GAIA - Green Awareness In Action

D4.3 –Trial and Educational Evaluation

Document Ref.	D4.3
Document Type	Report
Work package	WP4
Lead Contractor	EA
Author(s)	Georgios Mylonas (CTI), Pavlos Koulouris (EA), Joerg Hofstaetter (OVOS), Andreas Friedl (OVOS), Federica Paganelli (CNIT), Giovanni Cuffaro (CNIT), Fredrik Lindqvist (SK), Joakim Gunneriusson (SK), Mariano Leva (OVER), Giuseppe Mollinaro (OVER), Lidia Pocero (CTI), Panagiota Tsetso (CTI), Konstantina Papageorgiou (EA), Nelly Leligou (SYN), Katerina Papadopoulou (SYN), Nikos Kanakis (SPARK)
Contributing Partners	CTI, EA, OVOS, CNIT, SK, OVER, SYN, SPARK
Planned Delivery Date	M39
Actual Delivery Date	M42
Dissemination Level	Public
Status	Submitted
Version	V1.1
Reviewed by	Nelly Leligou, Federica Paganelli, Pavlos Koulouris

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 696029.

Disclaimer

Partner Number	Name	Short Name	Country
1	Computer Technology Institute and Press “Diophantus”	CTI	Greece
2	Söderhamns Kommun	SK	Sweden
3	National Interuniversity Consortium for Telecommunications	CNIT	Italy
4	Synelixis Solutions Ltd	SYN	Greece
5	OVER	OVER	Italy
6	Ellinogermaniki Agogi	EA	Greece
7	SPARK Works ITC Ltd.	SPARK	Greece
8	Ovos Media Consulting Gmbh	OVOS	Austria

Document Revision History

Date	Issue	Author/editor/contributor	Summary
20/5/2019	0.1	Georgios Mylonas, Pavlos Koulouris	Initial draft
3/6/2019	0.3	Georgios Mylonas, Pavlos Koulouris, Joerg Hofstaetter, Mariano Leva, Joakim Gunneriusson	Evaluation of software components and building profiles
21/6/2019	0.5	Georgios Mylonas, Nelly Leligou, Katerina Papadopoulou, Joerg Hofstaetter, Andreas Friedl	Additions concerning the evaluation of the BMA and the GAIA Challenge
28/6/2019	0.7	Georgios Mylonas, Panagiota Tsetso	Educational evaluation
8/7/2019	0.8	Georgios Mylonas, Federica Paganelli, Mariano Leva, Giuseppe Mollinero, Pavlos Koulouris	Education and energy savings evaluation
24/7/2019	1.0	Georgios Mylonas, Pavlos Koulouris	Review Version
29/7/2019	1.0	Georgios Mylonas, Pavlos Koulouris	Submitted version
29/10/2019	1.1	Georgios Mylonas	Additions and corrections

Abbreviations

Abbreviation	Expression
BMS	Building Management System
DoW	Description of Work
EC	European Commission
EPB	Ethics and Privacy Board
GA	General Assembly
IoT	Internet of Things
IPR	Intellectual Properties Rights
KPI	Key Performance Indicator
PhC	Phone Conference
PIR	Passive InfraRed (sensor)
PM	Person Months
RoI	Return of Investment
SC	Steering Committee
TC	Technical Committee
TCB	Trials Coordination Board

Executive summary

This deliverable summarizes the work conducted in Work Package 4 of the project, following the public release of Deliverable D4.2 on M22. The main trial activities in the schools participating in the project took place during this period, up until April 2019. After several changes in the school lineup of the project, a set of new schools were added to the project, resulting in a total of 25 schools with IoT infrastructure and 2 schools in Greece without infrastructure comprising the GAIA fleet of school buildings.

This lineup of schools has translated to an audience for the project activities that consisted of several thousands of students and teachers, which participated directly in GAIA. Overall, in these 27 schools in Greece, Italy and Sweden, 3084 students and 213 educators participated directly in GAIA's activities, while the total number of students in these schools, which were also affected by the project, was 7503 for the school year 2018-19. At the same time, the GAIA Challenge has proved to be a big success among GAIA's audience, with 3777 user registrations from students and educators and very high participation and completion rates. Moreover, a total number of 916 students have had the opportunity to participate in the educational lab kit activities at their schools.

In this deliverable, we discuss the activities in GAIA's schools and provide an evaluation of both the educational and energy-saving outcomes of the project. Essentially, it is the continuation of deliverable D4.2, "Final Trial Documentation", picking up from where the overall design philosophy and planning for the trials was laid out in detail. During this period, a number of additional tools and readjustments were made to the original plan, among which was the GAIA methodology definition, essentially a "blueprint" for schools to help them in structuring and reporting their activities.

