educators when deciding to take specific actions to lower energy consumption inside the building.

Step 3 – Experimentation and monitoring energy consumption in the school during a normal week

We now measure what the energy consumption is during a time period of a "normal" week, i.e. a week with no major schedule disruptions: for example, no excursions take place, and students and teachers do classes as usual. After having established the baseline in the previous step, this will help in identifying:

- *What is the actual percentage of the energy consumption that can be affected by the school community, i.e., the part of the total energy consumption that can be targeted without affecting the operation of the school*
- *Which will be the goals set for lowering the energy consumption and the possible strategies to achieve these goals.*

The time period during this step should be at least a week long, and could also take into account past data, e.g. data already available in the GAIA system.

Steps 2 and 3 help us to identify the portion of energy consumption in which we can intervene. Having identified in step 2 the constant energy needs that are "inflexible" and on which we cannot schedule some intervention, we can then calculate the interval between the difference in average consumption and the fixed needs. This is the part of the energy consumption of the building that we can influence, without affecting the orderly operation of the school.

Step 4 – Action to lower energy consumption and monitor the results

During a time period of at least a week, the school implements the actions scheduled by the educators to tackle energy consumption, with respect to each cycle of activity chosen by the school. For example, when the lighting thematic cycle is active, students implement specific strategies to lower lighting energy consumption. During this period, schools could choose to implement a strategy where they use the tools provided by GAIA to monitor results in energy savings daily, or weekly. The schools could also use strategies in how to implement the activities grouping students in different teams, rewarding them for positive results.

At the end of the period, each school will be able to see the result of such energy-saving actions in its building, and confirm in practice whether these actions will have any impact on the energy consumption of the school.

Step 5 – Staying focused on energy-saving actions and monitor progress

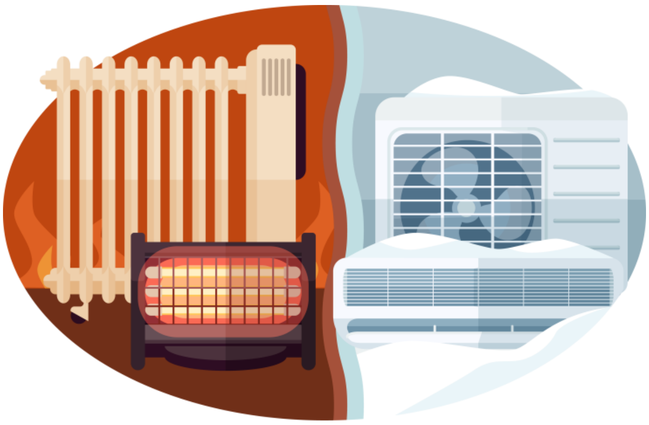
After having achieved certain energy saving results, schools should focus on continuing to monitor the results and check whether these results persist, or change in some manner. One way to achieve this step is to monitor the respective measurements weekly and reward students and classes based on their progress. Another way is through competitions, e.g. by organizing teams in the school to compete with each other in different parts of the school building.

5.2 Application of the methodology

During the GAIA project, several schools have utilised the above methodology, which has proved to be a simple and effective tool for the development of energy monitoring and saving activities. Some of those schools have followed the approach we proposed closely, while others chose to follow a looser version of it. The methodology was generally well-received, and it helped teachers a lot in terms of preparation before the activities, as well as reporting after the activities.

In the following Annex, you can find reports on energy-saving activities generated by a variety of schools based on the GAIA methodology template.


20 Watt



Examples of GAIA activities in schools

GAIA activities in Söderhamn, Sweden

Staffangymnasiet is the Upper Secondary School of the Municipality of Söderhamn in Sweden. The number of students is approximately 750 every year, while the number of staff is approximately 100.

Overview of GAIA activities in the school

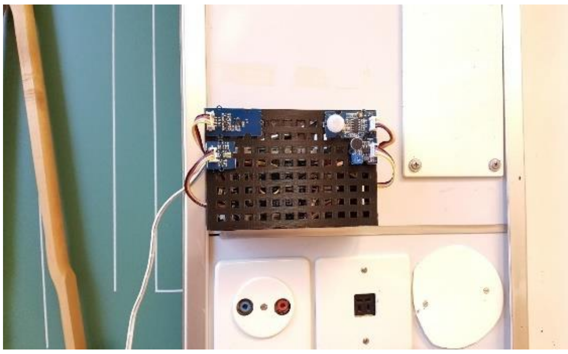
Every student at Staffangymnasiet has been invited to participate in GAIA. Teachers raised the question: "What can you as a student do and how can you engage your family and the local society?" Below we describe GAIA activities performed in the school.

Installation and configuration of infrastructure

***Goal:** To make some students more involved in the project.*

***Task:** We let the students put the Raspberry Pi´s together and connect them to our WIFI. They also designed cages for the Raspberry Pi and printed them out on one of our 3D-printer. The student also installed them in the participating classrooms.*

***Time spent for this subject:** Approximately 3-4h of lecture time.*



***Implementation:** The teacher brought the Raspberry Pi with the sensors to the lecture. The students opened all the boxes and started to investigate the material. Then they got the manual for the Raspberry Pi (provided in the end of this document) and they were assigned with the task to make the equipment work. That means: Make them collect data and send them to the right server given in the manual. Of course, the teacher stood by their side in case needed.*

***Outcome:** The students liked the task and they managed to figure it out together with the teacher. This task requires some computer skills. This task was performed in September – October 2017, and involved 15 students from the Technical program, third grade.*

GAIA-Challenge - Contest

***Goal:** To make as many students as possible to play GAIA-Challenge*

***Task:** The students played GAIA-Challenge.*

***Time spent for this subject:** 1-2 hours of class time.*

***Implementation:** One teacher started mission teams for a selected number of classes. Then he sent instructions to the mentors of these classes containing the URL to the game, the code to join their mission team, and the rules. The rules were simple: the mission team with the highest score on a given date will get cake, and the student with the highest score at the same date will get a special personal price.*

Outcome: Some classes played a lot, while some didn´t. The cake party was enjoyed! At Staffangymnasiet, this task was performed 4 times during the GAIA-project and it has involved exactly 300 students. It has been a lot of green cake!

Your shower!

Goal: To make students aware of how much energy their showering consumes.

Task: The students' task was to make measurements on their showering and calculate how much energy is needed to heat their showering water in one year. Then they were tasked to estimate how much energy they could save by changing their behaviour regarding their showering.

Time spent for this subject: 1-2 hours of class time.

Implementation: The students were given the following information:

> *Task: Find out how much energy is required to heat your shower water for an entire year, how much it costs and how much you should be able to save.*
> *Method:*
> *1. Study your shower for a week and answer the following questions:*
> *a) How long do you shower in average?*
> *b) How many times do you shower in a week?*
> *c) About how many minutes do you shower for a whole year?*
> *2. Now you need to figure out how much water you consume every minute of your shower. How you do this you must figure out on your own. Answer the following questions:*
> *a) How much water do you consume every minute of your shower?*
> *b) How much water does your shower consume for a whole year?*
> *3. You will now find out how much energy is required to heat your shower water for an entire year. To do this, you must in some way measure how hot your water is before it warms and how hot it is when you shower. How you do this you must figure out on your own. Answer the following questions:*
> *a) How hot is the water before it is heated? (The coldest water you can get out of your crane)*
> *b) How hot is your shower water?*
> *c) How many degrees did your water heat?*
> *d) How much energy does it take to heat 1 litre of your shower water?*
> *e) How much energy is needed to heat your shower water for a whole year?*
> *4. Your shower water has been heated in some way. For simplicity we assume it has been heated with a simple electric water heater. It simply adds energy through the mains. 1kWh electricity from the mains today costs just over 1sek with all taxes and fees.*
> *How much does the heating of your shower water cost for a whole year if we assume that the water is heated with an electric water heater?*
> *5. Could you reduce your showering time and temperature? Estimate how much energy and money you should be able to save on your shower for a whole year.*
> *6. How much energy and money would be saved if all the pupils of the school (approximately 1000) did the same reduction?*
> *Presenting: A short report that reports your measurements, calculations and conclusions. Photographs are a plus!*

Outcome: Most of the students that were given the task managed it well. They were surprised of the amount of energy that could be saved. This task has been performed with approximately 30 students during the GAIA-project. All of them from the Science program.

Temperature inside classrooms

Goal: To make students aware on temperature regulation of buildings and how to optimize it.

Task: The students' task was to study data from the Raspberry Pi in one classroom and out of these make suggestions on how the building manager could change the behaviour of the system to reduce energy consumption.

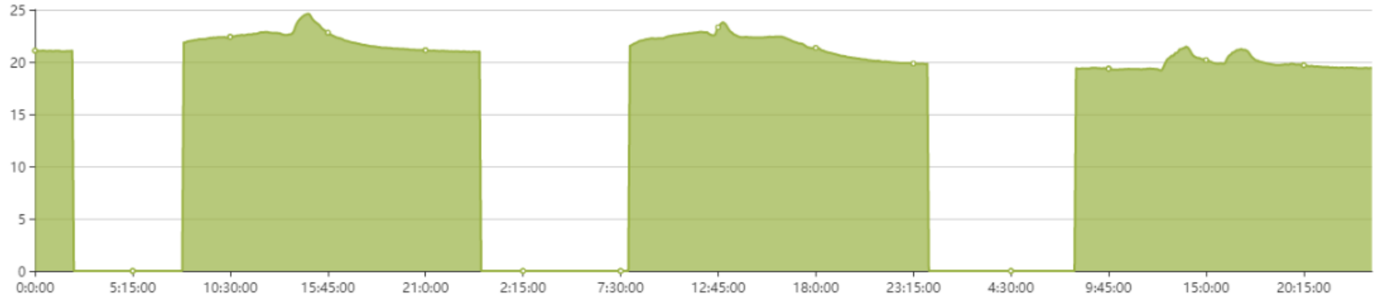
Time spent for this subject: 1 hour of lecture time

Implementation: The students were given the following information:

> *Task: Study the temperature in room 222 and based on these measurements provide suggestions for energy-saving actions.*
> *Method: We have installed Raspberry Pi with different sensors in many classrooms. To access measurement data from these, use the BMS. When you log in, you will get a list of all GAIA schools - you can read sensor values from schools in Greece, if you like!*
> *Your task is to study the temperatures in room 222 and determine if the heating system is properly set, or need to be adjusted.*
> *In order to save energy, the heating system should lower the temperature in the classrooms during the afternoon and night, and warm them up to 20 degrees in the early morning.*

Study measurement data from room 222 to determine how well the temperature control works. Presenting: A short report with suggestions for changes to save energy. Screenshots showing the measurement data you refer to.

Outcome: *The students found some adjustments to be made in some classrooms. The building manager made the adjustments. Below you can see how the temperature was lowered in room 222; the values that appear as 0 in the night hours are due to the sensor nodes being turned off. The spikes you can see is due to students occupying the room.*



This task was performed in November 2017 by 15 students from the Technical program, third grade. More students have been involved in similar assignments during the GAIA-project.

Lighting in classrooms

Goal: *To make students aware of the energy consumed by the lighting in our building*

Task: *Students were tasked to study data from the Raspberry Pi to investigate how much energy could be saved by turning of the lights when they were not needed.*

Time spent for this subject: *1 hour of lecture time.*

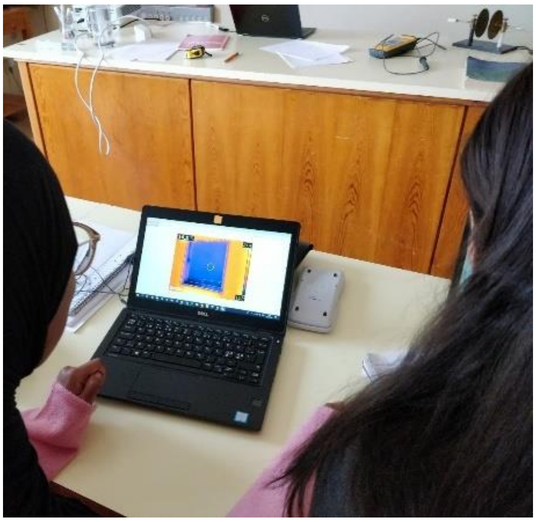
Implementation: *The students were given the following information:*

Task: Find out how much energy the lights in room 123 consume over a year, how much it costs and how much we should be able to save.
1. First, you need to find out how much the lights are consuming when they are on. In each luminaire there are two fluorescent lamps of 36W each. These consume 72W when they are lit. However, there is a power source for each luminaire consuming closer to 30W when the lights are on. You can thus expect a luminaire to consume 100W when it is lit. Answer the following questions:
a) How many luminaires are there in the room?
b) How much do they consume when they are lit?
2. To find out how much energy they consume in one year, you need to know how many hours they are lit. We have installed sensors in the room that show when the lights have been lit or not. Data from these sensors can be found in the BMA (link to the BMA). Answer the following questions:
a) How many hours was the light in the room lit last week?
b) How many hours would that be in a whole academic year? (36 weeks)
c) How much energy do the lamps use during a full year if they are lit as much as last week?
3. To find out how much we should be able to save by keeping the lights out, you need to know how long they were unnecessary. On the schedule page you can find the schedule for room 123 last week. Answer the following questions:
a) How many hours was there a lecture in the hall?
b) How many of these were during daytime when the light should not be ignited?
c) How many hours did the light need to be lit?
d) How much energy would the lamps do in a reading year if they were only lit when needed?
4. The lamps are powered by electricity from the mains. The school pays about 1 sek per kWh of electricity we consume. Answer the following questions:
a) How much money could we save in a school year if the light in the room is only lit when needed?
b) How much would it represent for all the school classrooms if we assume they are used in the same way as this room?

Outcome: *The students found out that there was nothing to save here – the lights were only lit when they were needed. Instead they suggested that we could change the fluorescent lights to LED instead. So, the students did exactly this, as you can see in the following pictures.*

Checking the insulation

Description: *Students at Staffangymnasiet's science program examined one of the school's buildings with a thermal camera. The goal was to find prominent heat leakage. Since Söderhamn is so far north, heating its buildings is the single largest energy consumer. Reducing this is of great interest. The students quickly realized that the windows are the absolute weakest link in this building. They suggested that these be replaced with new, modern windows with better insulation ability.*



Application of GAIA methodology in Söderhamn

We now proceed to describe a complete application of the methodology in one of the GAIA schools, in order to explain a bit better how we envisioned its implementation in GAIA's schools. Söderhamn and Prato were the first GAIA schools to apply this procedure. We also briefly discuss some other more focused examples of discoveries of existing energy-related issues inside school buildings.

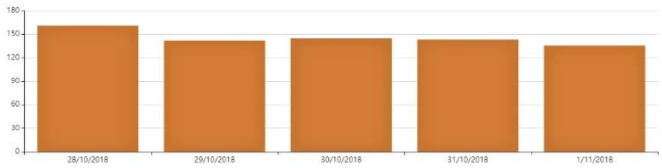
As a part of its activities in the project, the school monitors the electrical energy consumption in one its buildings. The thematic cycle chosen by the school for GAIA focused on electricity consumption, attributed mainly to electrical appliances and equipment used during classes. Since this is a technical high school, there are many computers and other related equipment used for a number of hours each day. The school used the methodology as a means to organize an intervention to lower energy consumption engaging mainly the students to act, and the teachers to understand better the patterns of energy consumption and identify the long-term impact of GAIA interventions. This task was performed during November – December 2018 and involved 300-400 students and approximately 20 staff. The goal was to make students aware of their possibility to save energy. The task given to them was simple: save as much electrical energy as possible during one week. With respect to time spent for this subject, almost no lecture time was dedicated by the school, but a lot of time was consumed in preparations for the arranging staff.

Step 1 Awareness and Preparatory steps

The building overall contains eight classrooms, one computer room, one room with 3D printers and laser cutters, three teacher rooms and a couple of small study rooms. Teachers in the school and mapped class hours that are conducted inside the classrooms in the monitored school building. During an ordinary week, in general the building is used for approximately 140 hours of lecture time. This amount of lecture hours varies depending on things like excursions and visits to external sites.

Step 2 Observation and establishing a baseline for energy consumption

The first thing the school did was to measure how much energy the building consumes when it is not occupied. They did that during a week of no class, and specifically the 44th week of the year, which is a holiday period for Sweden. That week the school kept the ventilation running as if it were an ordinary week. The graph below shows the consumption during that week. The higher consumption on Monday is because there was some staff working in the building that day. The reduced consumption on Friday is due to the fact that the school shut down the ventilation one hour earlier on Friday as is done during a typical school week in most schools. The school's baseline consumption was calculated from this week.



Electric energy consumption week 44, the baseline week

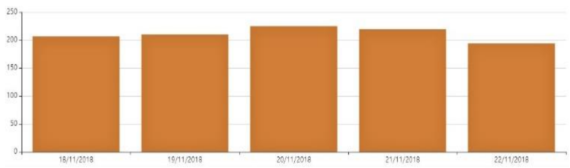
The mean value for this week was calculated as follows:

1) *Calculating the mean value for Tuesday Thursday.*
2) *Approximating the consumption on Monday as the mean value from point 1. This is because the ventilation is turned on the same time during those days. We could not use the real consumption from Monday due to staff working this day.*
3) *Calculating the mean value for Monday Friday.*

This was done because the ventilation is turned off earlier on Fridays, and the fact that there was staff working on Monday. The mean value for this week was 141,9kWh/day (calculated as described above). This will essentially be the baseline for this school building.

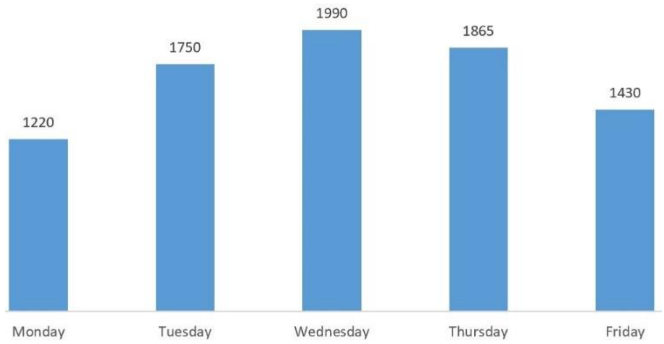
Step 3 Experimentation and monitoring energy consumption in the school during a normal week

The next thing to do was to measure the consumption during a regular week. The best week for that was week 47. During this week, all student groups were on site, with no field trips and absent teachers. Below you can see the consumption during this week:



Electric energy consumption during week 47, the comparison week

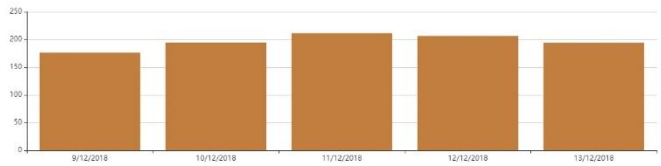
As you can see, the consumption varies over the week, and that is due to the different amount of lecture time for each day. Below you can see a graph showing the lecture time in the building within the same week. Consumption clearly correlates with the room usage, with a mean value that week of 211 kWh/day.



Room usage during week 47 (minutes)

Step 4 Action to lower energy consumption and monitor the results

Week 50 was the energy saving week for the school in Söderhamn. This week, all the students and staff were told to turn off electrical equipment when not needed. Several students were monitoring the building and turning off equipment not in use. At the same time, two groups of students competed with each other in the GAIA Challenge game. Below you can see the consumption for this week:



Electric energy consumption during week 50, the energy saving week

The mean value for this week was 196,5 kWh/day. During this week, the school was slightly more occupied than the comparison week (week 47), due to students working until late to finish the preparations for a Christmas show. When we subtract the baseline consumption from the comparison week and the energy saving week, we ended up with a reduction of the energy usage by 21% during the energy saving week. The difference with week 44 and the baseline, is essentially the part of the energy where the school can intervene. Below you can see a table summarizing some interesting measurements.

Consumption mean values per day

Week	Consumption [kWh/day]	Consumption relative to week 44 [kWh/day]
44 – Baseline week	*141,9*	*0*
47 – Comparison week	*211*	*69,1*
50 – Energy saving week	*196,5*	*54,6*

Total students:	750 (approximately)
Directly involved:	400
Square meters:	15,020 m^2
Volume:	54,057 m^3
Working schedule	45 hours/week

Inside the building, the following infrastructure has been installed:

- *7 x Raspberry Pi to measure Temperature, motion, humidity, noise and luminosity;*
- *Electrical energy meter for whole school to measure Electrical energy consumption;*
- *Electrical energy meter for part of building C to measure Electrical energy consumption;*
- *Heat energy meter for whole school to measure Heat energy consumption.*

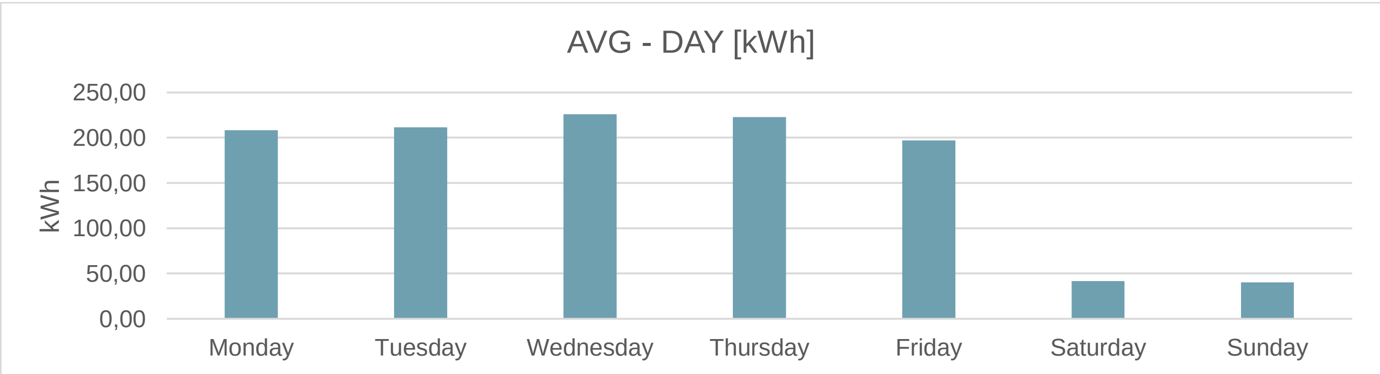
Energy consumptions before energy saving activities

The average – day chart shows the energy consumption during a week inside the school. It is almost constant during the workweek days (from Monday to Friday) with a daily consumption of about 213 kWh per day. During the weekend there is the minimum of consumption with a value of 41,6 kWh on Saturday and 40,2 kWh in Sunday. The week average is 164 kWh/day and 1147 kWh/week.

The work activities determine more energy consumption for 172 kWh/day equal to 83,5%. In terms of money, we are talking about 20 €/day.