In terms of results regarding energy awareness and savings, 18 out of the total number of schools, with GAIA infrastructure installed, managed to implement educational in-school activities. Such activities produced in many cases energy savings during certain periods in the range of 15-20%, while a number of schools have managed to exceed this figure.

TABLE OF CONTENTS

1. Introduction – Overview and Deliverable Organization

After having designed and implemented software tools, educational content and other tools to realize in-school activities related to sustainability awareness and energy savings, the last period of the project was devoted to putting all of these planning to practice and produce actual results in GAIA's schools. In order to achieve this goal, the participating teachers and students utilized the produced GAIA applications, which connect with infrastructure available at schools and have undertaken several activities based on educational scenarios co-created with the schools themselves. Overall, WP4 activities in previous years enabled the consortium to put into practice in real school contexts the educational scenarios and applications developed, leading to their evaluation and validation. The term "trials" refers to the whole set of activities that enable the validation and evaluation of the GAIA approach.

Summarizing the results of the evaluation carried out for the trials, the following achievements stand out:

- Over 8000 students from 27 schools in Greece, Italy and Sweden, have been involved directly and indirectly in GAIA's activities during the project lifetime, along with students from the Sapienza University in Rome. From those students, 3084 have participated directly in GAIA's educational and energy-saving activities, during the school years 2017-18 and 2018-19.
- An estimated total of 213 educators were involved *directly* in the design and implementation of the project's activities.
- A total of 3777 users have registered in the GAIA Challenge.

The rest of this document is organized in the following chapters:

- **Chapter 2** provides the finalized list and an overview of the schools participating in the trials of the project, along with overall statistics.
- **Chapter 3** provides a short description of the 7 new schools that joined the project in the last year of the project, along with an overview of the installed infrastructure.
- **Chapter 4** continues with an overview of the trial activities in the schools of the project, summarizing the preparatory, educational and energy-saving activities conducted in this period, before going into the evaluation details in the following chapters.
- **Chapter 5** presents briefly the GAIA methodology, a tool developed to help simplify the organization and reporting of trial activities in the schools of the project.

We then continue with a more detailed description of the activities that took place in the four large schools that participated in the project:

- **Chapter 6** details the activities and results of the project at the Staffangymnasiet in Söderhamn, Sweden.
- **Chapter 7** presents the activities and results of the project at the Gramsci Keynes School in Prato, Italy.
- **Chapter 8** details the activities and results of the project at the Sapienza University of Rome, Italy.
- **Chapter 9** details the activities and results of the project at the Ellinogermaniki Agogi School in Greece.

We then continue with an overview and a more detailed presentation of activities and results from some of the 21 Greek schools in the project in **Chapter 10.**

- A presentation of results regarding indoor environmental parameters related to comfort is included in **Chapter 11**.

We must stress that since schools essentially designed their own interventions and activities for the project, there is a great diversity in the activities reported in this document. The evaluation of the software components of the project is included in **Chapters 12** and **13**, where a detailed overall evaluation of the Building Manager Application and the GAIA Challenge are presented, respectively.

- **Chapter 14** provides a description of the GAIA contests conducted during school years 2017-18 and 2018-19, along with a discussion on their role in engaging students to become more active within the context of GAIA.
- **Chapter 15** provides a detailed discussion on the evaluation of the educational lab kit component of the project, by presenting the results of a survey conducted within Greek schools with over 700 responses.
- **Chapter 16** continues with another survey evaluation, with respect to the sustainability awareness of the students that participated in the project, again with over 700 responses from students. We believe that these response numbers provide a good approximation of the overall student groups of the project.
- **Chapter 17** provides a discussion with respect to the costs associated with installing an IoT infrastructure like the one used in GAIA, as well as some guidelines in the ways it can pay for itself and practical considerations regarding how to decide where and what to install.

After having presented the results from the trials in detail for the schools and components of the project, **Chapter 18** provides an analysis structured on the KPIs defined in previous deliverables, in order to present the results in a more structured approach. Our analysis suggests that the project has superseded its initial aims in a number of aspects.

We conclude this document in **Chapter 19**, summarizing the overall results of the project with respect to trial activities. Finally, **Annex I** contains the questionnaires referenced in this document.

2. Overview of participation in the trials and final list of schools

In this section, we provide the overall numbers in terms of participation in the GAIA trials, as well as the finalized list of schools participating in the project. Throughout the second period of the project, the consortium has continued its efforts to attract new schools to join the existing list of participating schools. This activity has resulted in 7 schools joining GAIA, which are described in Chapter 3 of this document in detail. The list of participating schools in GAIA project has been shaped as detailed in the next table (following the naming conventions of D4.2).

Code	Schools	Location
GR01	1st Junior High School of Nea Filadelfeia	Athens
GR02	1st Junior High School of Rafina	Athens
GR03	8th Junior High School of Patras	Patras
GR04	Primary School of Lygia	Lefkada
GR05	Primary School of Megisti	Kastelorizo
GR06	Junior High School of Pentavrissos	Kastoria
GR07	Experimental Junior High School of Patras (Laggouras)	Patras
GR08/09	1st Tech. High School of Patras/1st Laboratory Centre of Patras (located in the same building)	Patras
GR10	46th Primary School of Patras	Patras
GR11	2nd Primary School of Paralia	Patras
GR12	6th Primary School of Kaisariani	Athens
GR13	5th Primary School of Nea Smyrni	Athens
GR14	Ellinogermaniki Agogi	Athens
GR15	1st Primary School of Psychiko	Athens
GR16	Ekpedeftiria Panou	Nafpaktos
IT17	Gramsci Keynes High School	Prato
IT18	Sapienza University	Rome
SE19	Technical High School of Söderhamn	Söderhamn
GR20	3rd High School of N. Filadelfeia (without GAIA infrastructure)	Athens

GR21	2nd Junior High School of N. Ionia (without GAIA infrastructure)	Athens
GR22	Experimental Primary School of the University of Patras (new)	Patras
GR23	Experimental Junior High School of the University of Patras (new)	Patras
GR24	Experiment High School of the University of Patras (new)	Patras
GR25	8th Junior High School of Volos (new)	Volos
GR26	TALOS Robotics School, University of Thessaly (new)	Volos
GR27	7th High School of Trikala (new)	Trikala
GR28	8th Junior High School of Korydallos (new)	Athens

Two schools in the list are located in the same building (GR08 and GR09) and we therefore treat them as one building in this document. Two schools in the list (schools GR20 and GR21) participated *without GAIA infrastructure* installed. In the following page, we have compiled a table outlining the most important numbers in terms of participation of students and educators for school years 2017-18 and 2018-19. We have included also separate columns for the educational lab kit activities, in order to highlight the large scale that these activities reached. Regarding the numbers for students and educators, we include two numbers: the first one is the number of people participating directly to GAIA, through a specific educational activity during the academic year, while the second one refers to people in the school that interacted with GAIA through activities in the school of other type, e.g., workshops or other school-wide activities.

Table 1 Overall trial participation statistics

School		Students (2018-19)	Students (2017-18)	Discrete students estimation (2017-19)	Students directly participated	Students indirectly affected	Teachers (2018-19)	Teachers active in GAIA	Teachers indirectly affected	Students in Lab Kit activities (2018-19)	Students in Lab Kit activities (2017-18)
GR01	1st Junior High School of Nea Filadelfeia	237	227	315	76	239	33	4	29	25	34
GR02	1st Junior High School of Rafina	405	398	537	127	410	45	6	39	-	-
GR03	8th Junior High School of Patras	200	201	267	35	232	29	3	26	20	11
GR04	Primary School of Lygia	82	85	95	54	41	17	8	9	54	-
GR05	Primary School of Megisti, Kastelorizo	24	19	28	5	23	6	2	4	-	-
GR06	Junior High School of Pentavryso	46	42	57	44	13	15	7	8	44	-
GR07	Experimental Junior High School of Laggouras, Patras	180	179	239	143	96	18	8	10	42	25
GR08/09	1st Laboratory Center & Prof. High School of Patras	237	246	324	30	294	59	6	53	15	10
GR10	46th Primary School of Patras	243	239	285	60	225	25	5	20	62	39
GR11	2nd Primary School of Paralia, Patras	163	171	190	47	143	27	5	22	24	20
GR12	6th Primary School of Kaisariani	226	224	270	100	170	34	7	27	31	31
GR13	5th Primary School of Nea Smyrni	321	323	377	209	168	33	8	25	-	-
GR14	Ellinogermaniki Agogi (EA)	2200	2200	2475	760	1715	55	8	47	148	14
GR15	1st Primary School of Psychiko, Athens	283	298	345	89	256	34	7	27		34
GR16	Junior High School of Ekpaideftiria Panou	67	91	113	43	70	10	6	4	43	20