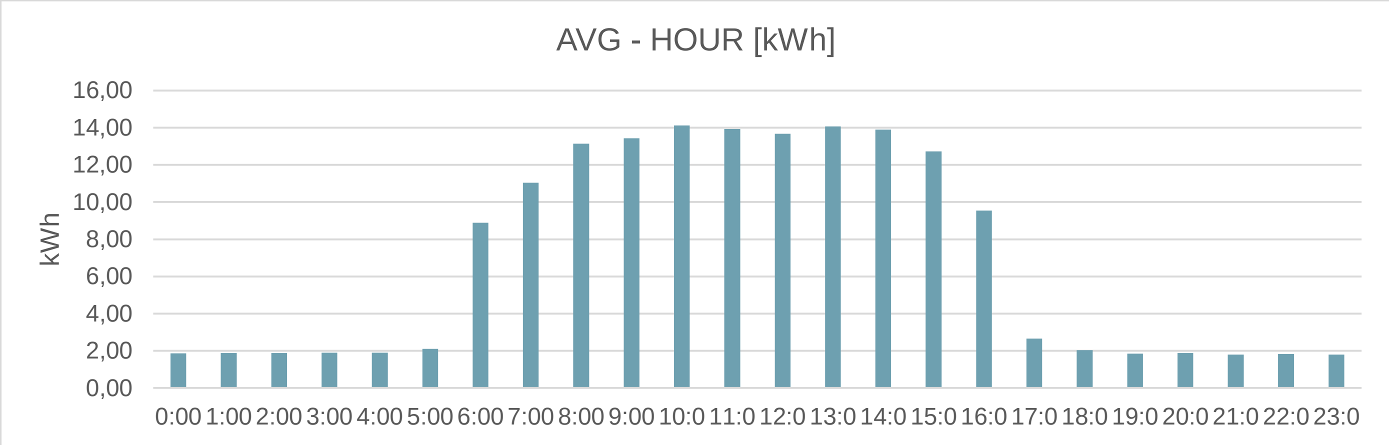
In the average – hour chart you can see that there is perfect correlation between working hours and energy consumption, in fact the energy consumption is minimum during the night and grows up from 6:00 to 8:00. Then, it remains constant till 15:00. In the afternoon, energy consumption begins to decrease till 17:00. You have the maximum energy consumption from 10:00 to 14:00 with 13,9 kWh per hour, and the minimum from 18:00 till 5:00 in the morning with almost 2 kWh per hour. That means that the electrical utilities are switched off when the school is closed.

To better understand the level of the energy saving obtained thanks to the activities, it is possible to calculate the energy baseline due to utilities that are not possible to turn-off. The students of the school have calculated the energy baseline of the school during the period from the 28th of October to the 1st of November. They have calculated that the energy consumption that is not possible to avoid is of 141, 9 kWh/day, this is because of the ventilation that cannot be turned-off.

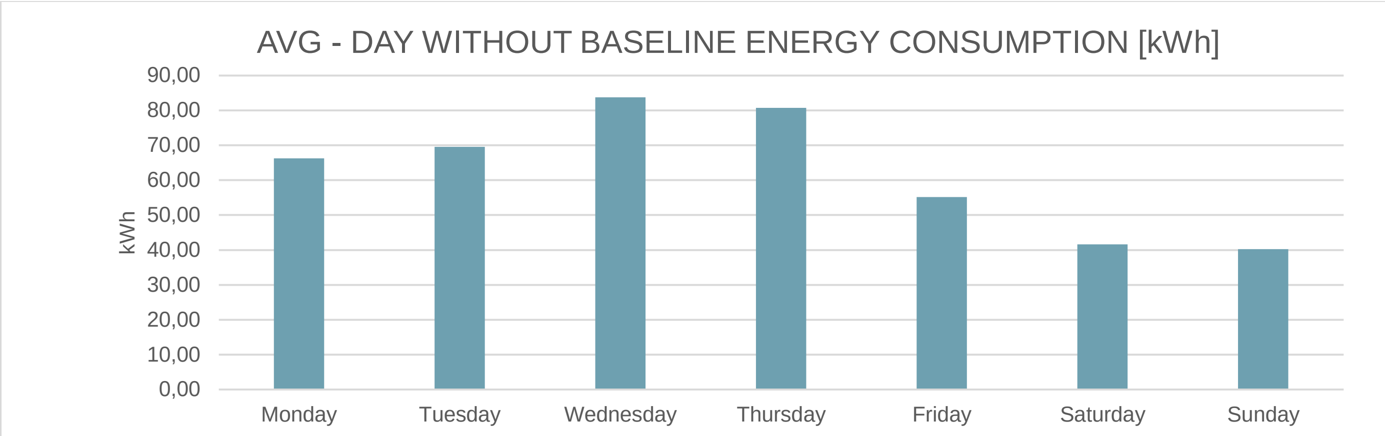


Daily average energy consumption into the school. Period 19th of November 2018 - 25th of November 2018

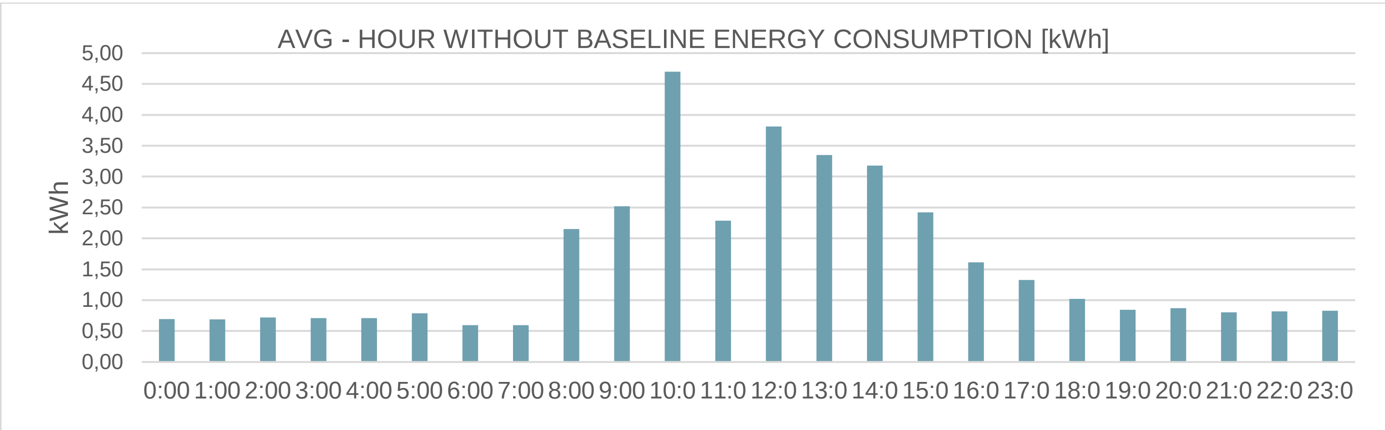
Days of the week	Average energy consumption [kWh]	Delta [%]
From Monday to Friday (workweek)	213	-
Weekend	41	-80,8%



Hourly average energy consumption into the school. Period 19th of November 2018 - 25th of November 2018



Daily average energy consumption into the school subtracting the baseline energy consumption
Period 19th of November 2018 - 25th of November 2018



Hourly average energy consumption into the school subtracting the baseline energy consumption
Period 19th of November 2018 - 25th of November 2018

Energy efficiency activities - description

In order to try to reduce the energy consumption and increase the energy efficiency of the building, the school, as described in this chapter, implemented two activities.

ACTIVITY 1 – ENERGY SAVING WEEK: The activity involved 3 steps. In the first step, students have been involved in the individuation of energy wastes into the school. During the second step, students had the possibility to try to find solutions to save energy with solutions correlated to the energy wastes seen during *the first step. In the third step, students acted to save energy. The activity had a duration of a week, from the 10th to the 16th of December.*

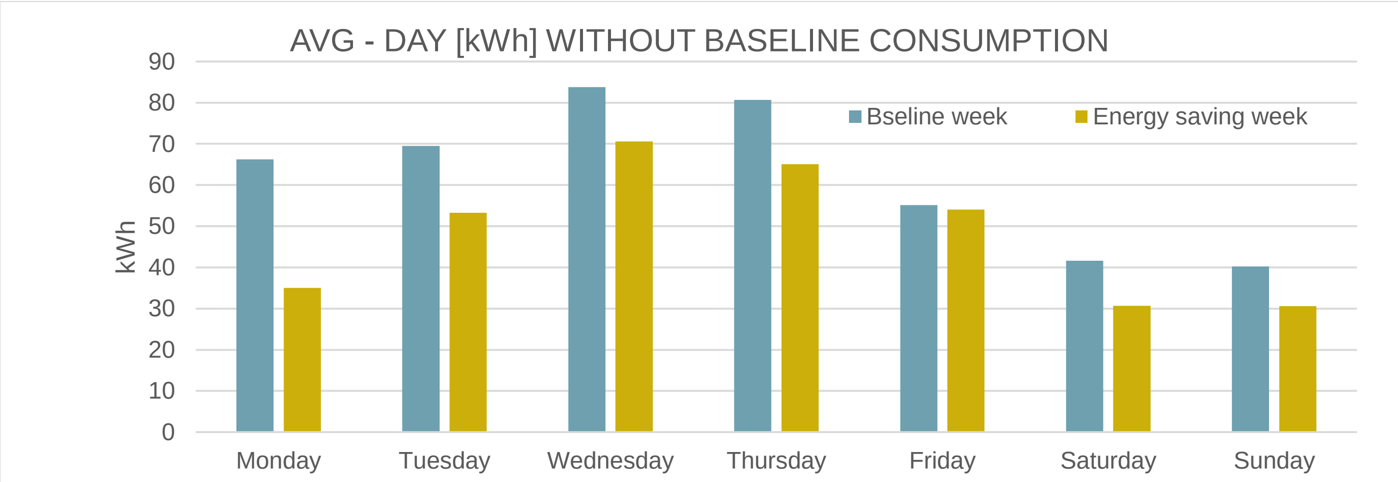
ACTIVITY 2 – LIGHTING CHANGE: All the lights into the school have been changed with the LED technology. In this way, the school can save a lot of energy thanks to a more energy efficiency technology. The activity has a duration of two years; as it started during the 2018, it is still ongoing.

Energy efficiency activities - data analysis

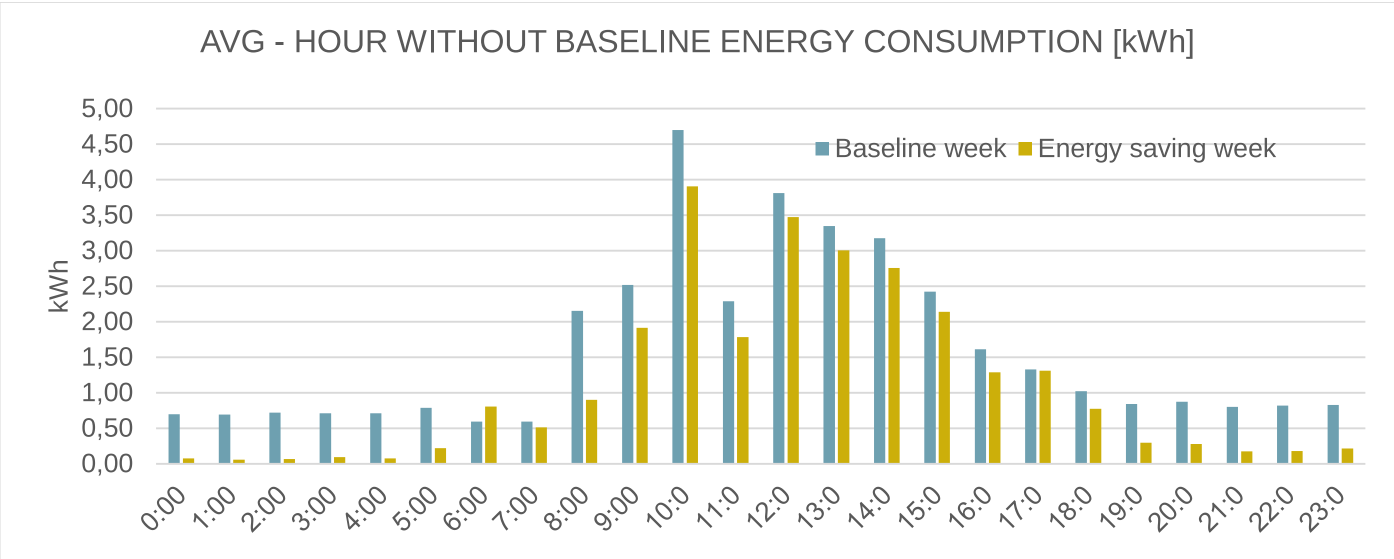
ACTIVITY 1 – ENERGY SAVING WEEK: The energy saving has been of 9% of the energy consumption of a baseline week, while is 22% if we consider the fact that there are 141,9 kWh that cannot be avoided. Numerically, the weekly energy saving amounted to 98 kWh, that in terms of money is 12€/week.

The energy saving is present during the whole week, with the best performances on Monday, while on Friday energy consumption is similar. During the weekend, energy saving is lower because of low baseline energy consumption. To understand how energy saving has been achieved could be interesting to analyse the hourly energy consumption during the energy saving period and compare it with the baseline chart.

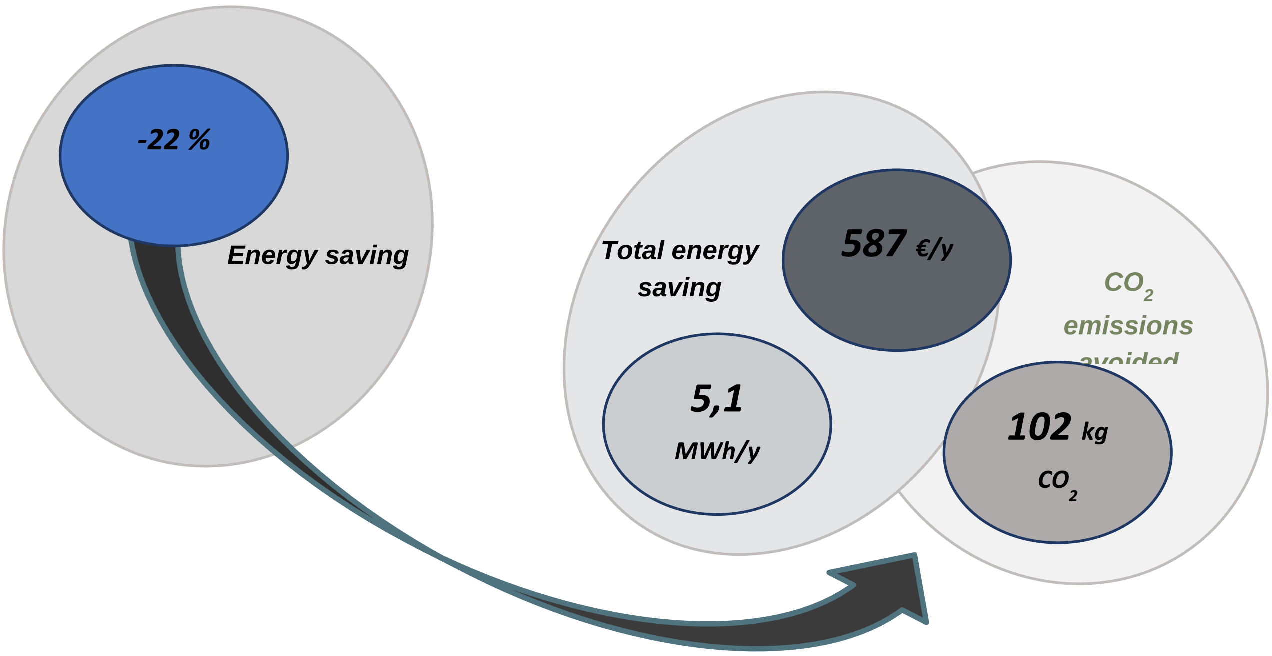
It is interesting to see how the energy saving has been achieved during the whole day, except for the transition hours except for the hours 06:00-17:00. During working hours, energy saving is high. To calculate a full year forecasting, we have assumed that the weekly energy saving could be constant for the rest of the year. Under this assumption, the full-year forecasting shows energy savings of 5,107 kWh/year, equal to 102 kg CO_2.



Daily average energy consumption – Comparison
Baseline week: 19th -25th of November 2018; Energy saving week: 10th – 16th of December 2018



Hourly average energy consumption – Comparison
Baseline week: 19th -25th of November 2018; Energy saving week: 10th – 16th of December 2018

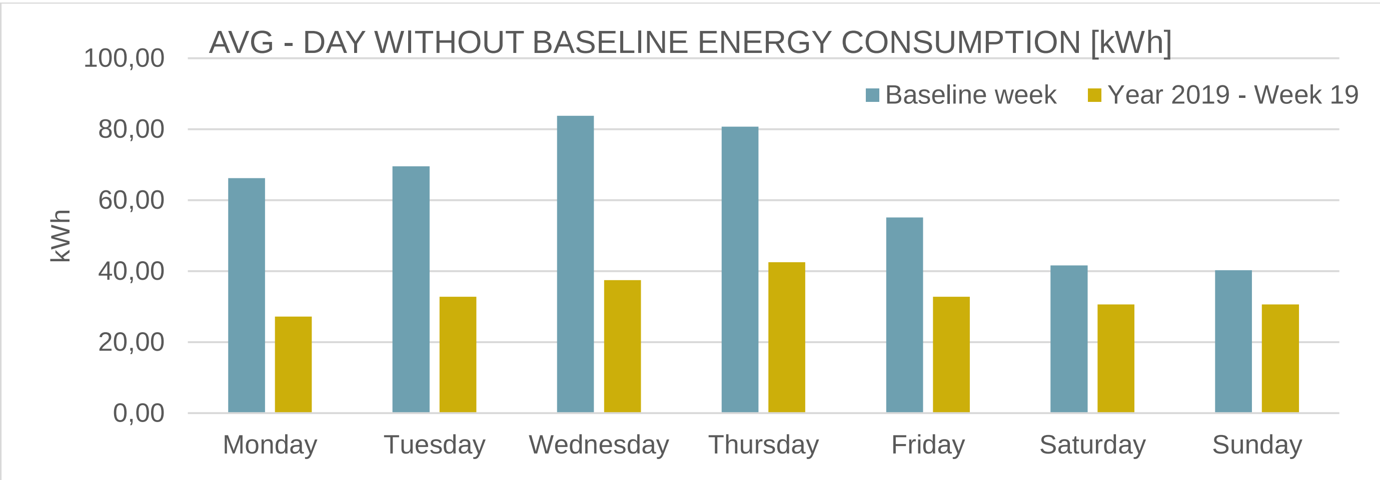


ACTIVITY 2 – LIGHTING CHANGE: *To understand the energy saving related to this activity, we need to use energy consumption of the last period because the activity is still in progress.*

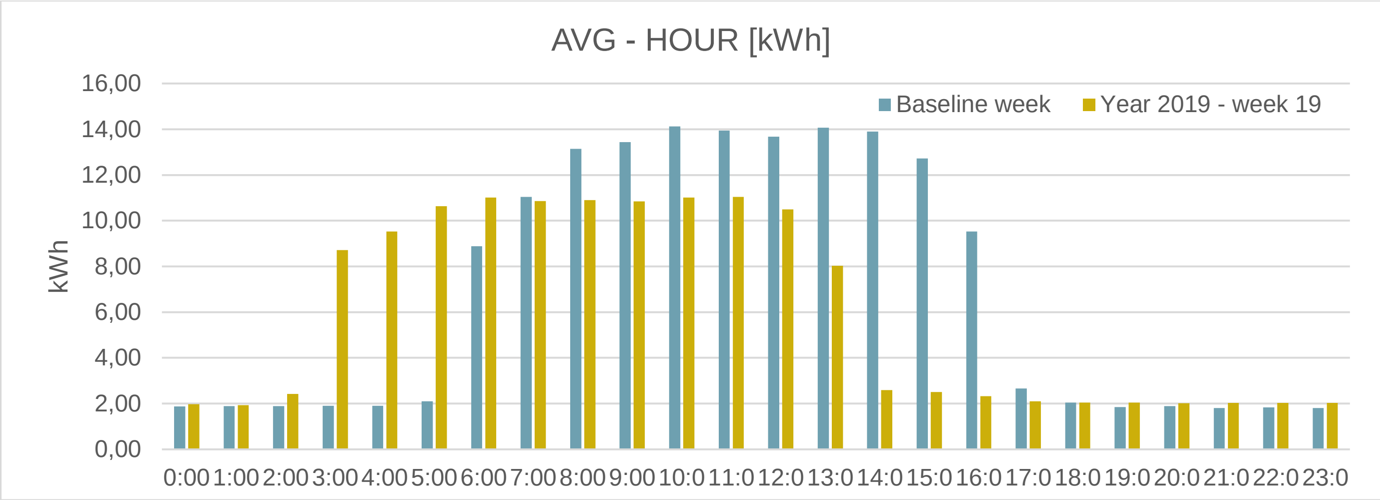
The energy saving has been of 46% of the energy consumption. Numerically, the weekly energy saving amounted to 203 kWh that in terms of money is 30 €/week. Energy saving is very similar during the week, while during the weekend energy consumption is lower.

Analysing the hourly chart, it is possible to better understand how the energy saving result has been achieved.

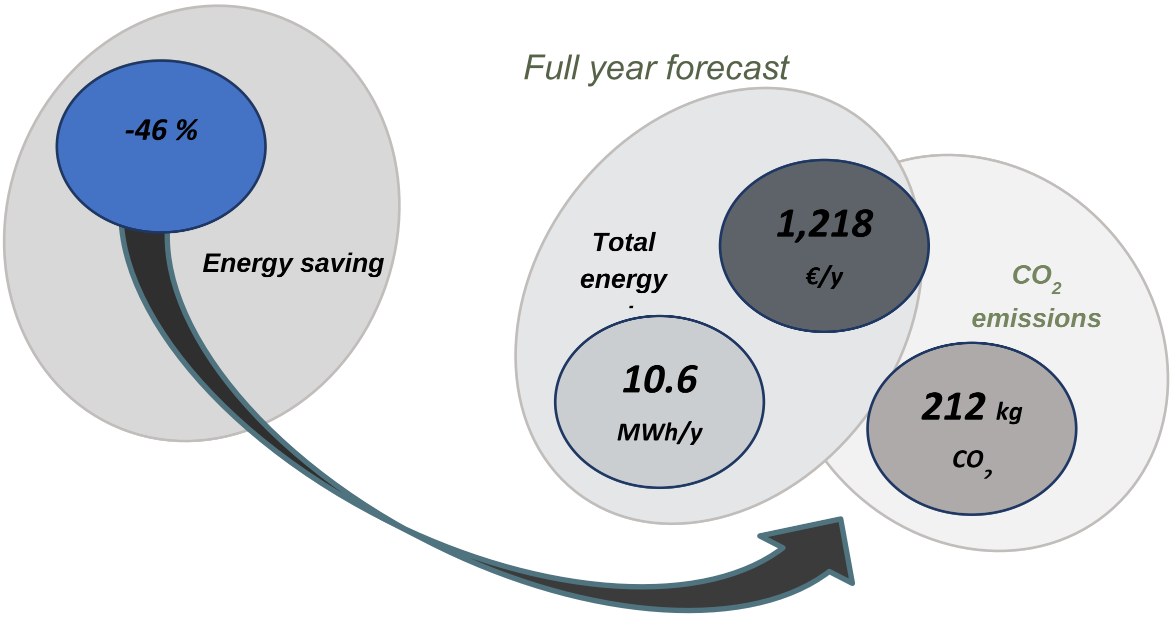
During the week 19, lights are switched on earlier than the baseline week, but they are switched off before in the afternoon. This difference can be associated at a different period of the year and luminosity is different. To calculate a full year forecasting, we have assumed that the weekly energy saving could be constant for the rest of the year. Under this assumption, the full-year forecasting shows an energy saving of 10,592 kWh/year equal to 212 kgCO_2.



Daily average energy consumption – Comparison
Baseline week: 19th -25th of November 2018; Week 19: 6th – 12th of May 2019



Hourly average energy consumption – Comparison
Baseline week: 19th -25th of November 2018; Week 19: 6th – 12th of May 2019



Comparison

Activity 1	Consumption [kWh/week]	Difference with baseline [kWh/week]
Baseline week (without baseline energy consumption)	437	-
Energy saving week	339	-98

Activity 2	Consumption [kWh/week]	Difference with baseline [kWh/week]
Baseline week	437	-
Week 19	234	-203

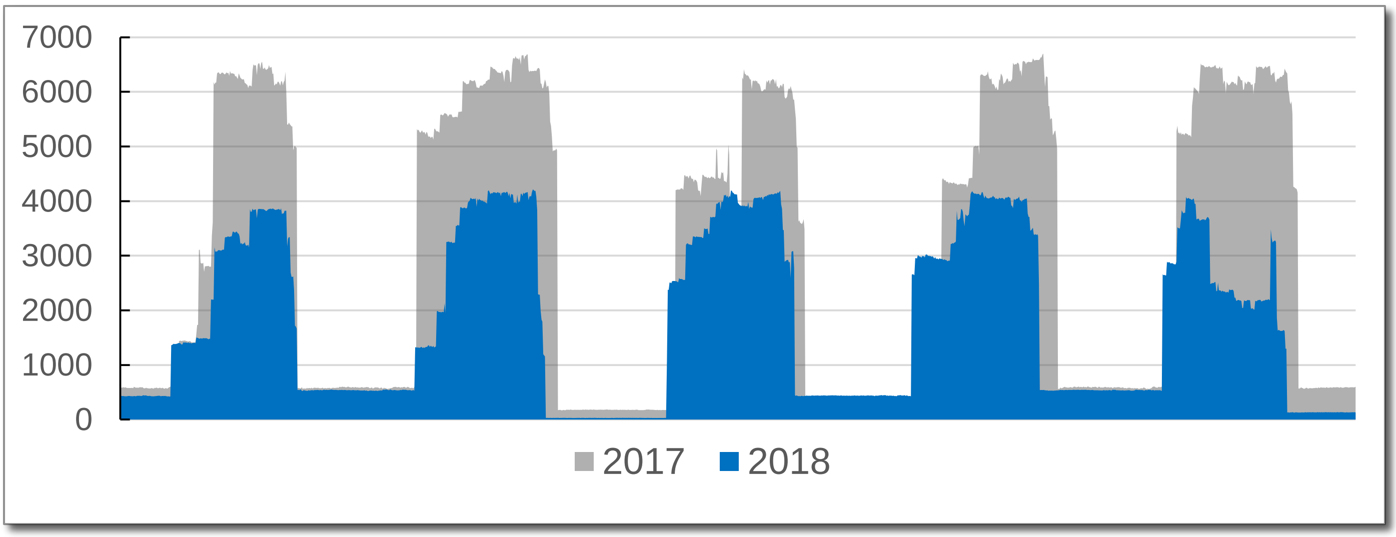
NOTES: Electricity cost: 0,115 €/kWh, National emission factor: 0,02 kg CO_2/kWh (the lowest in the EU)

In 2017 and first months of 2018, several workshops were organized to explain GAIA's objectives and involve teachers actively in designing and performing activities with their students. Three classes participated in the GAIA Contest and performed activities following the GAIA educational methodology, including participation to the GAIA Challenge, observation of sensors' measurements and energy-saving activities, while another 5 classes participated mainly to the GAIA Challenge. Two teachers have coordinated the activities of these classes. We now describe the activity carried out by the classes I ELS, II DLS and I EE of the Scientific Lyceum.

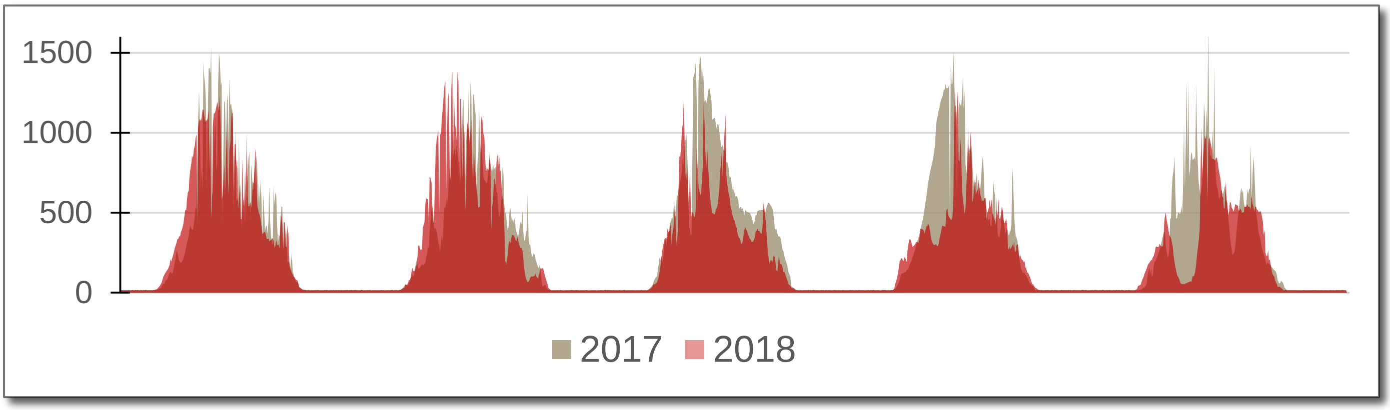
Exploit Natural Light in the school Hall

- *Thematic area: Use of Lighting*
- *Age: 14 - 15 years*
- *Number of Students: 61*
- *Goal: Exploit natural light in the hall of the school*
- *Description: Students were asked to observe potential energy wasting regarding the use of lights.*
- *Duration: 4 weeks*
- *Tools: Building Manager Application (BMA), spreadsheets*

The students noticed that in the school hall the lights are kept open from early morning to closing time no matter the brightness of the sunlight coming through the windows. Students used the BMA application to validate with data their observation by setting a threshold for a good luminosity and trying to switch off the lights. After a week of measurements, they studied the data and estimated how much energy may be saved (in kWh, money and equivalent CO2). As final steps the students created content to be shared with their mates on this theme, they also designed some possible activities to involve the school staff in energy saving, for example creating posts asking to turn off the lighting in some areas when the brightness of the natural sunlight is enough. For completing this activity, classes have been divided in teams. Each team created a complete slideshow describing all the steps. Self-evaluation strategy of the outcome: team grade given by the other groups and personal grade given by the other members of own group. Student's grade is the weighted average of the two previous. The students realized a short video aimed at involving their mates and their families.



Active Power (W). Weekdays only, 8-12 May 2017 vs 7-11 May 2018 as a sample



Luminosity in the hall (lux). Weekdays only, 8-12 May 2017 vs 7-11 May 2018 as a sample

The average luminosity recorded during the sample week is 280 lux in 2018 and 326 lux in 2017. In 2017, the luminosity has been over the threshold for 45 hours while in 2018 for 36 hours. Considering this week as sample of common usage of the hall lighting system during spring/summer we can observe a reduction in power demand of about 40% or 140 kWh. During winter months, this result is reduced but we can estimate that the target of 15% reduction has been reached in this area.

Lessons learnt:

- *The Engagement of school technical staff is very important.*
- *Direct and informal support to the teachers is vital, since they support the GAIA mission on a voluntary basis.*
- *Provide short, complete and graphically captivating material as examples of ad-hoc activity for the specific school, this has been a turning point to go beyond the awareness phase.*

School year 2018-19

Two teachers and two classes (with 30 students) have been involved in the GAIA activities in school year 2018-19. The two classes have participated to a workshop held on 13 February 2019 and organized in two parts: a seminar held by OVER about energy consumption awareness and carbon footprint and presentation of the Gaia tools, example of GAIA school activities and the announcement of the GAIA Contest by CNIT. One of these classes has then decided participating to the GAIA project and, coordinated by the teacher of Computer Science, the students have performed an activity leveraged by the GAIA NodeRed plugin.

The educational activity has been designed by the CNIT and CTI research team involved in GAIA with the help of the computer science professor. Twenty-two students of the high school participated in the activity. The activity has been carried out weekly in the 2-hours slot of computer science classes from February to end of April 2019. The students chose to monitor the temperature of their computer science laboratory, since they experienced a too high and uncomfortable heat. The availability of the Lab Kit and NodeRed (together with the GAIA plugin) allowed them to monitor the environmental conditions of the lab and correlate it with outdoor weather conditions retrieved through GAIA. They measured very high temperature values (in the range of 25-30^{o}C) also in cold days and also during night, when heating was supposed to be off. They also analyzed these data while varying the room conditions (windows on/off, curtains open/closed). Since radiators in the laboratory were not equipped with thermostatic valves, they could not turn their observations into direct energy saving actions (e.g., regulating radiators).

As an outcome of the discussion on Day 9 they elicited a set of questions and energy-saving proposals and decided to submit them to the school principal. This resulted in a 20-minutes discussion with the principal on pragmatic actions for guaranteeing comfort while achieving energy savings. The discussion was initially focused on the experimental findings in the computer science laboratory and, at the end, was extended to other critical areas of the school. The discussion ended up with a set of actions to be performed by the school principal and ideas for follow-up activities to be performed by students. In the tables below, a more detailed activity report is provided. At the end of the activity, the teacher assessed the knowledge acquired by the students through a questionnaire.

Building description

Total people:	1500
People directly involved:	80
Square meters:	12166 m^2
Volume:	63212 m^3
Working schedule	60 hours/week

List of sensors and meters installed

Inside the building has been installed:

- *3 Three-phase Power Meter (B23-112-100) to measure Active/Reactive/Apparent Energy*
- *One GPRS Gateway to measure Current for each phase;*
- *3 Temperature sensors;*
- *3 Humidity sensors;*
- *4 Luminosity sensors;*
- *1 Weather station SynField to measure solar radiation, temperature, humidity, wind speed and direction, rain gauge.*

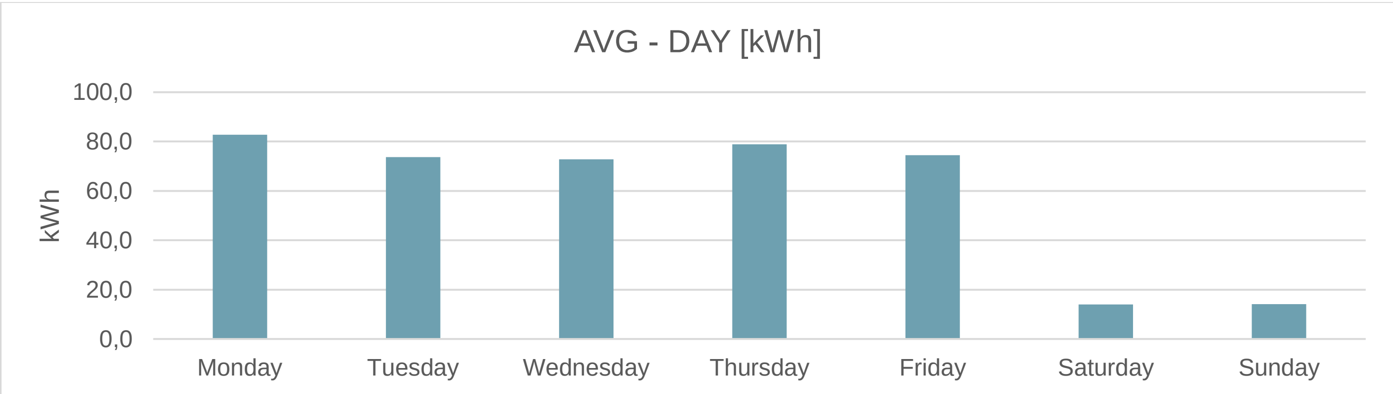
The school is open from Monday to Friday from 7:00 to 19:00 (12 hours per day). Classrooms and laboratories are used for learning activities mainly during morning hours. Some learning activities can last till the late afternoon (using classrooms and laboratories). The hall is open from 7:00 to 19:00. The administration and technical activity occur from 8:00 to 17:00/18:00. The gymnasium is open from 8:00 to 24:00 (some sports associations are given the permit to use the gymnasium in the afternoon and evening). The library and cafeteria are open from 8:00 to 17:00. The auditorium is used only for scheduled events.

Energy consumptions before energy efficiency solutions

The average – day chart shows the energy consumption during a week for the Hall (Common Area). It is almost constant during the workweek days (from Monday to Friday) with a daily consumption of about 76,5 kWh per day. During the weekend there is the minimum of consumption with a value of 14 kWh on Saturday and 14,1 kWh in Sunday. The week average is 58,67 kWh/day and 410,7 kWh/week.

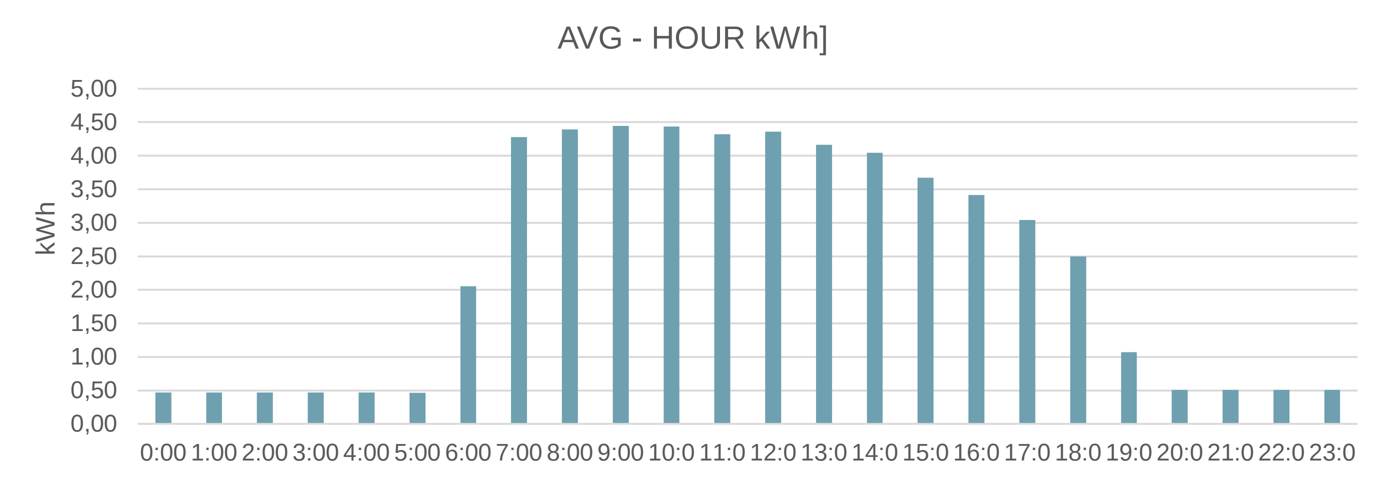
The work activities determine more energy consumption for 62,4 kWh/day equal to 81,6%. In financial terms, this amounts to about 12 €/day.

In the average – hour chart you can see that there is perfect correlation between working hours and energy consumption, in fact the energy consumption is minimum during the night and grows up from 6:00 to 12:00. In the afternoon the energy consumption begins to slow down with a speed of 0,3 kWh/h till 18:00. You have the maximum energy consumption at 10:00 with 4,43 kWh, and the minimum from 20:00 till 5:00 in the morning with almost 0,5 kWh. That means that the lights in the hall area are switched off when the school is closed.



Daily average energy consumption in the common area. Period 1st of May 2017 - 15th of May 2017

Days of the week	Average energy consumption [kWh]	Delta [%]
From Monday to Friday (workweek)	76,5	-
Weekend	14,1	-81,6%



Hourly average energy consumption in the common area. Period 1st of May 2017 - 15th of May 2017

Energy efficiency activities - description

In order to try to reduce the energy consumption and increase the energy efficiency of the building has been taken the following solutions.

ACTIVITY 1 – EXPLOIT NATURAL LIGHT: Students have been asked to observe potential energy wasting in their school about the use of lights. They noticed that in the school hall the lights are kept open from early morning to closing time no matter the brightness of the sunlight coming through the windows. Students used the BMS application to validate with data their observation by setting a threshold for a good luminosity and trying to switch off the lights. After a week of measurements, they studied the data and estimated how much energy may be saved (in kWh, money and equivalent CO2). As final steps the students created content to be shared with their mates on this theme, they also designed some possible activities to involve the school staff in energy saving, for example creating posts asking to turn off the lighting in some areas when the brightness of the natural sunlight is enough.

For completing this activity, classes have been divided in teams. Each team created a complete slideshow describing all the steps. Self-evaluation strategy of the outcome: team grade given by the other groups and personal grade given by the other members of own group. Student's grade is the weighted average of the two previous.

ACTIVITY 2 – COMPUTER SCIENCE WITH GAIA RESOURCES: The activity has been organized to achieve the following education goals:

1. *Introduction to Node-RED - Understand the concept of Internet of things.*
    - *Position the Flow-Based Programming paradigm into the set of main programming paradigms*
    - *Knowledge and use of Node-RED main nodes.*
2. *Plugin GaiaNode - Understand how relevant is extending Node-RED with new nodes.*
    - *Usage of main GAIA nodes.*
3. *Use of virtual sensors - Understand the role of temperature, humidity and luminosity sensors.*
    - *Learn how to manage GAIA sensor measurements retrieved via GAIA services.*
    - *Analyse and process data through a spreadsheet.*
4. *Development of a Web dashboard - Familiarize with HTML language.*
    - *Design and realize a small widget to visualize acquired data.*
5. *Energy consumption awareness - Observe and detect critical situations in the school concerning energy wastage.*
6. *Understand how Node-RED and the GAIA plugin may help monitoring and taking decisions towards energy saving.*

Energy efficiency activities - data analysis

To understand the energy saving obtained thanks to the energy efficiency activities we have compared the energy consumption before and during the energy efficiency activities. Here we focus on Activity 1 since this activity led to concrete results in the short terms, while outcomes of Activity 2 require long-term activities and in some part the involvement of the Province of Prato administration office.

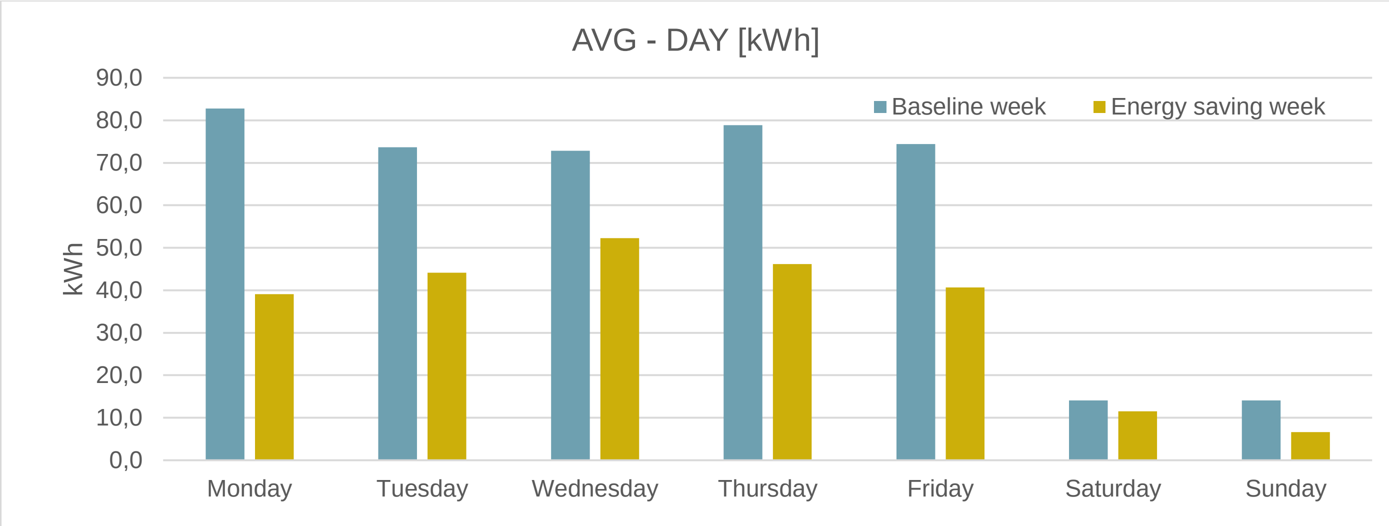
ACTIVITY 1 – EXPLOIT NATURAL LIGHT: The energy saving has been of 41,4% of the energy consumption associated with the lighting cluster. Numerically, the weekly energy saving amounted to 170 kWh that in terms of money is 32 €/week. Calculation has been done considering periods of time longer than a week. For the average baseline week has been considered the period from the 1st of May 2017 to the 15th of May 2017; for the average energy saving week has been considered the period from the 6th of May 2018 to the 19th of May 2018.

The energy saving is present during the whole week, with the best performances on Monday and Friday.