IT17	Gramsci Keynes (Prato)	40	200	200	90	110	132	4	128	22	-
IT18	Sapienza University of Rome	58	160	160	3	157	4	4	0	-	-
SE19	Technical High School of Söderhamn (SK)	750	750	1000	800	200	84	80	4	-	-
GR20	3rd High School of Nea Filadelfeia	154	161	215	24	191	23	2	21	15	14
GR21	2nd Junior High School of Nea Ionia	178	192	249	77	172	26	7	19	-	-
GR22	Experimental Primary School of the University of Patras	210	-	210	60	150	9	4	5	55	-
GR23	Experimental Junior High School of the Univ. of Patras	196	-	196	42	154	24	10	14	64	-
GR24	Experimental High School of the University of Patras	194	-	194	27	167	25	3	22	-	-
GR25	8th High School of Volos	198	-	198	16	182	36	3	33	-	-
GR26	Talos Robotics Team, Volos	170	-	170	30	140	2	1	1		-
GR27	7th High School of Trikala	223	-	223	68	155	28	4	24	-	-
GR28	8th Junior High School of Korydallos	218	-	218	25	193	27	1	26	-	-
	TOTAL	**7503**	**6406**	**9151**	**3084**	**6067**	**860**	**213**	**647**	**664**	**252**

The above numbers indicate that for the main trials period, 7503 students attended the schools that participated in the project for the school year 2018-19. The respective number for the previous school year was 6406. Given that the composition of our end-users group is not stable between successive school years, the total number of students affected by the project is even larger than 7500. According to data provided to the consortium, the number of *discrete* students during these 2 school years is estimated as being close to 9151. As an additional remark, there was a mini trials phase of the project during school year 2016-17, which was described in detail in Deliverable D4.2. All of these numbers were verified by numbers sent by the schools themselves and our own archives. The total number of students in Greek schools have been verified by the official IT systems of the Greek Ministry of Education.

We have included in this table a column named “students directly participated” for the last two school years. This number refers to students that have actively participated to at least one of the educational activities actually implemented in the schools that participated in the project. This number does not include students for the participating schools that did not participate directly in one of the core activities of the project, i.e., in-class activities, energy-saving activities, or the GAIA Challenge. The total number of these students largely corresponds with the number of GAIA Challenge registrations for the last two school years, which was 3777 (as detailed in Chapter 12 of this deliverable).

Thus, we believe this is a great success for the project: an estimated 9150 students have been reached by the project, through activities of the project in their schools. That 3084 students have participated directly with the project and dedicated considerable time interacting with the consortium is an additional important aspect. Another element that highlights the extent of GAIA’s activities and the effort and resources put forth by members of the consortium is the total amount of students that participated in the educational lab activities: 916 students in total, with 664 for the school year 2018-19 and 252 for the school year 2017-18.

In terms of teachers directly involved in the project, we have included in the table above a total number of 213 teachers that participated via in-class activities in GAIA. The discrepancies between the total numbers of teachers in a specific school between successive school years can be explained by the fact that in many schools, especially in Greece, there are changes to school staff from year to year. Again, the number of teachers reached by the project is much larger than this, when referring either to teachers in the participating schools that were not involved in the design and implementation of educational activities, or to teachers that participated in events like the project workshops. Moreover, having in mind the figures in Table 1 and that we have held a large number of workshops and other educational activities for the past 3 years (deliverables D4.2, D5.4), it is easy to see that GAIA has engaged with more than the 860 educators listed above.

3. New Schools participating in GAIA in Greece

In this section, we provide brief descriptions about the schools that have joined the GAIA project for the school year 2018-19. All of these schools are located in Greece, and through this expansion we have been able to include additional cities in the project (Trikala and Volos), schools with a more experimental curriculum (Experimental schools of the University of Patras), cover additional locations in the metropolitan area of Athens (Korydallos). We have also included a school with a clear technological orientation for minors (Talos, University of Thessaly), apart from greatly increasing the overall number of students directly involved in GAIA activities for the school year 2018-19.

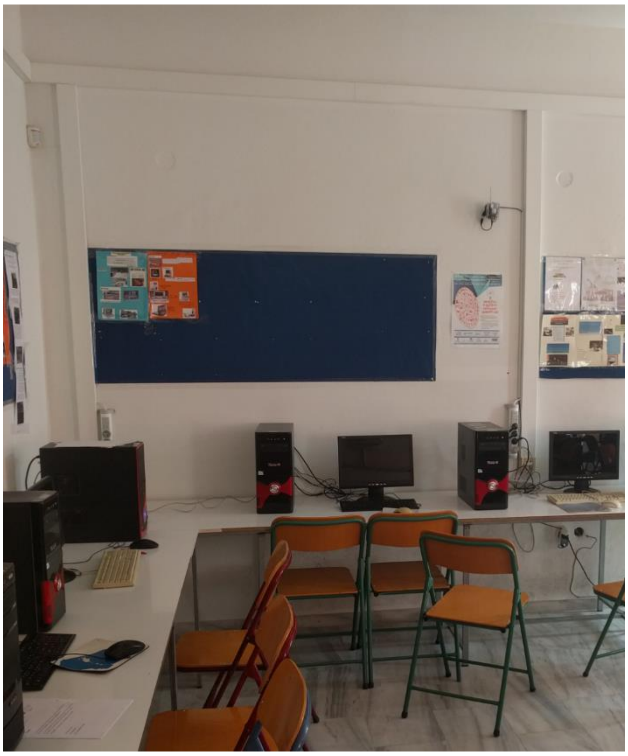
The 7 new schools added to the project are the following:

- The Experimental Primary School, Junior High School and High School of the University of Patras.
- The 8th Junior High School of Volos.
- The Talos Robotics School of the University of Thessaly, Volos.
- The 7th High School of Trikala.
- The 8th Junior High School of Korydallos, Athens.

The three Experimental schools of the University of Patras are located inside the university campus and are schools that are associated officially with the University of Patras, with students from various departments of the university often giving lectures as part of their university practice. Similarly, the Talos Robotics School is associated with the University of Thessaly, with university staff and faculty also participating in the educational activities of the team, while also having a close collaboration with the 8th Junior High School of Volos. The 7th High School of Trikala and the 8th Junior High School of Korydallos both have robotics clubs for several years. Thus, all of the new schools added to the project have a very good level of experience in participating in novel educational activities. The official letters of support from the new schools that have agreed to participate in these activities are available in Annex I of this deliverable.

We continue in the rest of this section with the brief descriptions of these schools, including additional details about the educators that participated in the project activities, as well as details regarding the actual GAIA infrastructure installations in the respective school buildings.

Experimental Primary School of the University of Patras, Greece (GR22)



This is a public school, with its building located at the area of the University of Patras campus. As one of the schools belonging to the Experimental group of the Greek school network, the school has a greater flexibility than most schools in scheduling extracurricular educational activities and integrating them into the school's schedule.

Headmasters: Alexopoulos Haralampos

<table>
<tr><th>Teacher Name</th><th>Subject</th><th>Classes</th><th>Total students</th></tr>
<tr><td>Kriparopoulou Antigoni</td><td>Teacher</td><td rowspan="4">5th grade classes</td><td rowspan="4">60 Directly Involved</td></tr>
<tr><td>Stavropoulos Petros</td><td>IT teacher</td></tr>
<tr><td>Tsezou Athina - Spyridoula</td><td>Teacher</td></tr>
<tr><td>Mani Foteini</td><td>Teacher</td></tr>
</table>

The infrastructure on this school was installed on September 2018. The list of the GAIA infrastructure in the building is as follows:

Overview of IoT devices available		
IoT Gateway (LoRa communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	4
Weather Station	No	-
Atmospheric Conditions Unit	No	-
Power meter	Yes	2

The diagram of the GAIA installation inside the building follows. The areas of the school building monitored for power consumption are included within the purple boxes.