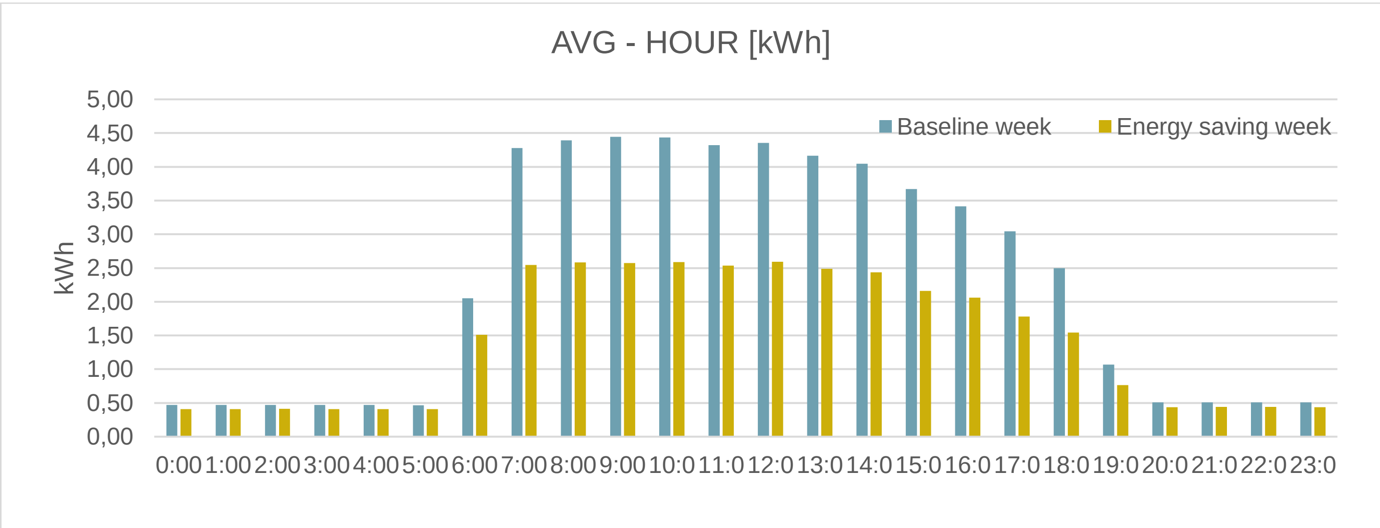
During the weekend, we have few energy saving because of low baseline energy consumption.

To understand how energy saving has been achieved could be interesting to analyse the hourly energy consumption during the energy saving period and compare it with the baseline chart.

It is interesting to see how the energy saving has been achieved during the working hours. In fact, when the school is closed, lights energy consumptions is minimum and energy saving has been rather low. To calculate a full year forecasting we have supposed that the weekly energy saving could be constant for the rest of the year. Under this assumption the full-year forecasting shows an energy saving of 8,870 kWh/year equal to 4,284 kgCO_2.

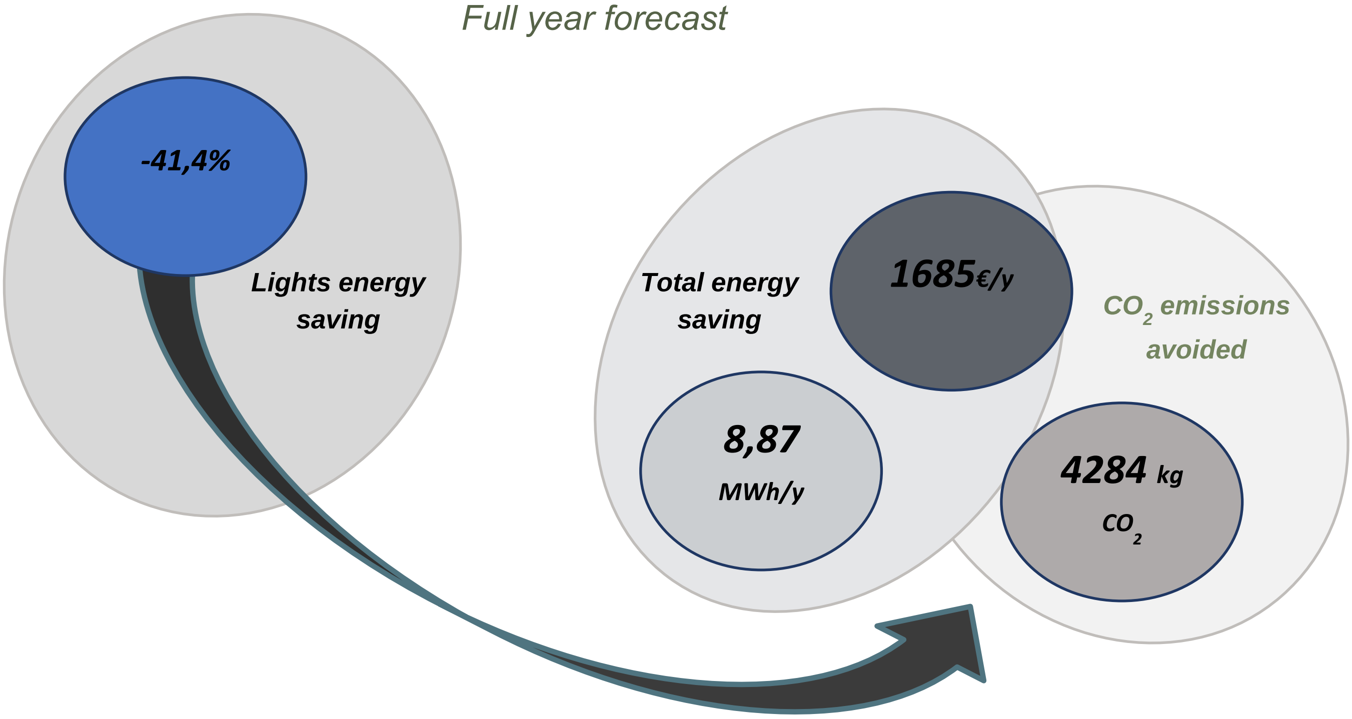


Daily average energy consumption in the hall – Comparison. Baseline period: 1st -15th of May 2017; Energy saving period: 6th – 19th of May 2018



Hourly average energy consumption in the hall – Comparison. Baseline period: 1st -15th of May 2017; Energy saving period: 6th – 19th of May 2018

Full year forecast



Comparison

Week	Consumption [kWh/week]	Difference with baseline [kWh/week]
Baseline week (lights)	410,7	0
Energy saving week	240,6	170,1

NOTES: Electricity cost: 0,19 €/kWh, National emission factor: 0,483 $kgCO_2/kWh$

In GAIA, Ellinogermaniki Agogi systematically monitored the consumption of electricity in 7 classes of the 6th grade of its primary school. One of the thematic areas chosen by the school focused on the consumption of electricity mainly from the lighting used during lectures.

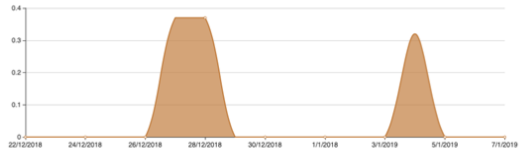
Description of the activities

1st Step- Sensitization and preparation

The building includes a total of 7 classrooms, which are monitored by the GAIA special equipment. The teacher at the school mapped the hours of teaching that took place in the classrooms of the school. During a typical week, generally the building is used for about 230 hours of teaching. This number of teaching hours varies depending on parameters such as excursions and outdoor visits, holidays, etc.

2nd Step-Observation and recording of basic energy consumption

The second thing the students did was to calculate how much energy consumes the part of the building where the classrooms are located when are not used for teaching purposes. This happened during two weeks without courses, namely the last week of the year and the first week of the New Year, which is a holiday season in Greece. The following chart shows the consumption in the halls during these two weeks. The biggest consumption occurred on Thursday 27/12, Friday 28/12 and Friday 4/1, because some of the staff were working on the building that day, so operations took place in the classrooms of the 6th grade of Primary School. Basic schoolroom consumption was calculated through weekly observations using the GAIA Building Manager App metrics.

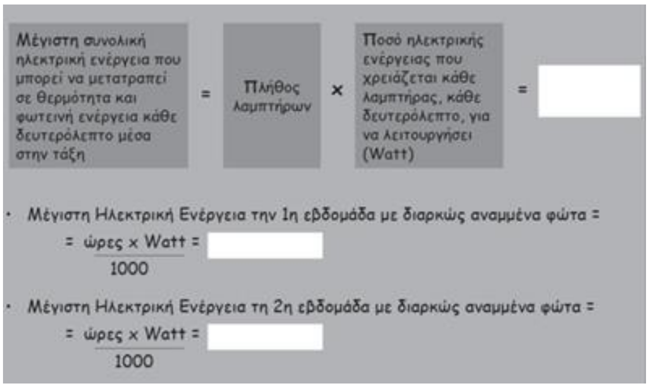


Current consumption in the last week of the year and the first week of the New Year

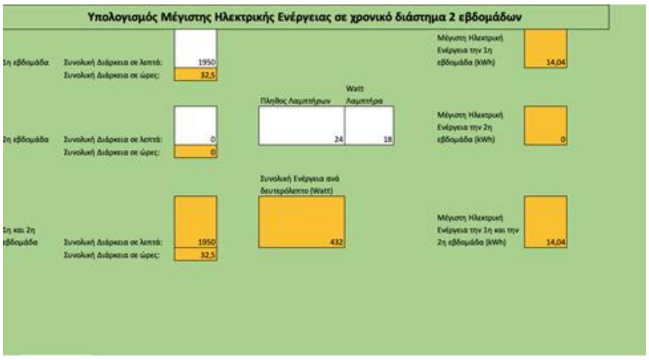
The average value for this time period was 0.35 kWh per day. This was considered to be the basic energy consumption for these halls, i.e. consumption that is inelastic, and cannot be changed easily, or its change will have implications for the way and organization of the school's operation.

3rd Step- Experimenting and monitoring energy consumption at school during a typical period

The next thing that did the school was to measure consumption during a typical week. This was done with the help of the calculations made by students during the teaching process as they had a lamp of those used to illuminate the rooms to know the Watt. With the help of the teacher, the students calculated the use in kWh during the one-week period required to illuminate their class if the lights were not extinguished at all during school hours. They verified their calculations using a spreadsheet file. Examples of these calculations are shown in the following pictures:



Calculating energy consumption by students - the comparison interval

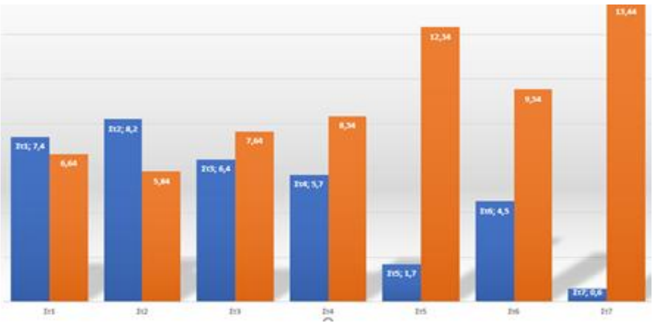


Verification of energy consumption calculations using the Excel file "CalkWh" - the comparison interval.

The average value this week was 2.8 kWh per class per day. In total, the average energy consumption for 7 classrooms of the 6th grade of Primary School is 19.7kWh. This average weekly value was used in the next step to determine the energy savings percentage.

4th Step - Action to reduce energy consumption and monitor results

In the following week, the students were asked to record the time intervals in which the lights were on during the course. During the discussion, it turned out that switching the lights off during lessons outside the classroom, during the breaks and during lessons when the weather is comfortable, helps the students to focus better during lessons in the board. After completing the recording week, the pupils summed up the time intervals where their lights were in use. They then reiterated the above calculations as well as the verification to calculate the amount of electricity they saved. From the results of all the segments the following graph emerged:



Presentation of results (blue column) and savings (orange column) of energy per segment

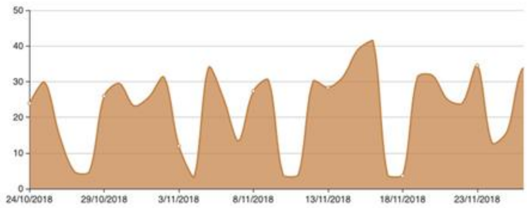
The average electricity used per room per day is 1.38kWh, while the average electricity saved per room per day is 1.96kWh. This week, the students were divided into groups, every group monitored the intervals when the class lights were on, recorded the information, and were responsible for turning off the lights when they did not need them.

With the help of the bar charts, the teacher designed and implemented a special teaching where students were faced with, assumed, compared, interpreted and eventually made connections between the necessary and unnecessary hours of lighting uses and their respective energy sources and transformations. At the beginning of the lesson, their bar graphs were presented to students as well as the information they contain. The display was made in such a way (double consumption and energy saving with bars of different color coupled per section) so that comparisons between energy consumption and energy savings can be obtained in each section separately and in all segments at the same time.

The conclusions that emerged from the discussion are as follows:

- Class ST7 managed to save all the energy it used before on lighting (there was also a relative competition that ST7 probably "cheated for their results" from other classes).
- Classes ST1 and ST2 consumed more energy than the one that saved.
- Classes ST3 to ST6 saved more energy than they consumed in the end.

The discussion with students led to the need for more data, so we used the GAIA Building Manager app where we saw the power consumption chart of all sections together (ST1 to ST7), including the two laboratories that did not participate in the activity. The graph we analyzed is shown below:

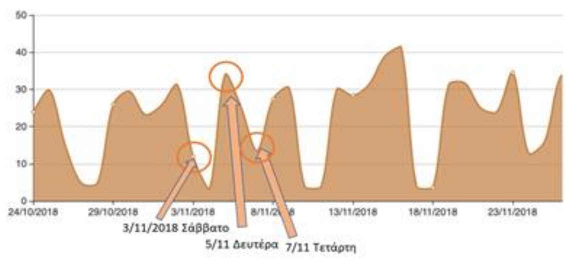


Total energy consumption in kWh.

In the first graph, the students observed the peaks and valleys and immediately came into the process to interpret what that might mean. The students searched for the calendar to see what the days of the peaks and valleys correspond to. The repeatability shown in the chart made them very impressed. The students concluded that repetitive valleys are due to weekends where energy consumption is the least possible since the school is closed. The following diagram shows the students' observations:

Student observations after comparing their calendars (a).

But then they noticed from the graph that there are some "anomalies" in this rule. These "abnormalities" are shown in the graph below:



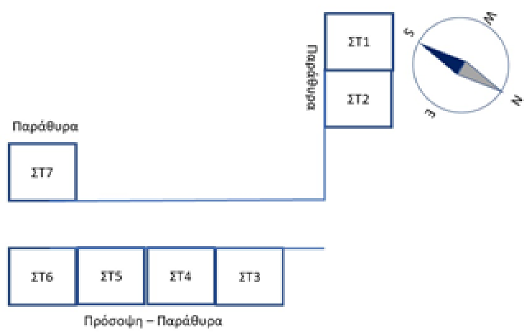
Student observations after comparing their calendar (b).

In detail, as emerged from the discussion:

- *Saturday 3/11/2018: students noticed that energy consumption is higher than other Saturdays. After we went back to the school calendar where there was no event for that day, I told the kids about the conference that was held this Saturday at school. Some students wondered why the energy consumption was increased due to the conference and then a dialogue between the children started on these grounds. The students reported their computers, lights, microphones and projectors that were operating during the conference, where they needed electricity to function.*
- *Monday 5/11/2018: In the chart, the students found a vertex slightly higher than the others. From the school calendar, they saw that the afternoon of that day was the parent's briefing from the teachers, where the lights were left open for longer than usual.*
- *Wednesday 7/11/2018: In the chart, the students found a low value that should not have been normal since it is an intermediate day of a week. But very quickly they realized that this was a day when they were not in training. Moreover, fortunately they did not forget to turn off their lights before they left.*

Then the debate returned to the "comparison" between the two departments, regarding which section of the building made more power savings from the light usage. The discussion about the bar graphs revealed the issue of the small energy consumption of the ST7 segment, where it was related to the location and orientation of the particular class. This extended the discussion to the orientation of all classes in relation to the solar lighting they have but also the needs of each class for electrical lighting according to the time of day.

Initially the students drew a sketch with their classes and how they are placed in the building. The students found that the two classes ST1 and ST2 have a similar consumption, as well as the classes from F3 to F6; ST7 is the only one that managed to save the electricity from the lights of its class. Therefore, students checked with the help of compass the orientation to see if there is a correlation. The students recorded the orientation of the windows of each class separately. In each class, the following floor plan of the sections emerged from discussion.

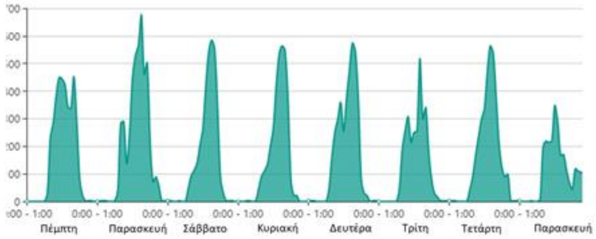


The students discovered that the orientation of their classrooms is such that:

- *Northeast-oriented sections (ST3-ST6) need their lights turned on after 11, when the sun is almost above the building,*
- *Southwest-oriented sections (ST1-ST2) need their lights on from morning until noon, because just outside their windows there are trees that block sunlight and opposite the windows there is the building of the high school,*
- *West-facing section F7 needs its lights in only in the morning as during the day it is illuminated adequately by the sun.*

The discussion on the energy savings achieved by each class, as well as the correlation with the orientation of the class, gave rise to the question of whether a class "cheated" to produce better results and did not turn the lights on while it needed them. Especially for a specific class (ST7), where it was able to save almost all the electricity from the lights of its class, as shown by the graphs, the discussion arose in all classes where the same questions were formulated which the students responded using the above information.

By taking the opportunity from the above discussion, students visited the GAIA platform and looked for the data from the brightness sensors in each section separately. The students, having explained to them what is shown in the graph and the limits of the classroom brightness so that the lesson is done in the best possible way, recognized the brightness values at different times of the day. They naturally agreed that in some parts with direct solar light, where the brightness was great, indeed the lights did not need to be on. At the same time, in their own class where the brightness was low, students saw the brightness graph of the current measurement showing how small this value is. Students at this stage recognized that they could not do an activity that requires writing or reading under these conditions.



Brightness recording of the segment that managed to save all the electricity needed for the lights

Indicatively, we report the graph from the brightness sensor of class ST7 from 4 / 10-11 / 10 per hour per day, where this time the children made the recording of the duration of the lights. This graph clearly shows that although the lights were closed during the activity, the brightness of the class was very good. In addition, the students found that the brightness remained unchanged during the weekend. After the students finally found that F7 did not "cheat" to produce their results, but also that the Sections 1 and 2 that used more energy than the ones that saved, a lesson emerged as follows: that all of the classes in 6th grade managed to save energy and that the great savings of the ST7 meet the needs of the energy-consuming parts of ST1 and ST2. The conclusion was that “the whole process is aimed at understanding that we can all save energy together according to our needs”.

5th Step - Monitoring of energy-saving actions and their evolution

The results from the students actions were summarized on a board installed inside one of the school’s corridors to inform the students’ parents about GAIA-related activities during the school year.

Total students:	2000
Directly involved:	700
Square meters:	8361 m^2
Volume:	29365 m^3
Working schedule	50 hours/week

In EA's classrooms and 1 science lab there are:

- *8 Environmental Sensor Units (based on Raspberry Pi) to measure temperature, Relative humidity, Illuminance, Motion detection and Noise.*
- *7 power meters for lights*
- *1 CO_2 metering device*

Energy consumption before energy efficiency solutions

The average – day chart shows the energy consumption during a week inside the school. It is almost constant during Monday, Tuesday and Thursday, while it is less on Wednesday and more on Friday. The workweek days (from Monday to Friday) average daily consumption is about 26 kWh per day. During the weekend there is the minimum of consumption with a value of 3,6 kWh on Sunday and 7,9 kWh on Saturday. The week average is 20 kWh/day and 143 kWh/week.

The work activities determine more energy consumption for 20,2 kWh/day equal to 77,7%. In terms of money, we are talking about 5 €/day.

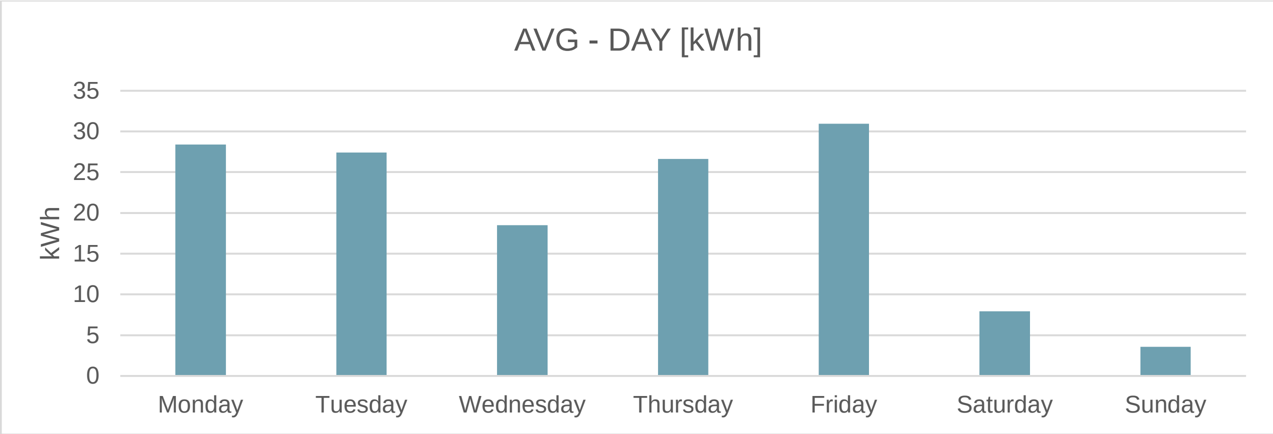
In the average – hour chart you can see that there is perfect correlation between working hours and energy consumption, in fact the energy consumption is minimum during the night and grows up from 7:00 to 8:00. Then, it remains almost constant till 13:00. In the afternoon, the energy consumption begins to decrease until 19:00. You have the maximum energy consumption at 8:00 with 2,2 kWh per hour, and the minimum from 20:00 till 6:00 in the morning with almost 0,14 kWh per hour. That means that the electrical utilities are switched off when the school is closed. In order to try to reduce the energy consumption and increase the energy efficiency of the building has been taken the following solutions.

Activity 1 – exploit natural light to save energy for lighting

The activity involved 7 classrooms (ST1, ST2, ST3, ST4, ST5, ST6, ST7). In each classroom, there are 24 lamps of 18W each, so the power involved in the activity is about 3 kW. The activity had a duration of a week during the month of October. The energy saving has been of 54% of the energy consumption. Numerically, the weekly energy saving amounted to 77 kWh that in terms of money is 19 €/week.

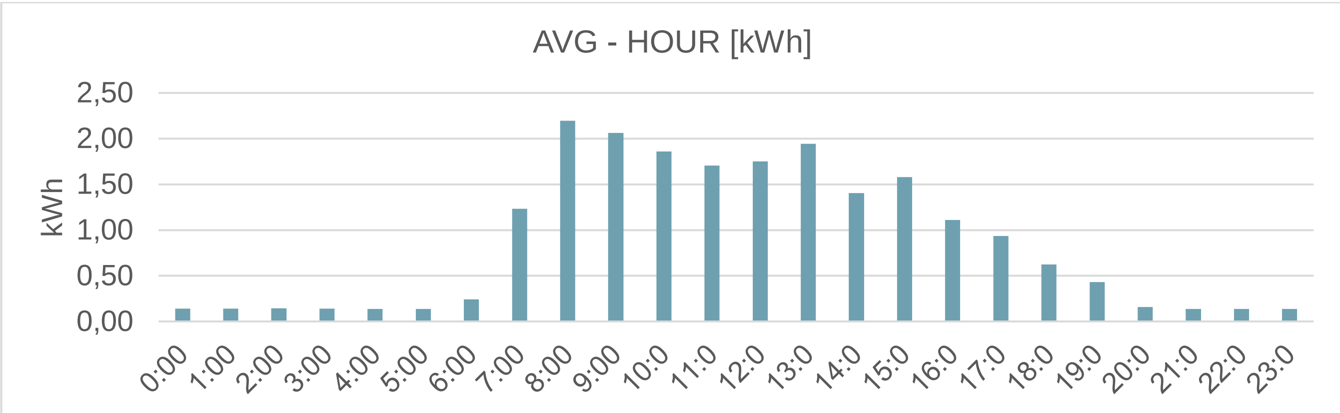
The energy saving is present during the whole week except for Sunday. The best performance has been on Friday, with 76% of less energy consumption. On Saturday, energy savings are smaller because of the low baseline energy consumption, while on Sunday energy consumption increased. To understand how energy saving has been achieved could be interesting to analyze the hourly energy consumption during the energy saving period and compare it with the baseline chart.

It is interesting to see how the energy saving has been achieved during the working hours. The energy consumption trend has been the same for the two compared periods, this means that the daily variation is due at the luminosity intensity, while the energy saving has been achieved removing the lighting of portions of the building not affected by luminosity like corridors (if without windows). To calculate a full year forecasting we have supposed that the weekly energy saving could be constant for the rest of the year. Under this assumption, the full-year forecasting shows an energy saving of 4,026 kWh/year equal to 4630 $kgCO_2$.

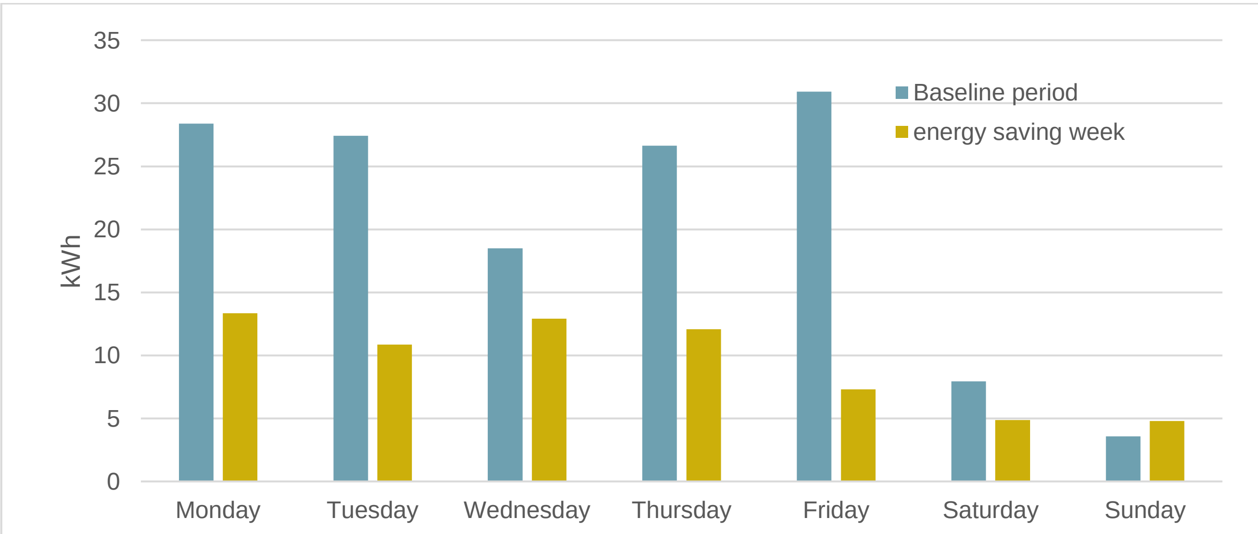


Daily average energy consumption into the school. Period 29th of October 2018 - 11th of November 2018

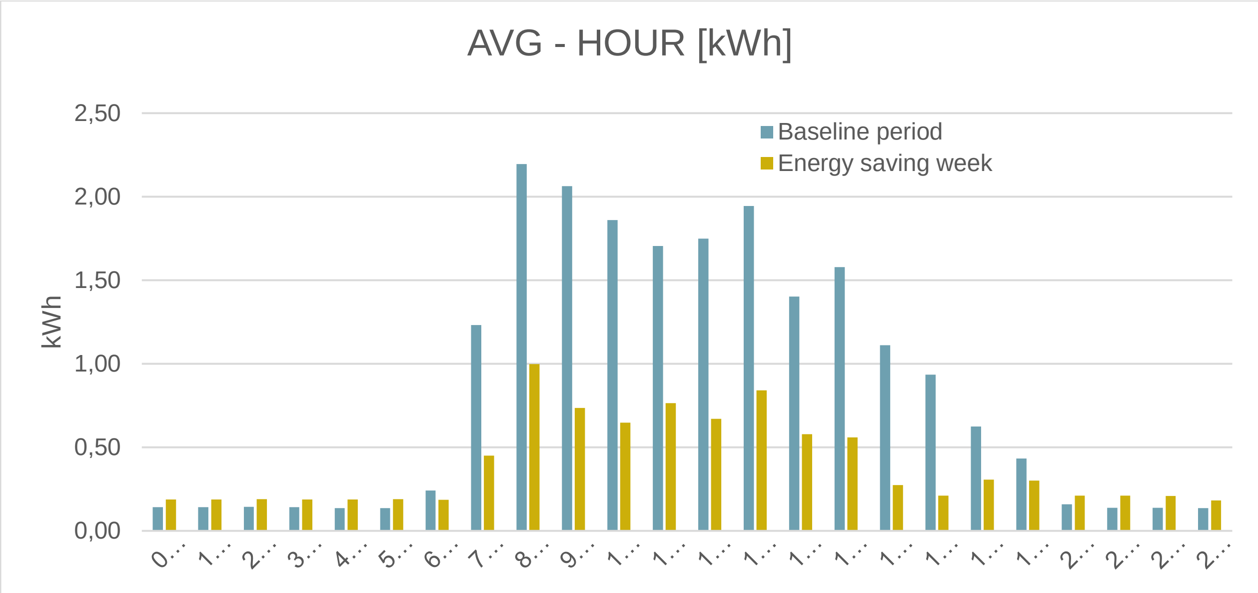
Days of the week	Average energy consumption [kWh]	Delta [%]
From Monday to Friday (workweek)	26	-
Weekend	5,8	-77,7%



Hourly average energy consumption into the school (October 29th 2018 - November 11th 2018)

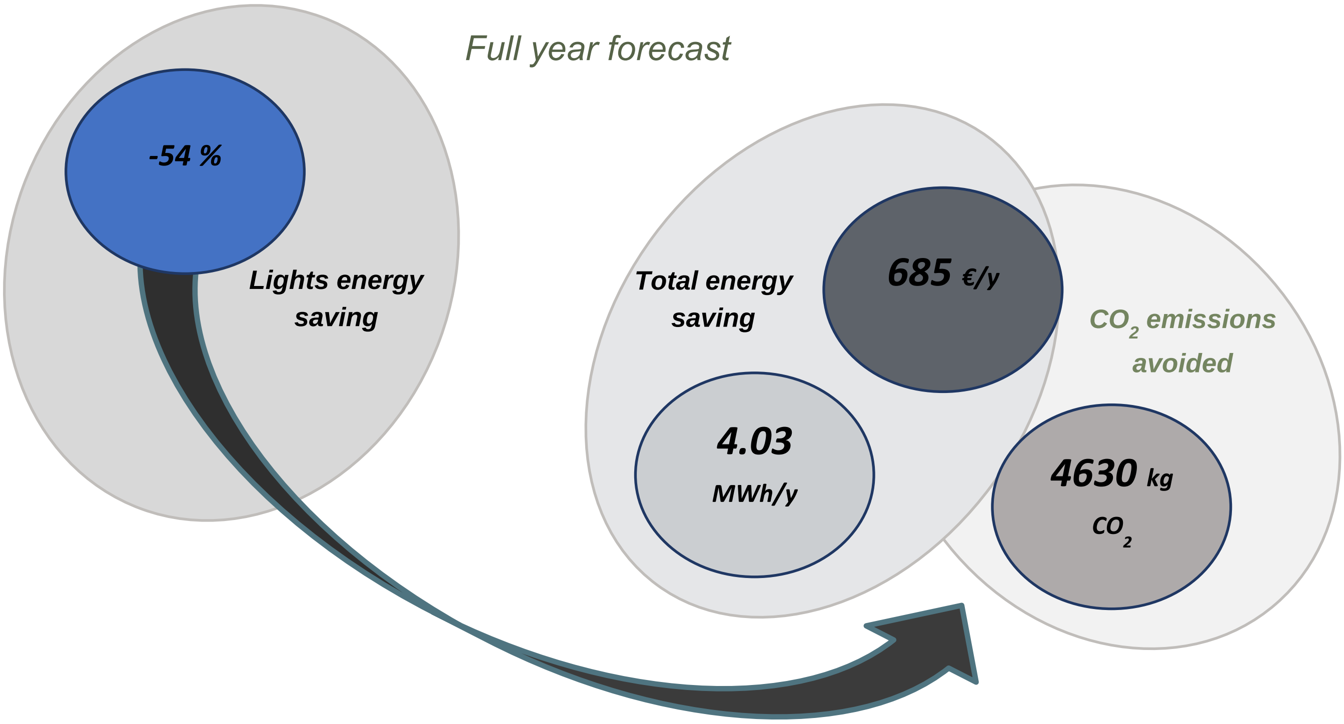


Daily average energy consumption – Comparison
Baseline period: 29th of October -11th of November 2018; Energy saving week: 8th – 14th of October 2018



Hourly average energy consumption – Comparison

Baseline period: 29th of October -11th of November 2018; Energy saving week: 8th – 14th of October 2018



Comparison

Activity 1	Consumption [kWh/week]	Difference with baseline [kWh/week]
Baseline period	143,4	-
Energy saving week	66,2	-77,2

NOTES: *Electricity cost: 0,17 €/kWh   National emission factor: 1,15 kg CO_2/kWh*

Total people:	*226*
People directly involved:	*30*
Square meters:	*210*
Volume:	*1764*
Working schedule	*30*

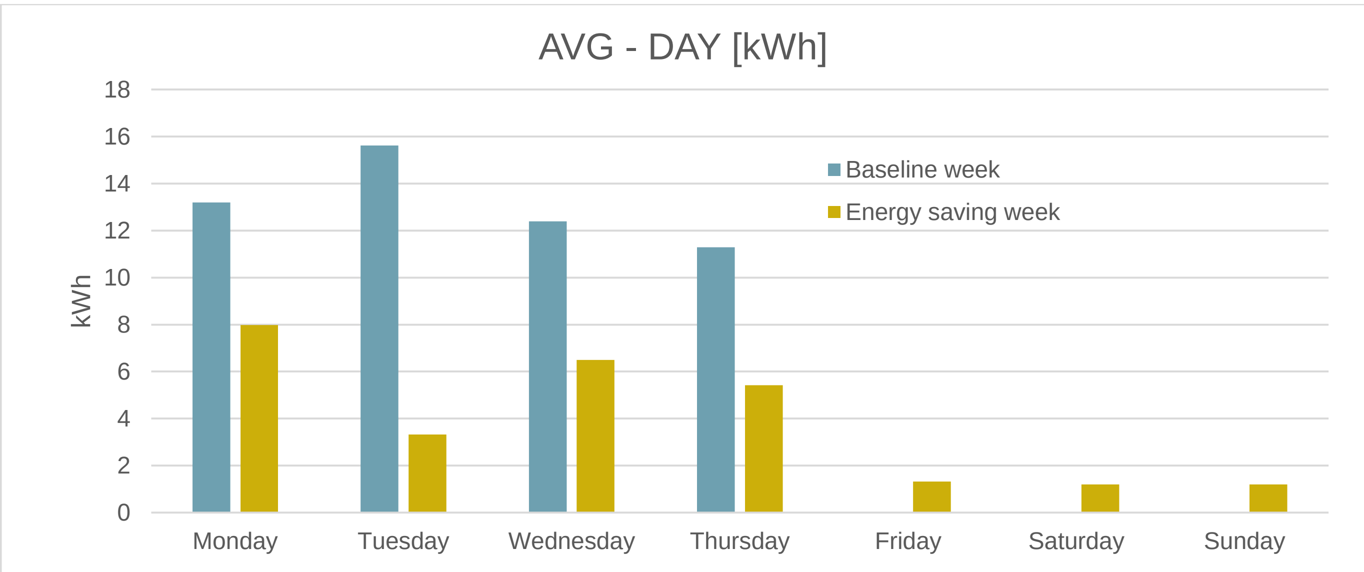
The 6th Primary School of Kaisariani (Athens) was one of the schools with the highest level of interaction with the GAIA project. The teachers of the school produced their own material to complement GAIA's activities, while they also produced a video overview of the school's participation (uploaded to GAIA's YouTube channel https://youtu.be/JsVxLcaUclg).

Students identified power consumption points for heating, lighting, refrigerators, microwave ovens, computers, printers, dishwashers, air conditioners, etc. The observations were initially general and concerned the entire school complex, and afterwards more specific and related to the parts of the building monitored. They created a school building profile and then produced a mobile measurement station. Afterwards, they appointed responsible students in order to monitor/control energy-intensive school points.

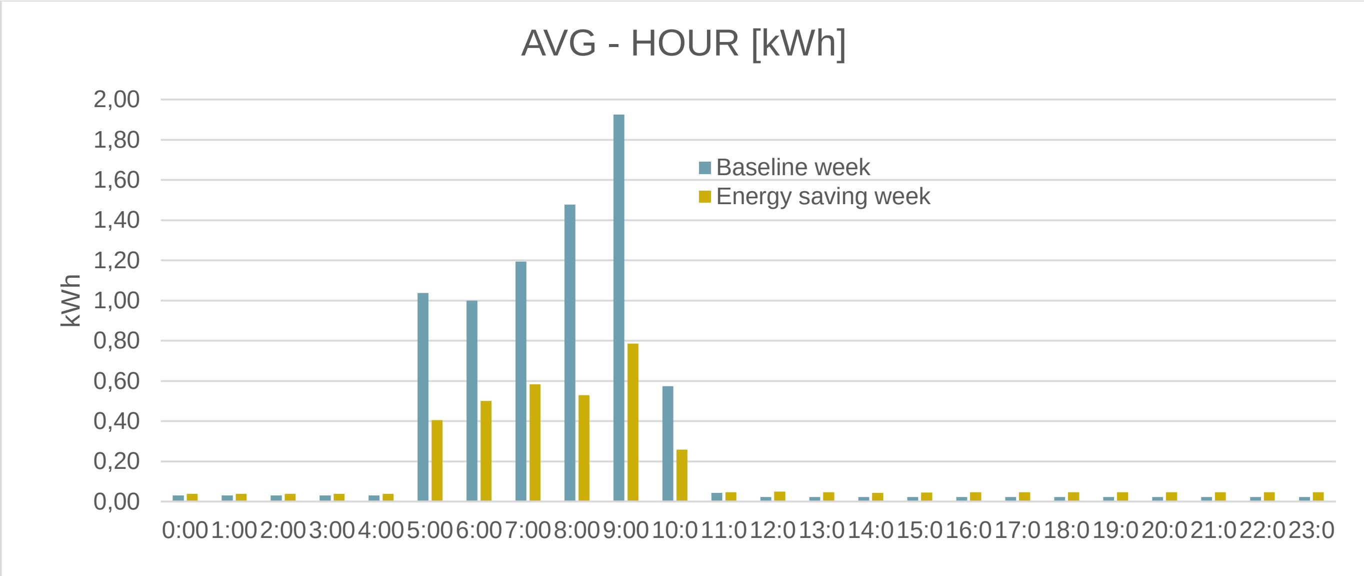
With respect to the implementation of the activity, they tried to save energy reducing waste consumption during the energy saving week from the 18th of March 2019 to the 24nd of March 2019. This is the week we analysed to calculate the energy savings. The energy savings achieved were at 54% of the energy consumption of the second floor of the principal building. Numerically, the weekly energy saving amounted to 25,5 kWh that in terms of money is about 4 €/week. Calculations were made considering the following periods: for the average baseline week has been considered the week from the 11th of March 2019 to the 17th of March 2019; for the energy saving week from the 18th of March 2019 to the 24th of March 2019.

The energy saving is present during the whole work week, with the best performance on Tuesday. During Friday and the weekend, we didn't have energy savings. To understand how energy saving has been achieved we can analyse the hourly energy consumption during the energy saving period and compare it with the baseline chart.

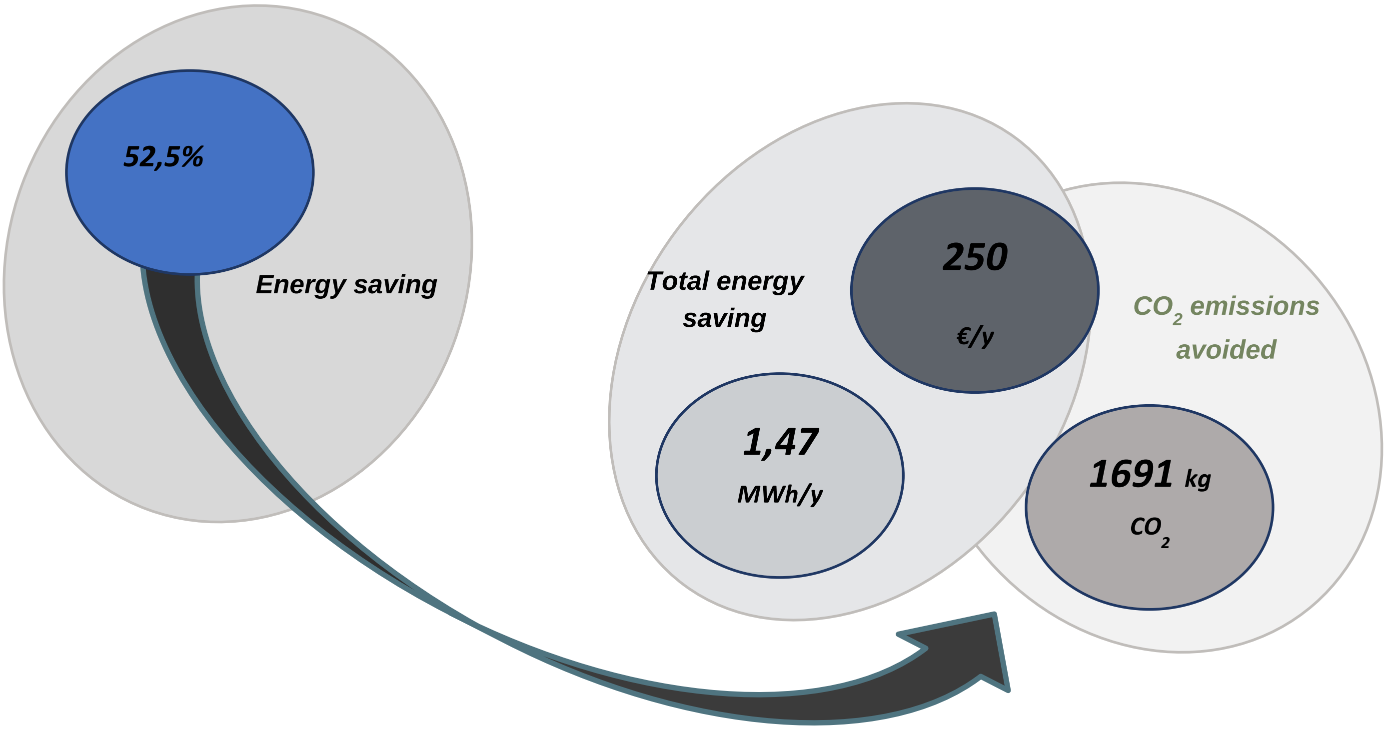
It is interesting to see that savings were achieved during working hours, while for the rest of the day energy consumption was too low to have variations. To calculate a full year energy saving forecasting, students assumed that the weekly energy saving could be constant for the rest of the year. Under this assumption, the full-year forecasting shows an energy saving of 1,332 kWh/year, equal to emissions of 1,532 kg CO_2 avoided.



Daily average energy consumption in second floor of the principal building. Period – Comparison Baseline period: 11th-17th of March 2019; Energy saving period: 18th – 24th of March 2019

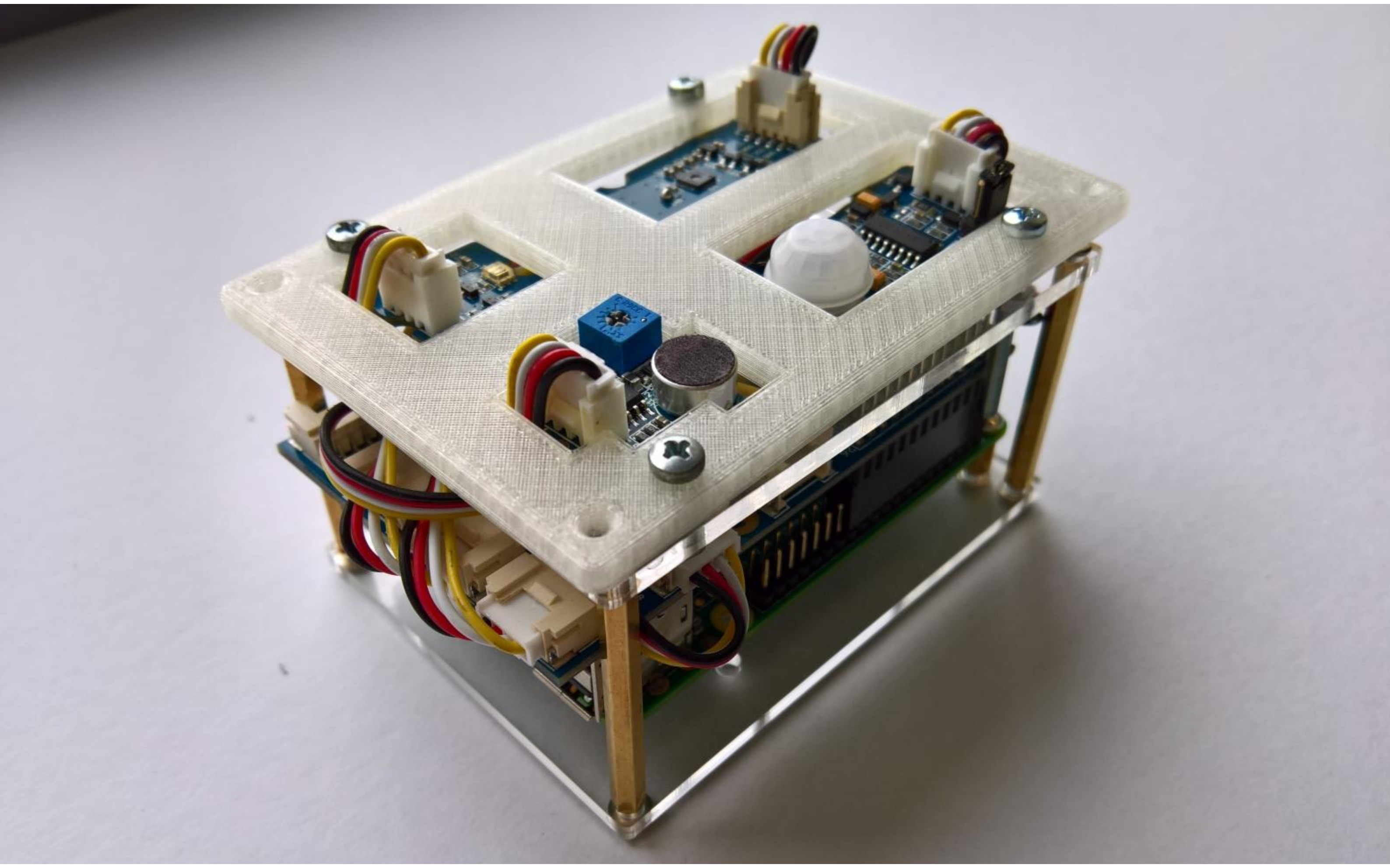


Hourly average energy consumption in second floor of the principal building. Period – Comparison Baseline period: 11th-17th of March 2019; Energy saving period: 18th – 24th of March 2019



Week	Consumption [kWh/week]	Difference with Reference [kWh/week]
Reference week	53,85	0
Energy saving week	25,56	28,29

Considering the yearly savings, the cost of the installation in the school will be reimbursed in 2,8 years.