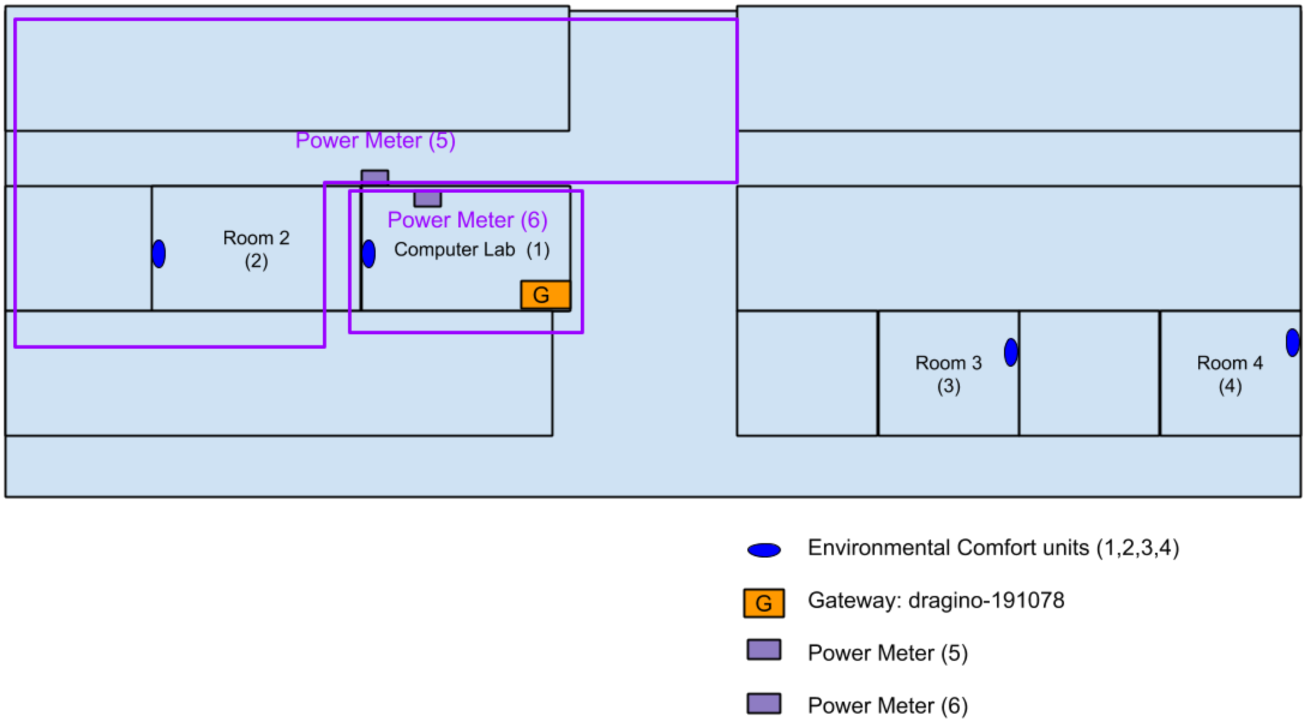


Figure 1 Diagram of GAIA installation in the school building of the Experimental Primary School of the University of Patras

Experimental Junior High School of the University of Patras, Greece (GR23)

This is a public school, with its building located at the area of the University of Patras campus. As one of the schools belonging to the Experimental group of the Greek school network, the school has a greater flexibility than most schools in scheduling extracurricular educational activities and integrating them into the school's schedule.

Headmasters: Schoinas Vasilios

Teacher Name	Subject	Classes	Total students
Armoni Aggeliki	IT teacher	1st, 2nd, 3rd Grade Classes	42 Directly, 198 Indirectly Involved
Alexandropoulou Aggeliki	IT teacher		
Soulioti Spyridoula	Mathematics		
Riga Vasiliki	Mathematics		

Avramidou Callifroni	Philologist		
Plakouda Aikaterini	Philologist		
Voutsina Lamprini	Physics and Electronics		
Schoinas Vasilios	English Philologist		
Diplari Xristina	French Philologist		
Poulou Paraskevi	Biologist		

The infrastructure on this school was installed on July 2018. The list of the GAIA infrastructure in the building is as follows:

Overview of IoT devices available		
IoT Gateway (LoRa communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	6
Weather Station	No	-
Atmospheric Conditions Unit	No	-
Power meter	Yes	1

The diagram of the GAIA installation inside the building is as follows. The areas of the school building monitored for power consumption are included within the purple boxes.