Total people:	228
People directly involved:	68
Square meters:	3695
Volume:	27712.5
Working schedule	27,4 hours/week

The ^{7th} High School of Trikala is one of the schools in the project with the most open philosophy to participating in extracurricular activities. Although it joined GAIA only on October 2018, it managed in very little time to participate and produce excellent results.

The average – day chart shows the energy consumption during a week for the portion of the building monitored. It is almost constant during the workweek days (from Monday to Friday) with a daily consumption of about 51,4 kWh per day. During the weekend there is the minimum of the energy consumption with an amount of 13,9 kWh/day. The week average is 40,7 kWh/day and 285 kWh/week.

Days of the week	Average energy consumption [kWh]	Delta [%]
From Monday to Friday (workweek)	51,4	-
Weekend	13,9	-72,8%

When this part of the building is not used, the energy consumption is 73% less than the energy consumption during the working days.

In the average – hour chart you can see that the energy consumption grows during the morning to the maximum amount of 5,92 kWh at 7:00 in the morning. During the working hours, the energy consumption remains almost constant to decrease during the afternoon till 14:00. During the closing hours the energy consumption is almost constant of about 0,6 kW. In order to try to reduce energy consumption and increase the energy efficiency of the building, several approaches were tried.

ACTIVITY – GENERAL CONSUMPTION REDUCTION

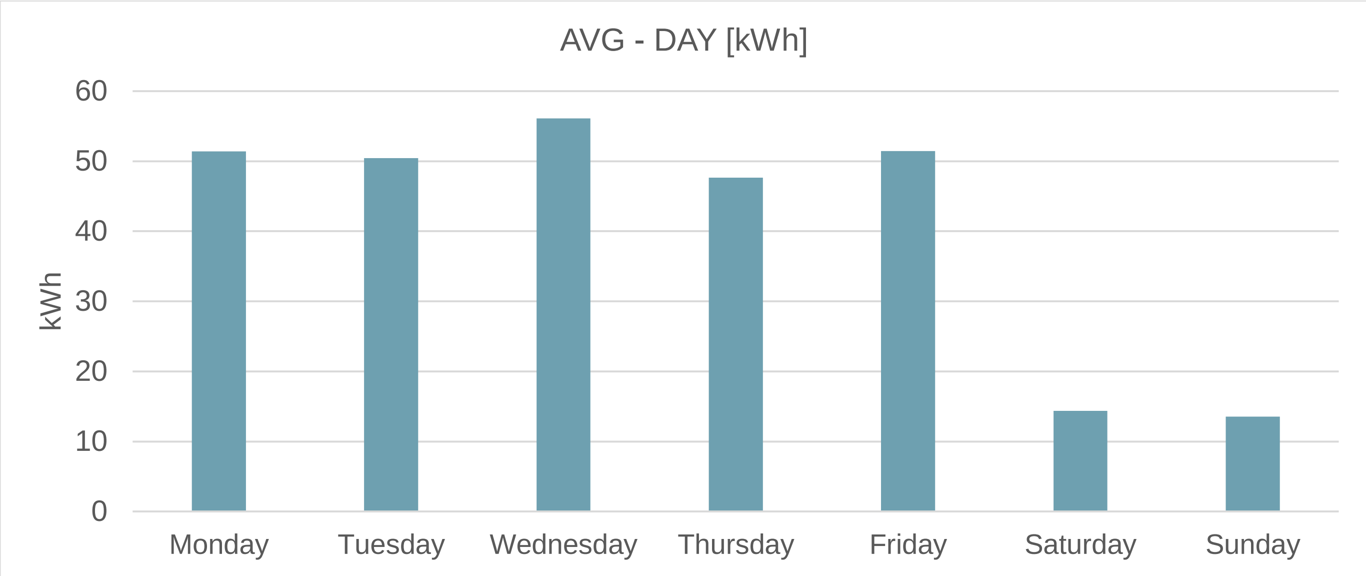
The activity was divided in three phases:

- AWARENESS: student understood how electric energy is made in Greece,
- OBSERVATION: students observed how energy is used into the school, with a differentiation between the ground floor and the 2nd floor;
- ACTION: students have taken energy saving actions including:
    - Close the lights during breaks and when there was adequate lighting.
    - Turn off electronic devices when are not used
    - Checking for possible heat leakage
    - Turn off the lights In the corridors
    - Trying to sensitize classmates about energy efficiency and energy consumption.

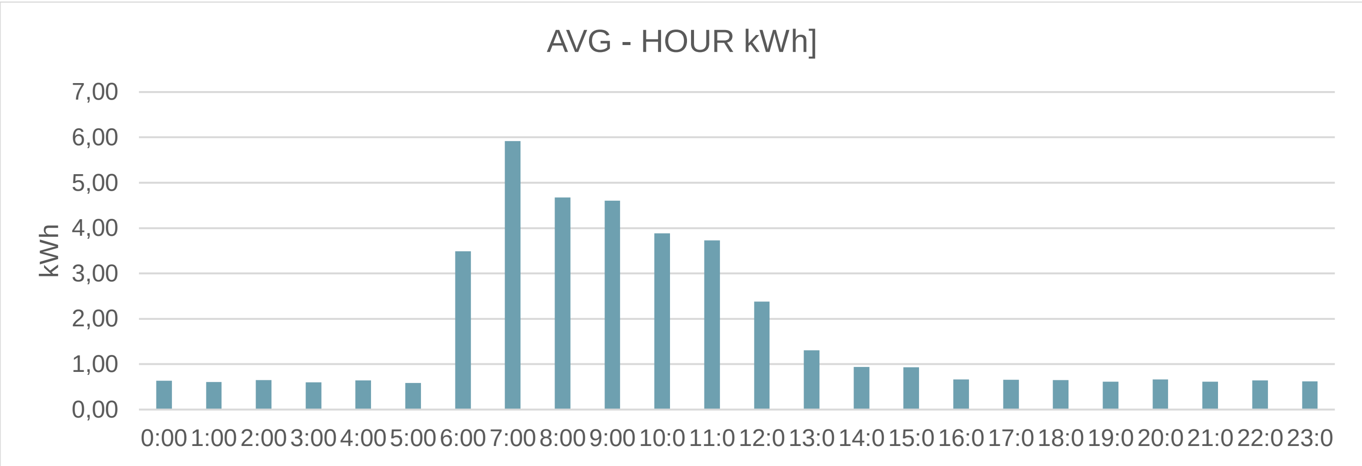
To understand the energy saving obtained thanks to the energy efficiency activities, students compared the energy consumption before and during the energy efficiency activities. The energy saving has been of 35,7% of the energy consumption for the part of the building monitored. Numerically, the weekly energy saving amounted to 101,8 kWh that in terms of money is about 17 €/week. Calculations were made considering the following periods: for the average baseline week has been considered the week from the 18th of February 2019 to the 24th of February 2019; for the energy saving week from the 4th of March 2019 to the 10th of March 2019.

The energy saving is present during the whole workweek; the best performance has been on Tuesday. During the weekend, we had the same energy consumption with no energy saving. To understand how energy saving has been achieved could be interesting to analyse the hourly energy consumption during the energy saving period and compare it with the baseline chart.

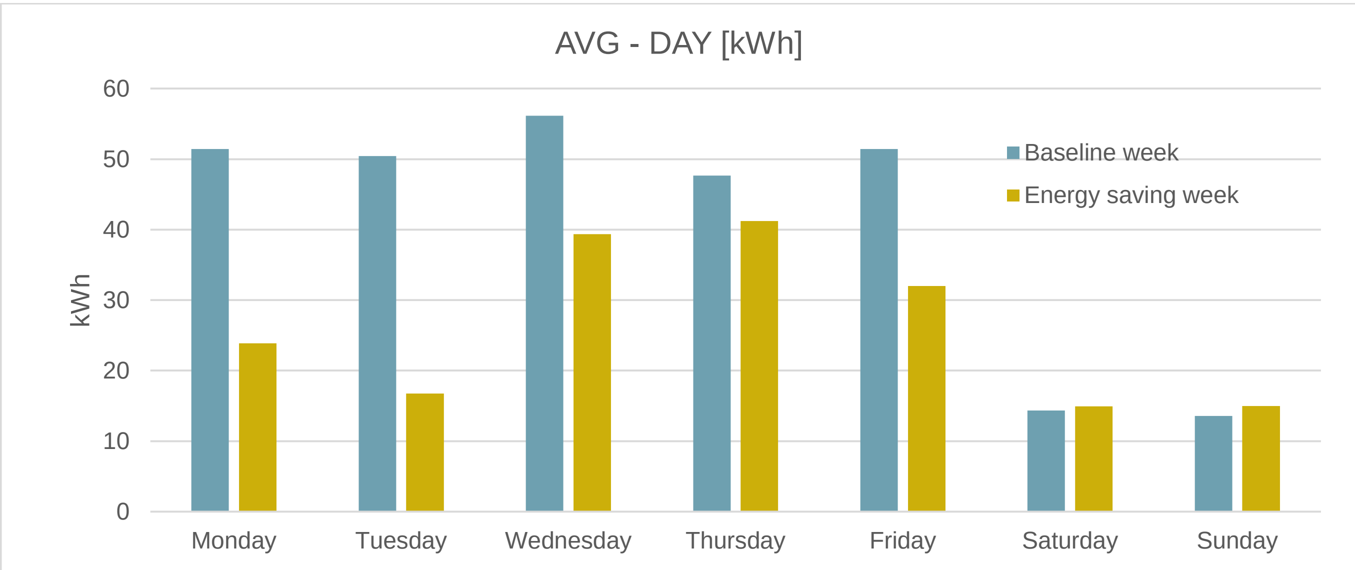
The energy saving has been achieved during the all day with no exceptions, we had the best performances during the working hours from 6:00 to 13:00. Students calculated also the energy saving separately for the ground floor and for the 1st floor. They obtained an energy saving of 33% for the ground floor and an energy saving of 60% for the 2nd floor. To calculate a full year energy saving forecasting we have supposed that the weekly energy saving could be constant for the rest of the year. Under this assumption, the full-year forecasting shows an energy saving of 5,311 kWh/year equal to 6,108 kgCO_2 avoided.



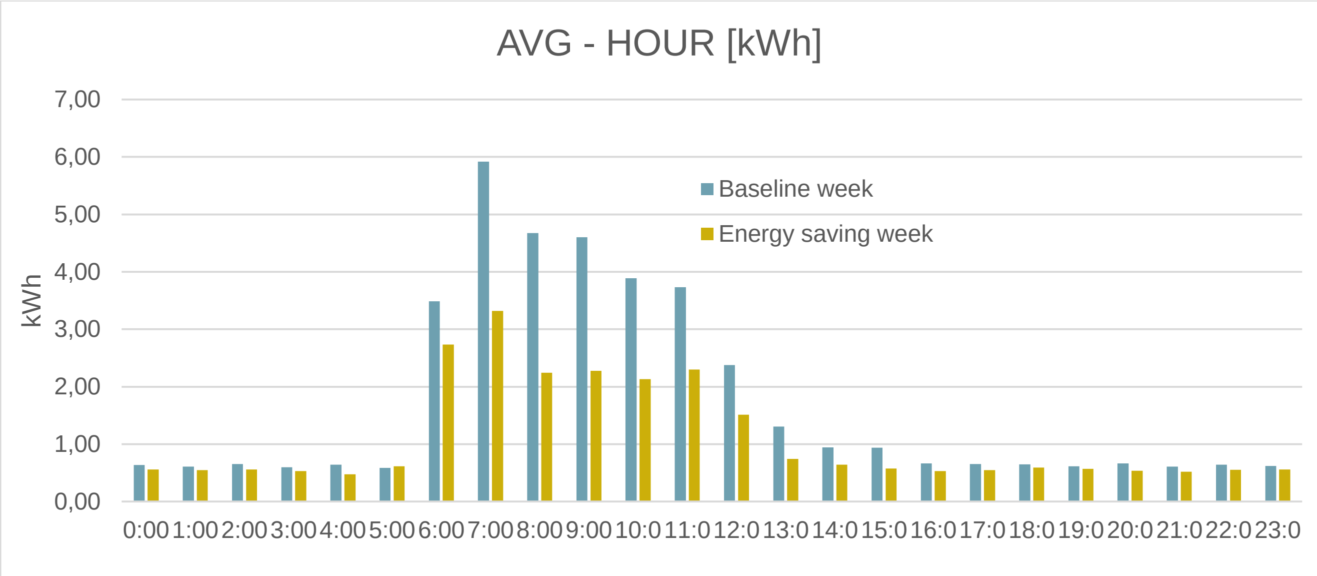
Daily average energy consumption for the portion of the building monitored. Period 18th of February 2019 - 24th of February 2019



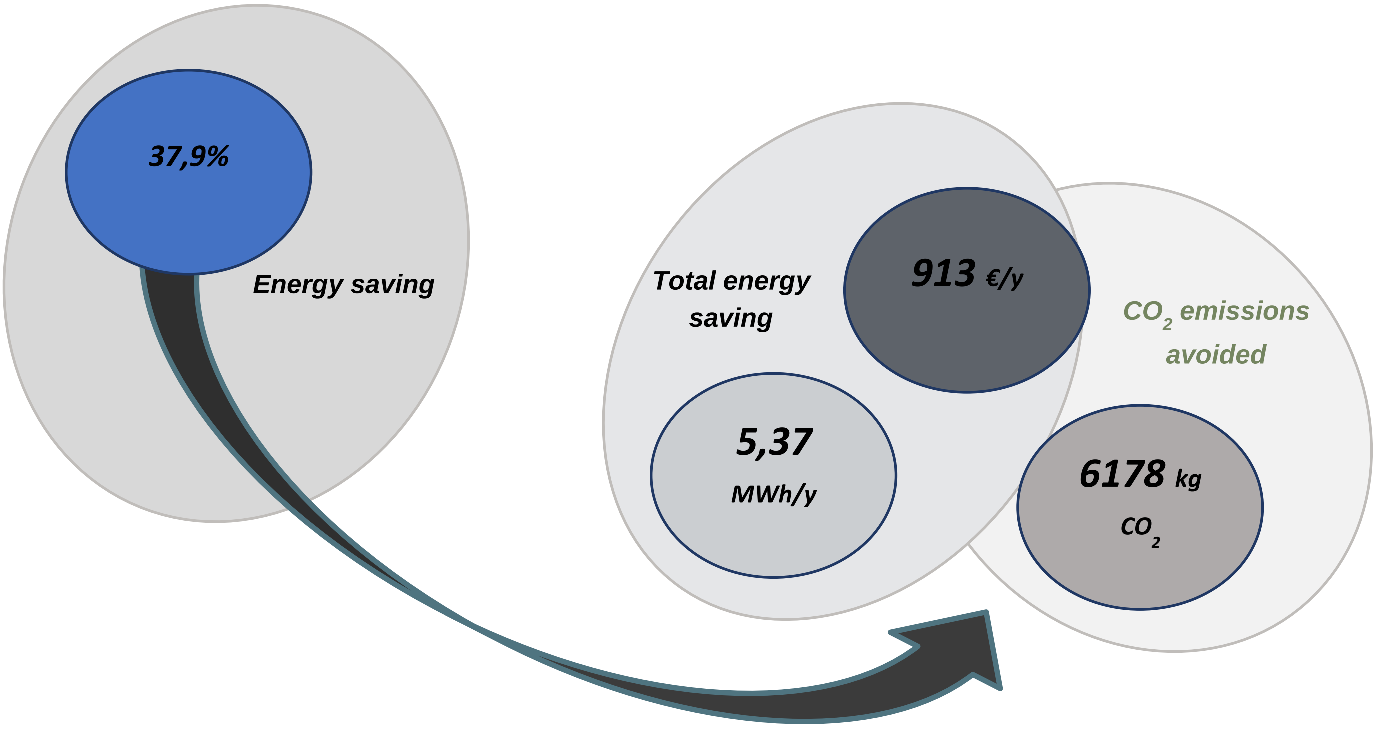
-Hourly average energy consumption for the portion of the building monitored. Period 18th of February 2019 - 24th of February 2019



Daily average energy consumption in portion of the building monitored. Period – Comparison Baseline period: 18th-24th of February 2019; Energy saving period: 4th – 10th of March 2019



Hourly average energy consumption in portion of the building monitored. Period – Comparison Baseline period: 18th-24th of February 2019; Energy saving period: 4th – 10th of March 2019



Week	Consumption [kWh/week]	Difference with reference [kWh/week]
Reference week	272,05	0
Energy saving week	168,73	103,32

Considering the yearly savings in energy consumption, the cost of the installation in the school will be reimbursed in 0,9 years.


Partners

Total people:	198
People directly involved:	42
Square meters:	2496
Volume:	8736
Working schedule	30 hours/week

The average – day chart shows the energy consumption during a week for the whole building. It is almost constant during the workweek days (from Monday to Friday) with a daily consumption of about 105,5 kWh per day. During the weekend, energy consumption falls to 40,7 kWh/day. The average is 87 kWh/day and 609 kWh/week.

Days of the week	Average energy consumption [kWh]	Delta [%]
From Monday to Friday (workweek)	105,5	-
Weekend	40,7	-61,4%

When the building is not used, energy consumption is 61,4% less than the energy consumption during the working days. In the average – hour chart you can see that energy consumption grows during morning hours to a maximum amount of 9,29 kWh at 9:00AM. During working hours, energy consumption increases from 7:00 to 9:00, and decreases from 10:00 to 14:00. During afternoon, the energy consumption is low and constant at 2,26 kWh and equal to the energy consumption of the closing hours.

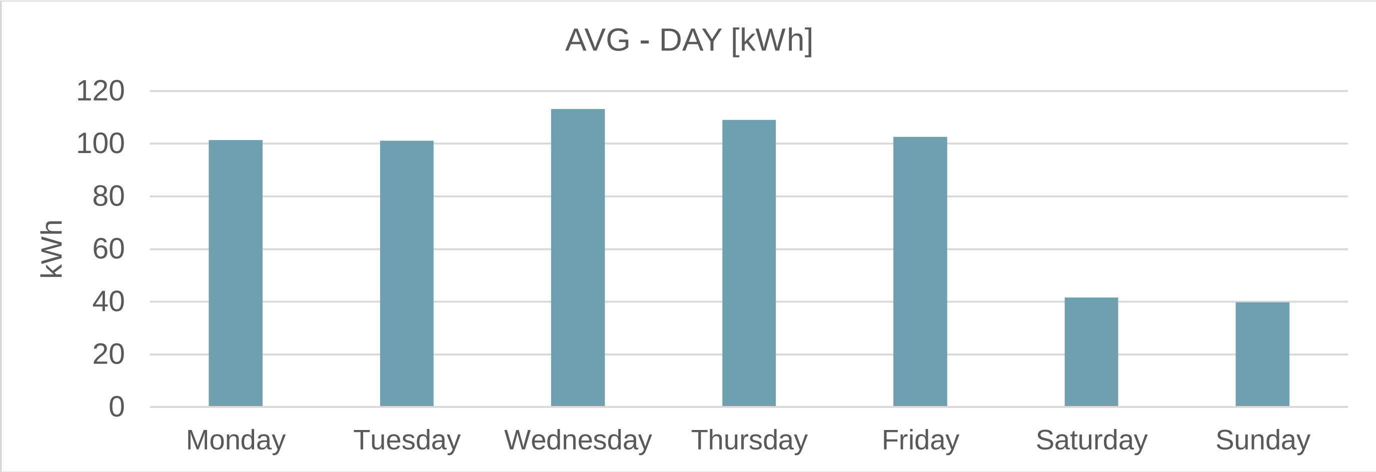
In order to try to reduce the energy consumption and increase the energy efficiency of the building, the school performed activities divided in three phases:

- *SENSITIZATION AND PREPARATION: students visited the GAIA challenge and experimented with these specific activities, moreover they used a well-designed Raspberry Pi set up kit in order to understand the goals of GAIA and became familiar with IT and electronics;*
- *OBSERVATION AND RECORDING OF BASIC ENERGY CONSUMPTION: students observed how energy is used into the school using the BMS of the school;*
- *ACTION: students decided to focus on reducing energy consumption in the school by controlling lighting. For this, they designated a "guardian" of lights for each room. At the same time, they created power-saving action stickers and placed them next to the switches. At the same time, students have been encouraged to take the same responsible attitude in their home, with the wider goal of rational use of energy-intensive devices in the direction of sustainability and sustainability.*

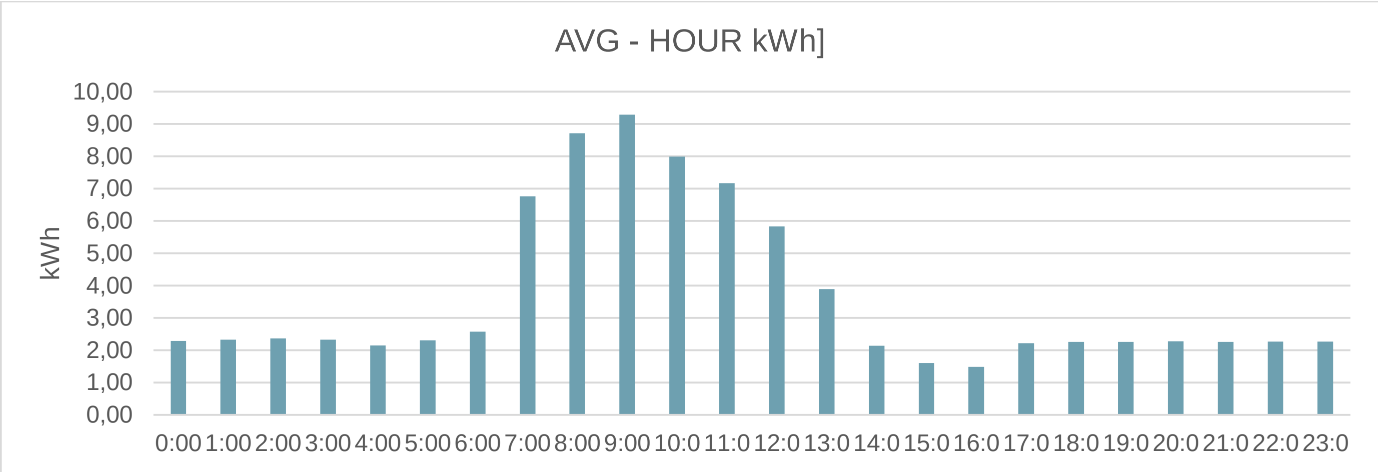
To understand the energy saving obtained thanks to the energy efficiency activities, students compared the energy consumption before and during the energy efficiency activities. The energy saving has been of 7% of the energy consumption of the building. Numerically, the weekly energy saving amounted to 42.5 kWh that in terms of money is about 7 €/week. Calculations were performed considering the following periods: for the average baseline week has been considered the week from the 18th of February 2019 to the 24th of February 2019; for the energy saving week from the 26th of March 2019 to the 1st of April 2019.