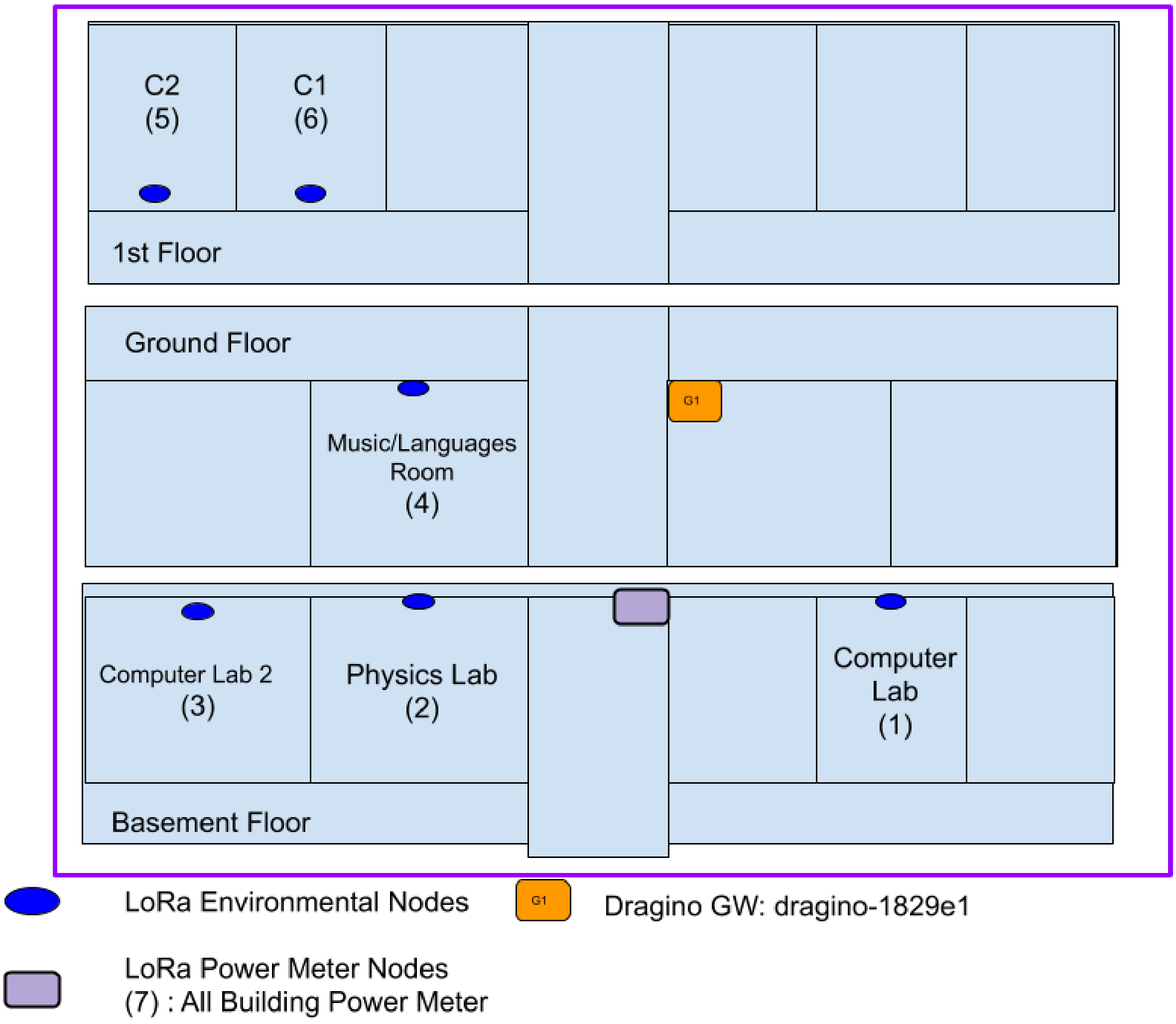
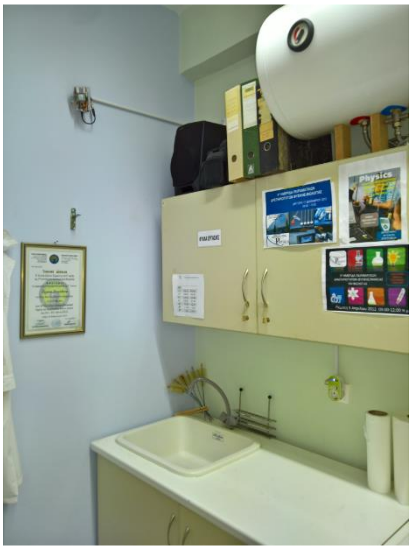
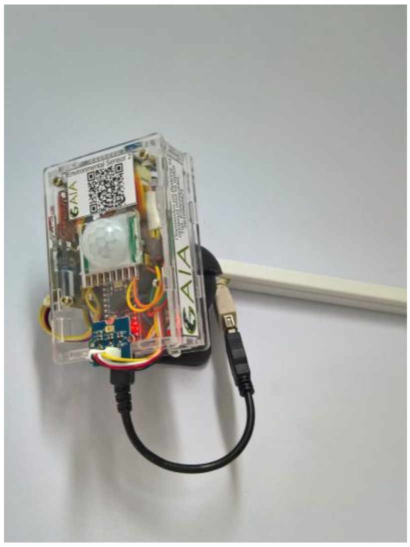


Figure 2 Diagram of GAIA installation in the school building of the Experimental Junior High School of the University of Patras

Experimental High School of the University of Patras, Greece (GR24)





This is a public school, with its building located at the area of the University of Patras campus. As one of the schools belonging to the Experimental group of the Greek school network, the school has a greater flexibility than most schools in scheduling extracurricular educational activities and integrating them into the school's schedule.

Headmasters: Sfaelos Ioannis

Teacher Name	Subject	Classes	Total students
Chiotelis Ioannis	Physics Teacher	1st Grade Class	27 Directly Involved
Fyttas George	Physics Teacher		
Tsiokanos Athanasios	Chemist		

The infrastructure on this school was installed on July 2018. The list of the GAIA infrastructure in the building is as follows:

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	6
Weather Station	No	-
Atmospheric Conditions Unit	No	-
Power meter	Yes	2

The diagram of the GAIA installation inside the building is as follows. The areas of the school building monitored for power consumption are included within the purple boxes.