Energy savings were more apparent on Monday and Wednesday, while almost zero on Tuesday and Friday. On Thursday, energy consumption during the energy-saving week was higher than the baseline week, maybe because of special conditions. The best performance was on Wednesday with a value of 25,5%. During the weekend, the school had the same energy consumption with no energy savings. This means that the lights are well managed in the school..

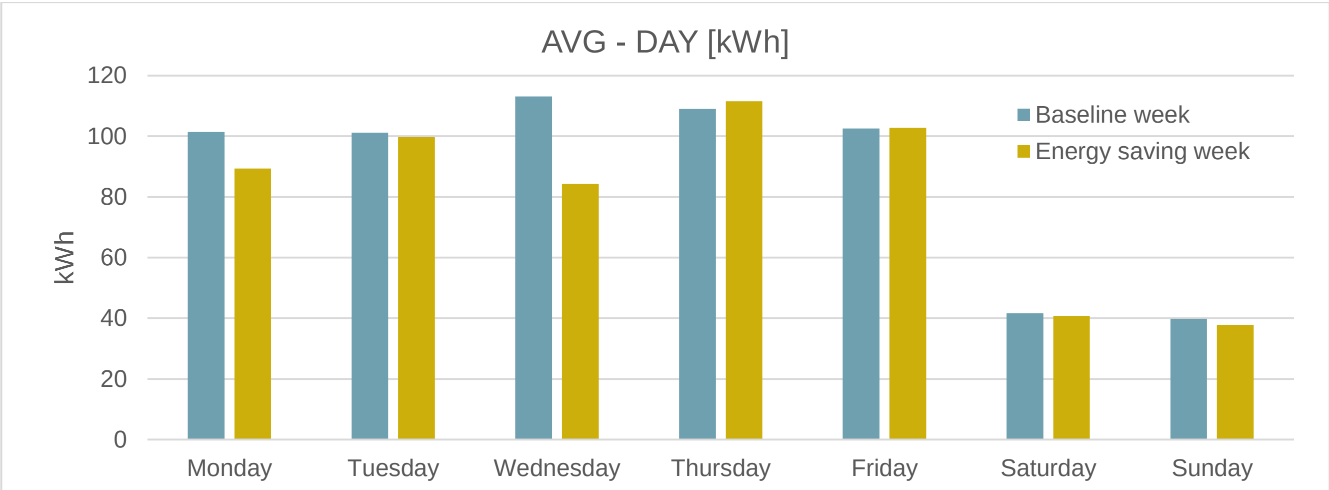
Energy savings were achieved during the working hours; the school had the best performance from 8:00 to 13:00. During the closing hours we did not have any energy saving. To calculate a full year energy saving forecasting we have supposed that the weekly energy saving could be constant for the rest of the year. Under this assumption, the full-year forecasting shows an energy saving of 2,215 kWh/year equal to emissions of 2,547 kgCO_2 avoided.



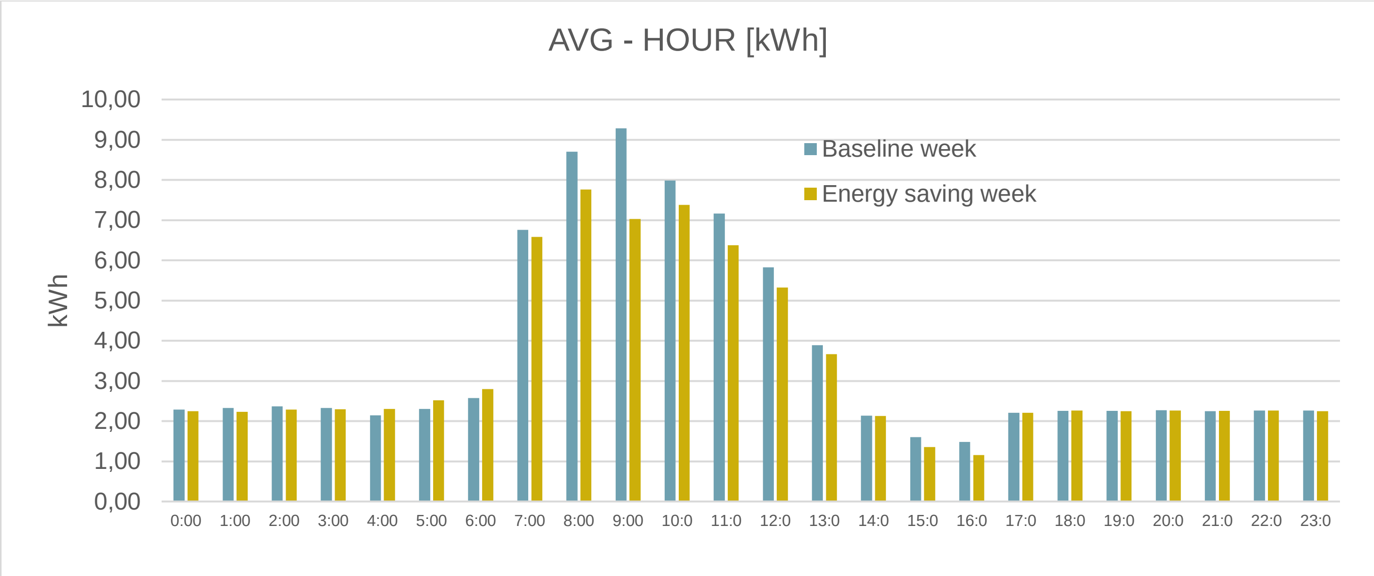
Daily average energy consumption for the whole building.
Period 18th of February 2019 - 24th of February 2019



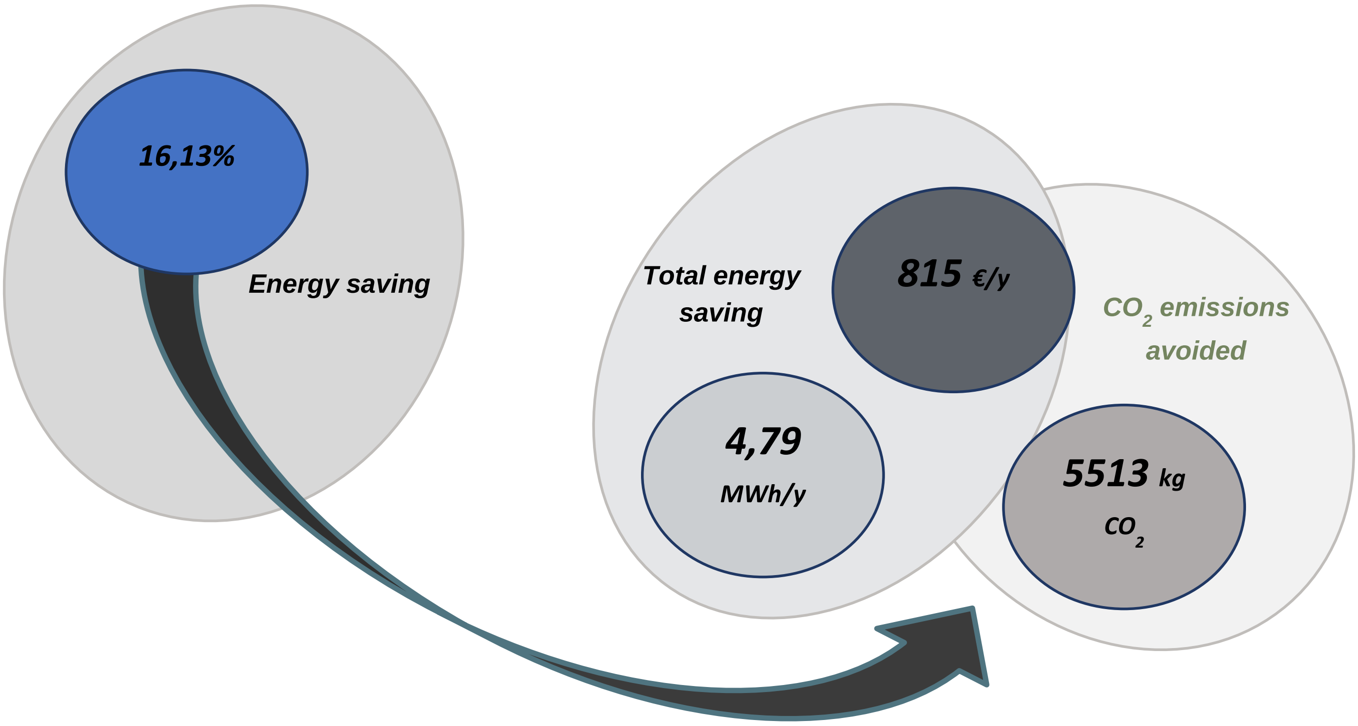
Hourly average energy consumption for the portion of the whole building.
Period 18th of February 2019 - 24th of February 2019



Daily average energy consumption of the building – Comparison
Baseline period: 18th-24th of February 2019; Energy saving period: 26th of March – 1st of April 2019



Hourly average energy consumption of the building – Comparison
Baseline period: 18th-24th of February 2019; Energy saving period: 26th of March – 1st of April 2019



Week	*Consumption [kWh/week]*	*Difference with reference [kWh/week]*
Reference week	*571,56*	*0*
Energy saving week	*479,36*	*92,2*

Considering the yearly savings in energy consumption, the cost of the installation in the school will be reimbursed in 0,8 years.

Φύλο:
Τάξη:
90% 3:38 μ.μ.
GAIA
Ρυθμίσεις
Μέση Τιμή Ανα Μήνα
(Raw Value)
114.99 Raw Value Μέση Τιμή Ανα Ημέρα
139.31 Raw Value Μέση Τιμή Ανα Μήνα
129.17 Raw Value 5/3/2018
Σχετική Υγρασία
Ανα 5 λεπτά
Ανα ώρα
Ανα ημέρα
Ανα μήνα
(%)
17:00 - 18:00
56.26 % Μέση Τιμή Ανα Ημέρα
51.68 % Μέση Τιμή Ανα Μήνα
51.72 % 5/3/2018
Θερμοκρασία
Ανα 5 λεπτά
Ανα ώρα
Ανα ημέρα
Ανα μήνα
(Centigrade)
Επικοινωνία/βοήθεια

Energy consumption levels monitoring examples using the GAIA tools

General Instructions

GAIA tools manuals

Manuals are available for all GAIA tools on the project website in English, Greek and Italian.

Quantities and Units used

*The quantities that are going to be used below are the electric **Current** (also referred to as **Current**), **Voltage**, electric **Power** and Electrical **Energy**. The quantity measured by the meters located in your school is the electric **Current** supplied to the three phases from the grid at the time of measurement.*

- *Electric **Current** is the flow of an electric charge and it is measured in **Ampere (A).***

- ***Voltage** is the difference in electric potential, it is measured in **Volt (V)** and in school building in Greece it can been considered constant at **230V.***

- ***Energy** is the amount of work required for a system, such as an electric appliance, to change its state. It is measured in **Joule (J)** but in this context, it can also be measured in **kilowatt-hours (kWh)**. **1kWh** is equal to **3.600J.***

- ***Power** is the transfer rate of **Energy** per second. It is proportional to the **Voltage** at the ends of the appliance and the **current** flowing through it. **Power** is measured in **Watt (W).***

*Out of these quantities, the most relevant for this document, are **Current** and **Energy**. **Current** is the quantity measured by the sensors installed in the electrical panels at your school. By using that measurement and assuming constant **Voltage** at **230V**, **Power** can be calculated using the formula*

$$Power = Current \times Voltage$$

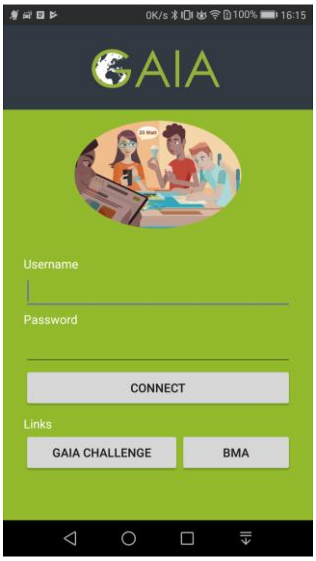
***Power** is used to calculate the **Energy** consumption for a given period by using the formula*

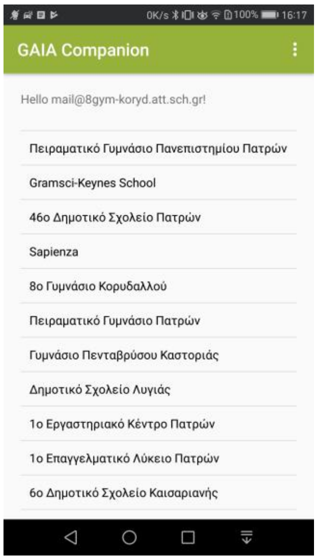
$$Energy[J] = Power[W] \times Time[s]$$

*The amount used to calculate the cost of **Energy** being consumed is **kilowatt-hours**, which is the **Energy** being consumed at a fixed rate of **1kW** for one hour.*

How to inspect the sensor measurements using the GAIA Companion Android app[1]

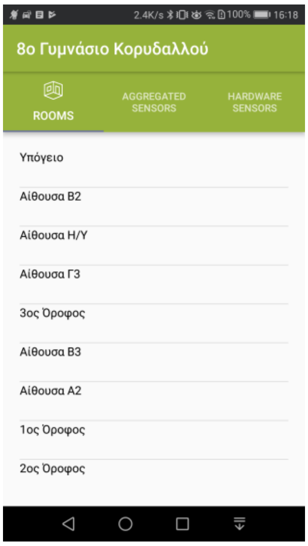
You can install the "GAIA Companion" Android application from the Google Play Store by searching using the term "GAIA Companion". After installation, please launch the app and after you confirm the access requests being requested by the app, enter your credentials and select your school from the available list.

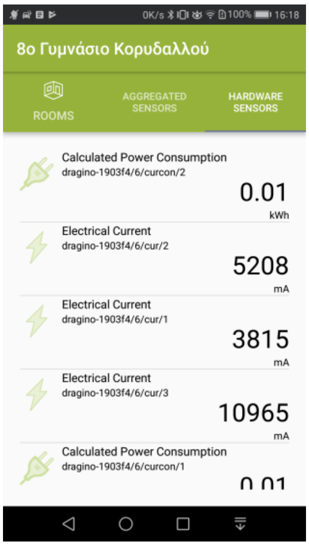




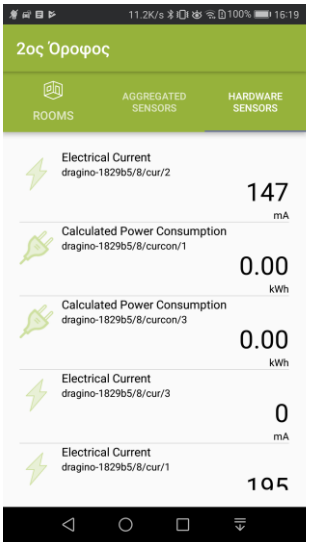
After selecting your school, from the home page you can access "HARDWARE SENSORS" to inspect the sensors in the school building. From the sensors titled "Electrical Current", you can inspect the latest measurements in each of the three phases. The name of each sensor is shown directly below the title and denotes the phase, which it refers to. E.g., in the following pictures, the names of the sensors are dragino-1903f4/6/cur/1, dragino-1903f4/6/cur/2 and dragino-1903f4/6/cur/3. The last character in each name (1, 2 or 3) denotes the phase measured.

1 https://play.google.com/store/apps/details?id=eu.gaiaproject.android.companion





In case your school has more than one sensor devices, the “HARDWARE SENSORS” starting page will be empty. In this case, you have to select the section that each sensor device monitors, e.g., “1st Floor” or “2nd Floor”, and then you can follow the procedure described above for each section.



An example on how to record the electric power of the appliances found in your school

During recording each appliance, the “state” of the school building should remain unchanged, i.e., there should be no appliances changing state (on/off) apart from the one being measured.

1. *Turn on the appliance measured and wait for a few minutes. Inspect the measurements in the GAIA Companion App for each phase and write them down in line “Current with Appliances ON” into columns “Phase 1”, “Phase 2” and “Phase 3” respectively.*
2. *Turn off the appliance being measured again. Inspect the sensor readings in the app for each phase and write them down in line “Current with Appliances OFF” for Phase 1, Phase 2 and Phase 3 respectively.*
   Note: If the values between “Draft Measurement” and “Current with Appliances OFF” differ, you will have to repeat the procedure to verify your measurements. The state of the school might have changed during the experiment. Small differences of 100mA can safely be ignored.
3. *For each line of the table, summarize the three phases and write down the result in column Phase Aggregate. Calculate the difference between the second the third measurements of the experiment using the formula* $Phase\ Aggregate\ Diff = Current\ With\ Appliances - Current\ Without\ Appliances$ *for the column “Phase Aggregate” and write it down in “Phase Aggregate Diff”.*
4. *To calculate the electric power required by the appliance being measured you could use the following formula* $Appliance\ Power = Phase\ Aggregate\ Diff \times 230 \div 1000$.

In the table on the next page, you can see an example of logging an experiment.

	Phase 1 (cur/1)	Phase 2 (cur/2)	Phase 3 (cur/3)	Phase Aggregate	Time of Measurement
Current With Appliances ON	2.000 mA	5.000 mA	7.000 mA	$CurA =$ 14.000 mA	13:20
Current With Appliances OFF	2.000 mA	3.000 mA	7.000 mA	$CurB =$ 12.000 mA	13:30
$\underline{Appliance\ Power =}$ $\underline{(\boldsymbol{CurA - CurB})\ \times 230 \div 1000}$			Appliance Power	460 W	

1st Step: Awareness and preparation

1. **Measurement of Electrical Power in General Use Classrooms.**
   By utilizing the procedure described in the above example, you can measure the Electrical Power required by each classroom to operate. The two appliance groups most commonly found in a classroom are the lighting and the combination of a computer and a projector. Each group must be measured separately. In the following tables, you can fill in the readings of the sensors and calculate the electrical power of each appliance group in the respective table. After you complete the procedure for one of the classrooms, you could assume that each similar classroom has similar power requirements.

Name of classroom being measured:					
Number of similar classrooms:					
Lighting					
	Phase 1 (cur/1)	Phase 2 (cur/2)	Phase 3 (cur/3)	Phase Aggregate	Time of Measurement
Current With Appliance ON	mA	mA	mA	$CurA =$ mA	
Current With Appliance OFF	mA	mA	mA	$CurB =$ mA	
$\underline{Appliance\ Power =}$ $\underline{(\boldsymbol{CurA - CurB})\ \times 230 \div 1000}$			Appliance Power	W	

Computer and Projector					
	Phase 1 (cur/1)	Phase 2 (cur/2)	Phase 3 (cur/3)	Phase Aggregate	Time of Measurement
Current With Appliance ON	mA	mA	mA	$CurA =$ mA	
Current With Appliance OFF	mA	mA	mA	$CurB =$ mA	
$\underline{Appliance\ Power =}$ $\underline{(\boldsymbol{CurA - CurB})\ \times 230 \div 1000}$			Appliance Power	W	

Measurement of Electrical Power in the Computer Laboratory.

Utilize the procedure described in the example above to measure the power requirements of the Computer Laboratory. Initially measure and write down the sensor readings while everything is powered-OFF in the laboratory in the line named **Draft Measurement**. Do NOT turn OFF the always-on appliances that might be present in the laboratory, such as router or servers. Afterwards turn ON the lighting of the laboratory and write down the sensor readings in the line "Current with Appliance ON". To confirm your measurements, turn off the lighting again and write down the sensor readings in the line "Current with Appliance OFF". Repeat the procedure by turning ON the computers, monitor and any other appliances used during the lecture. It is preferable to emulate a smooth operation of the laboratory during a lecture, such as activating as many computers as usually used by students. You can calculate the electric power requirements of the laboratory as described in the "General Instructions" section.

Computer Laboratory					
Lighting					
	Phase 1 (cur/1)	Phase 2 (cur/2)	Phase 3 (cur/3)	Phase Aggregate	Time of Measurement
Current With Appliance ON	mA	mA	mA	$CurA =$ mA	
Current With Appliance OFF	mA	mA	mA	$\boldsymbol{CurB} =$ mA	
$\underline{Appliance\ Power =}$ $\underline{(\boldsymbol{CurA - CurB})\ \times 230 \div 1000}$			Appliance Power	W	

Other appliances used during lectures					
Number of Computers and Monitors:					
	Phase 1 (cur/1)	Phase 2 (cur/2)	Phase 3 (cur/3)	Phase Aggregate	Time of Measurement
Current With Appliance ON	mA	mA	mA	$CurA =$ mA	
Current With Appliance OFF	mA	mA	mA	$\boldsymbol{CurB} =$ mA	
$\underline{Appliance\ Power =}$ $\underline{(\boldsymbol{CurA - CurB})\ \times 230 \div 1000}$			Appliance Power	W	

Measurement of electric Power required by school lighting.

By following the procedure described in the example, turn OFF the lighting in the whole building and inspect the sensor readings. Write down the readings in the table below in **Draft Measurement** for each phase. Turn ON the lighting and write down the sensor readings in line "Current with Appliance ON". The last step is to verify the measurement by turning OFF the lighting again and writing down the sensor readings in "Current with Appliance OFF". You can calculate the electric Power requirements of the lighting of the school as described in General Instructions.

Lighting in corridors, staircases, halls and other public rooms					
	Phase 1 (cur/1)	Phase 2 (cur/2)	Phase 3 (cur/3)	Phase Aggregate	Time of Measurement
Current With Appliance ON	mA	mA	mA	$CurA =$ mA	
Current With Appliance OFF	mA	mA	mA	$\boldsymbol{CurB} =$ mA	
$\underline{Appliance\ Power =}$ $\underline{(\boldsymbol{CurA - CurB})\ \times 230 \div 1000}$			Appliance Power	W	

2. Description of Teacher Hall

Describe what electrical appliances are in use in your teacher's hall and mention the nominal consumption as reported by the manufacturer in their labels.

3. Air Conditioners and electric Heaters

In the table below you can describe air conditioning or heating units per classroom as if they exist. You can also mention if there are any water heaters present in the school's water circuit. In column "Period of Operation", you can mention the period of the year in which each unit is in operation, preferably by noting the month each unit starts and ends its operations. In the column titled "Time of Operation", you can fill in the hours of the day each unit is being used. In the "Appliance Type" column, you can describe how each unit is being used, if it is an air conditioner or a heater as well as if it is being used for Cooling or Heating.

Classroom Name	*Appliance Type*	*Number of Units*	*Period of Operation*	*Time of Operation*

4. Description of school cafeteria

Describe what electrical appliances are in use in your school's cafeteria and mention the nominal consumption as reported by the manufacturer in their labels. Also, mention the operating hours of the cafeteria.

5. Registry of school schedule

Please register your school's schedule during the week. You can also mention which classrooms are being used beyond the regular school schedule, such as in the afternoon or in the weekend for different uses, for example, various clubs or remedial teaching.

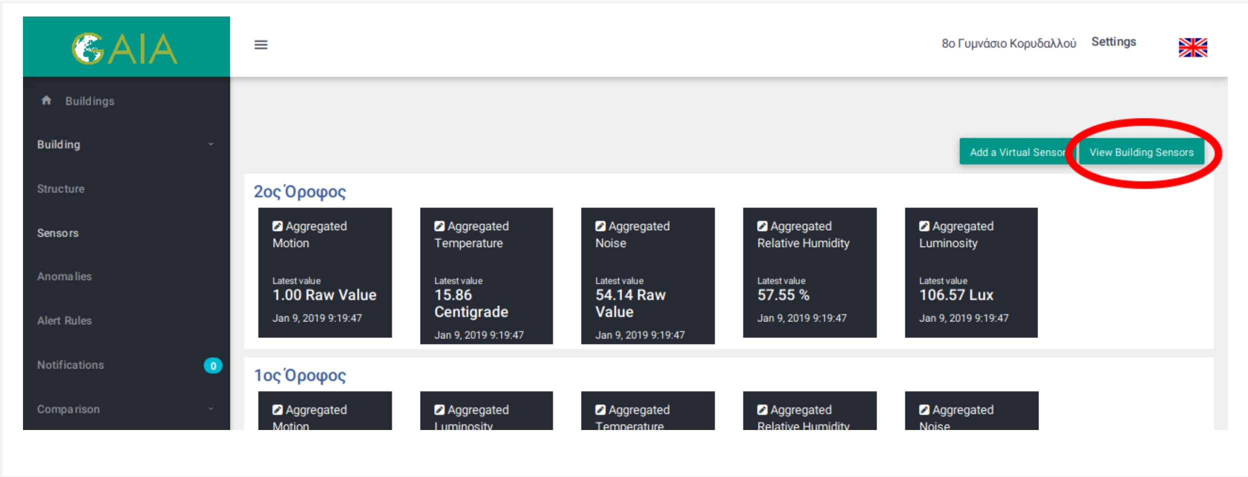
2nd Step: Observation and Recording of Base Energy Consumption

How to calculate the Base Energy Consumption of your school

*The term **Base Energy Consumption** in this context is being used to convey the energy consumption in your school during a typical day from always-on appliances, or from activities/appliances that cannot be "deactivated". Essentially, this part refers to processes in the building that consume energy, and which cannot be altered without having an effect on the daily operation of the school. If you calculate this type of energy consumption, it is then easier to detect the parts of energy consumption inside a school that can be effectively targeted by students and teachers.*

*To calculate the **Base Energy Consumption** you can use the following procedure.*

1. *Using the **BMA** (bms.gaia-project.eu) platform, navigate to the page of your school and select the "Sensors" option. Select "View Building Sensors" in the top right corner and locate the sensor named "Aggregated Calculated Power Consumption".*



2. *Select the "Aggregated Calculated Power Consumption" sensor to open its page, then select a day ("From" and "To" in the same day) during which the school didn't host any activity, for example in the weekend, with Granularity "Per Hour", Measurement Unit "kWh" and press Update. To calculate the Base Energy Consumption during one day with relative precision, hover the graph with your mouse pointer over an hour between 8:00 and 16:00. Multiply the measurement appearing in the pop-up box next to the cursor with the 24 hours of the day, to calculate the **Base Energy Consumption** for the whole day. If during the weekend your school hosts extracurricular activities, you can select a different day, for example a holiday. Preferably, select the day with the least non-zero energy consumption.*

$$Basic\ Energy\ Consumption\ (per\ day) = Basic\ Energy\ Consumption\ (per\ hour)\ \times 24$$

....

3. *In the right top corner above each graph there is a "Save as Image" icon (downwards arrow). You can use it to download each graph to be used in a report logging energy saving activities.*

3rd Step: Experimenting & Monitoring Energy Consumption

*In GAIA, we use the term **controllable energy consumption** to refer to the percentage of energy consumption, which can be manipulated by the school's users: it is the part of energy consumption that you can affect. To calculate it you will have to measure the **Regular Energy Consumption per day** of your school during a day of normal operation, and subtract from that the **Base Energy Consumption per day**, which was calculated in the previous step.*

1. *Using the **BMA** (bms.gaia-project.eu) platform, navigate to the page of your school and select the "Sensors" option. Select "View Building Sensors" in the top right corner and locate the sensor named "Aggregated Calculated Power Consumption".*
2. *Select the "Aggregated Calculated Power Consumption" sensor to open its page, select a day ("From" and "To" in the same day) during which the school was operating normally, with Granularity "Per Hour", Measurement Unit "kWh" and press Update. You can find the Summary on the left of the graph being shown.*

Time Period	***Regular Energy Consumption per day in kWh***

3. *To calculate the percentage you can manipulate, use the following formula:*

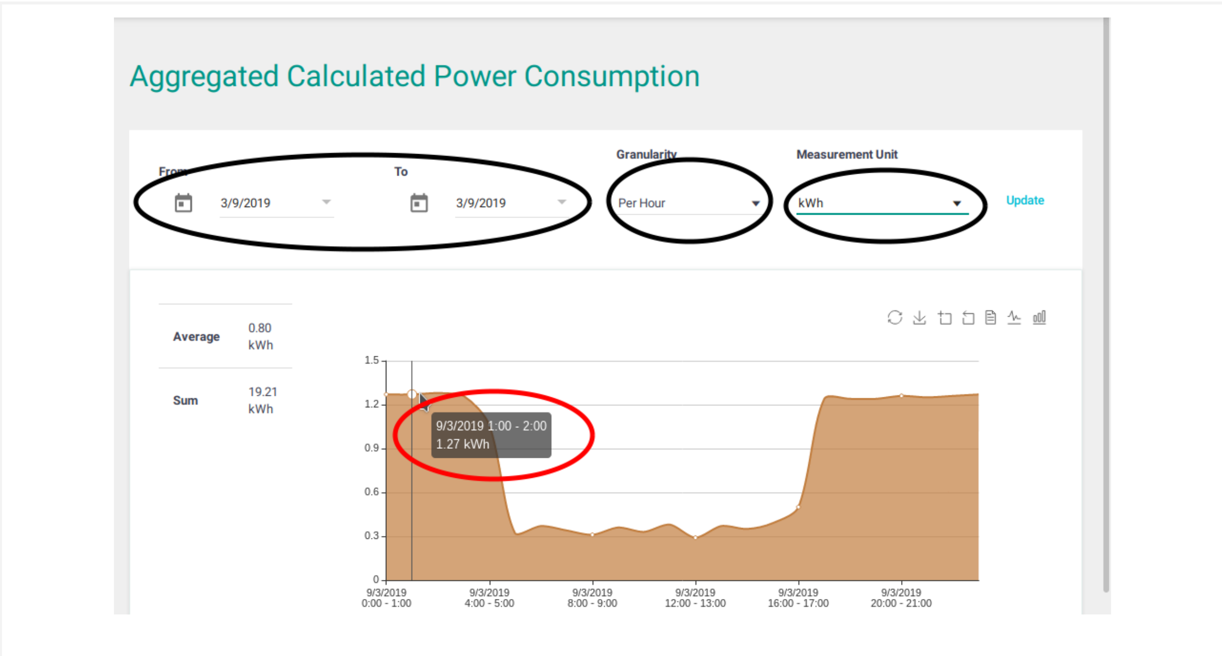
$$Controlled\ Energy\ Consumption\ (\%) = 100 \times (Regular\ E.C. - Base\ E.C) \div Regular\ E.C.$$

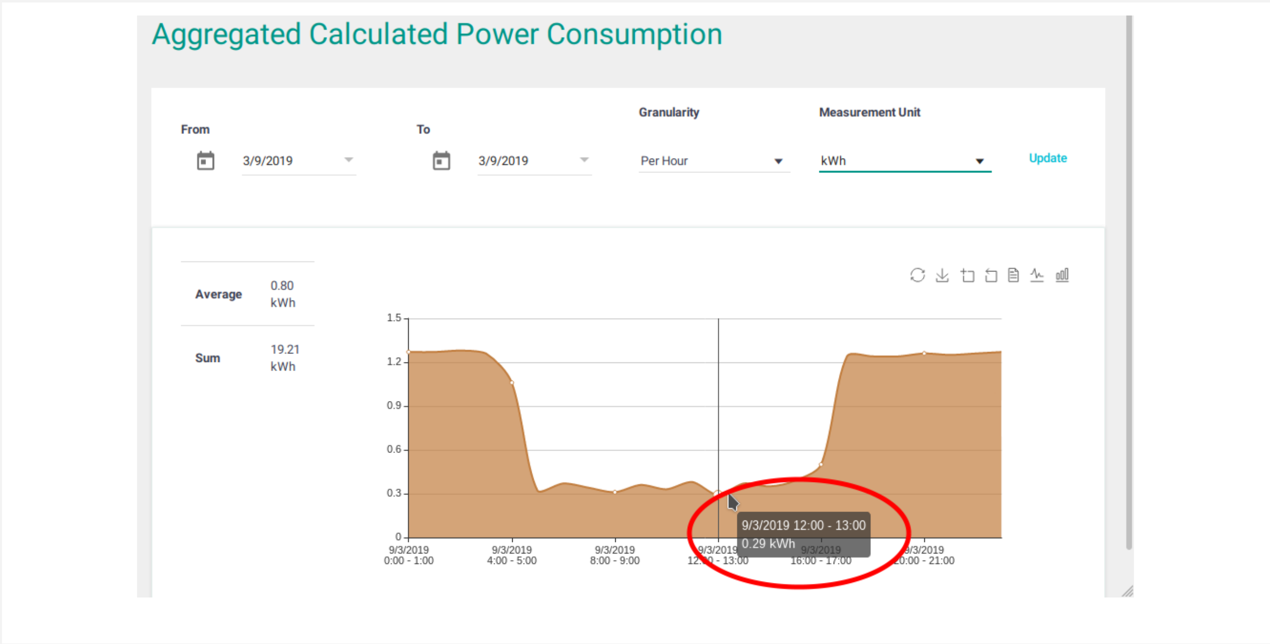
....

Determination of External Lighting Energy Consumption

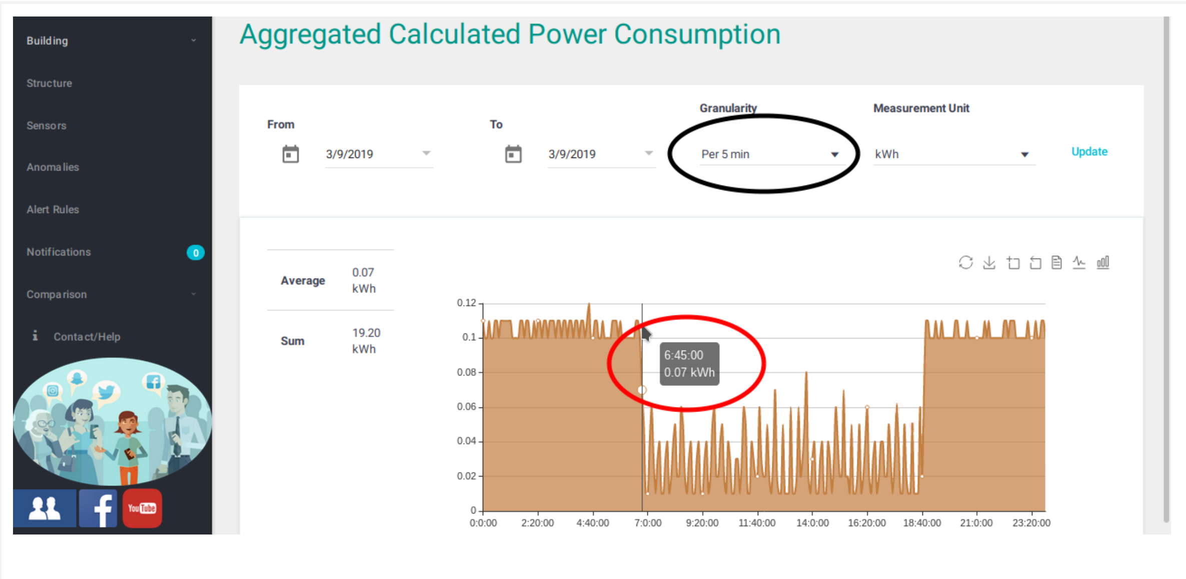
In case there is External Lighting operating in your school during the night, you can approximate its energy consumption by using the BMA platform.

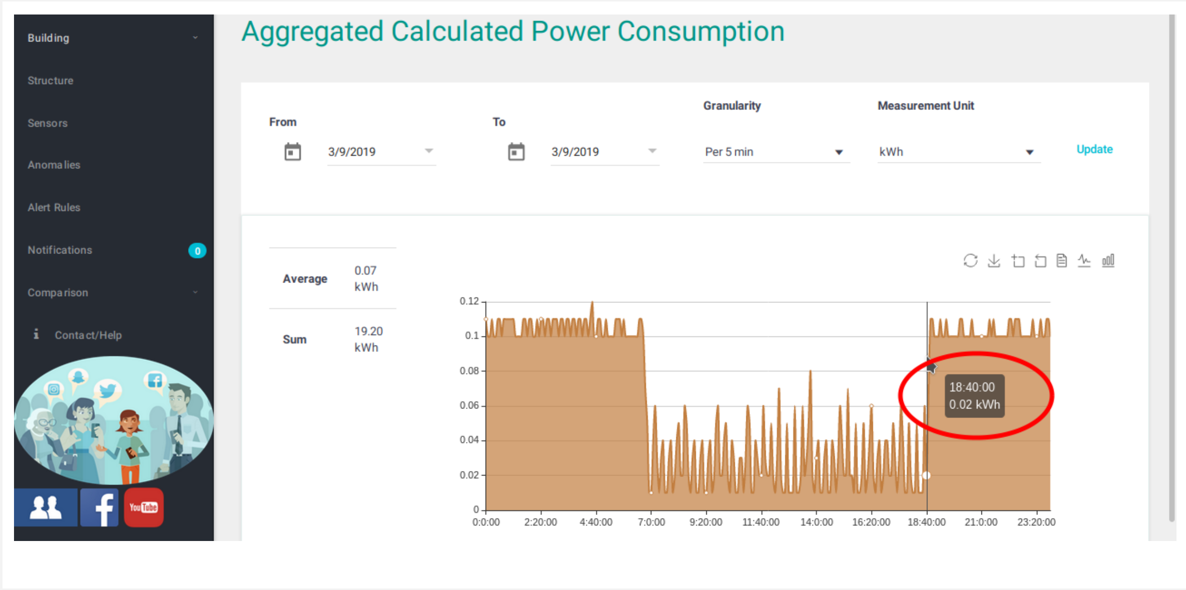
1. *Using the BMA (bms.gaia-project.eu) platform, navigate to the page of your school and select the "Sensors" option. Select "View Building Sensors" in the top right corner and locate the sensor named "Aggregated Calculated Power Consumption".*
2. *Select the "Aggregated Calculated Power Consumption" sensor to open its page, select a day ("From" and "To" in the same day) during which the school didn't host any activity, for example in the weekend, with Granularity "Per Hour", Measurement Unit "kWh" and press "Update". If during the weekend your school hosted extracurricular activities, you can select another day such as a holiday. Preferably, select the day with the least non-zero energy consumption. In case your school does not have, does not utilize or the sensors does not measure the external lighting, the graph will not have any differences between Day and Night. In this case, you can ignore the following procedure.*
3. *To calculate their energy consumption, find an indicative value during the night by hovering your mouse cursor over the graph. Afterwards, find an indicative value during the day.*





4. *To approximate the period of operation for the external lighting during the day, change the granularity to "Per 5 min" and press Update. Using your mouse cursor, hover over the edge of High to Low consumption in the morning and the Low to High edge in the evening. From the pop-up next to the cursor, you can find out the time that the change in the energy consumption was measured.*





5. *Calculate the difference between the Night Indicative Value and the Day Indicative Value and multiply it with their operating hours to approximate their energy consumption.*

$$Energy\ Consumption = (Night\ Indicative\ Value - Day\ Indicative\ Value) \times Operating\ Hours$$

……………………………………………………

Experimentation on energy savings in case the classroom lighting is turned off during a break/recess

In this experiment, you can calculate the energy consumed by lighting in classrooms in case it remains turned on during a break. Based on that you can determine how much energy can be saved if the lighting is being turned off.

1. *Using the information you collected in the step* ***Awareness and Preparation****, calculate the electric power required by the lighting in all general education classrooms by multiplying the result in the 1st Step* ($Classroom\ Lighting\ Electric\ Power[W]$) *with the number of classrooms* ($Number\ of\ Classrooms$).

$$Cumulative\ Lighting\ Electric\ Power[W] = Classroom\ Lighting\ Electric\ Power[W] \times Number\ of\ Classrooms$$

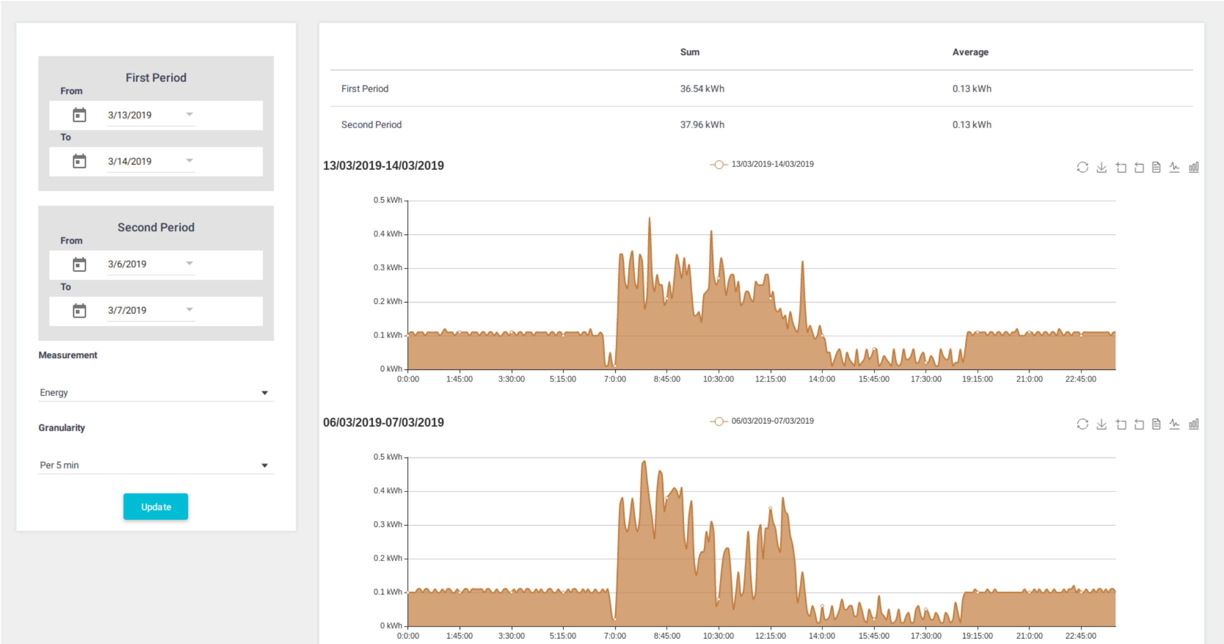
2. *You can approximate the energy consumption due to lighting with the following formula*

$$Energy\ Consumption[kWh] = Cumulative\ Lighting\ Electric\ Power[W] \div 60000 \times Recess\ Duration[minutes]$$

4th Step: Monitoring the Progress of Energy-Saving Actions

The BMA platform offers a "Comparison" tool, which enables the user to compare the aggregated sensor readings of a building for the measurements Energy, Luminosity, Relative Humidity, Temperature, Noise and Movement in the same or different buildings. It can also compare sensor readings in different periods.

1. *Using the BMA (bms.gaia-project.eu) platform, navigate to the page of your school and select the Comparison option. From the drop-down menu select "In your school".*
2. *In the presented page, under the "First Period box", select a day of the week during which you did not implement any energy-saving action. In the box "Second Period", select the same day but in a week during which you implemented such actions. Under "Measurement", select "Energy" and for "Granularity" select "Per 5 min". Please pay attention to the selection of days: if you wish to observe a specific day, you should not choose the same day in the "From" and "To" options, you have to select the previous day in "From".*



Comparison of energy consumption during two different periods

3. *In the following table, you can record a "Summary" of both periods. In the "Improvement-Energy" column, you can calculate the difference in total energy consumption (Summary) between the two periods. In the "Improvement-Percentage" column, calculate the percentage of energy savings using the formula*

$$Percentage = (Summary\ w/\ o\ Actions - Summary\ with\ Actions) \div Summary\ w/o\ Actions \times 100$$

4. *In the "Cumulative Improvement" row, you can calculate the respective values for a whole week.*

A useful practice is to "log" the implemented actions in a few paragraphs of text every few days, after you complete any of the suggested steps. To enhance your reports, you can use images from the BMA platform and pictures from your implementation of the actions, such as graphs and motivational/promotional material made by the students.

	Date		Summary		Improvement	
	Without Actions	With Actions	Without Actions	With Actions	Energy	Percentage
Monday			kWh	kWh	kWh	%
Tuesday			kWh	kWh	kWh	%
Wednesday			kWh	kWh	kWh	%
Thursday			kWh	kWh	kWh	%
Friday			kWh	kWh	kWh	%
Saturday			kWh	kWh	kWh	%
Sunday			kWh	kWh	kWh	%
Cumulative Improvement			kWh	kWh	kWh	%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