Building Installation Floorplan

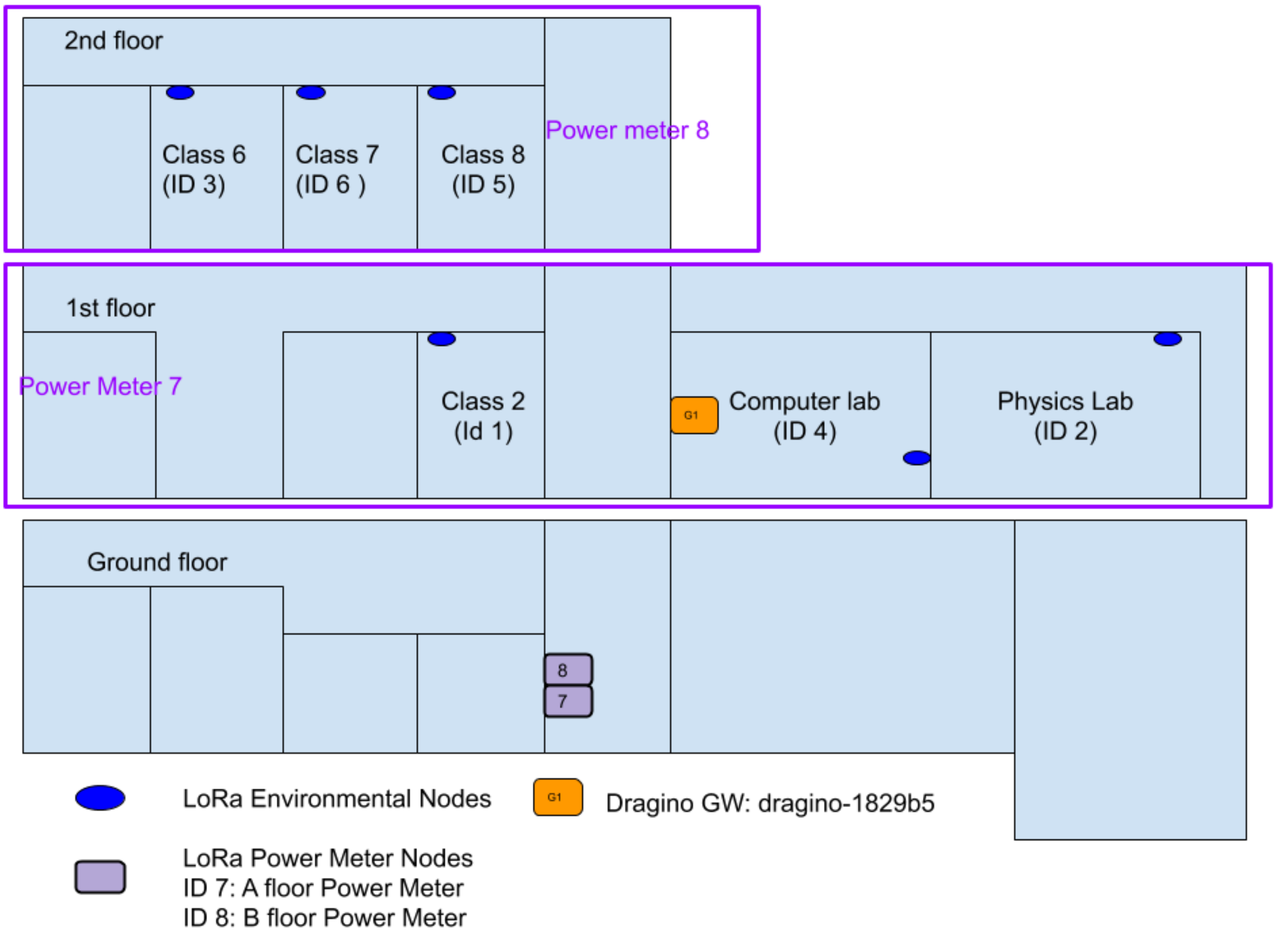


Figure 3 Diagram of GAIA installation in the school building of the Experimental High School of the University of Patras

8th Junior High School of Volos, Greece (GR25)

This is a public school, with its building located at the outskirts of the port city of Volos. The school has a long-standing collaboration with the University of Thessaly in educational matters related to technology.

Headmasters: Sykiotis Andreas

Teacher Name	Subject	Classes	Total students
Samaras Nikolaos	IT Teacher	1st, 2nd, 3rd Grade Classes	16 Directly Involved
Sikiotis Andrew	Philologist		
Koltsidopoulos Euripides	Biologist		

The infrastructure on this school was installed on July 2018. The list of the GAIA infrastructure in the building is as follows:

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	6
Weather Station	No	-
Atmospheric Conditions Unit	No	-
Power meter	Yes	3

The diagram of the GAIA installation inside the building is as follows. The areas of the school building monitored for power consumption are included within the purple boxes.

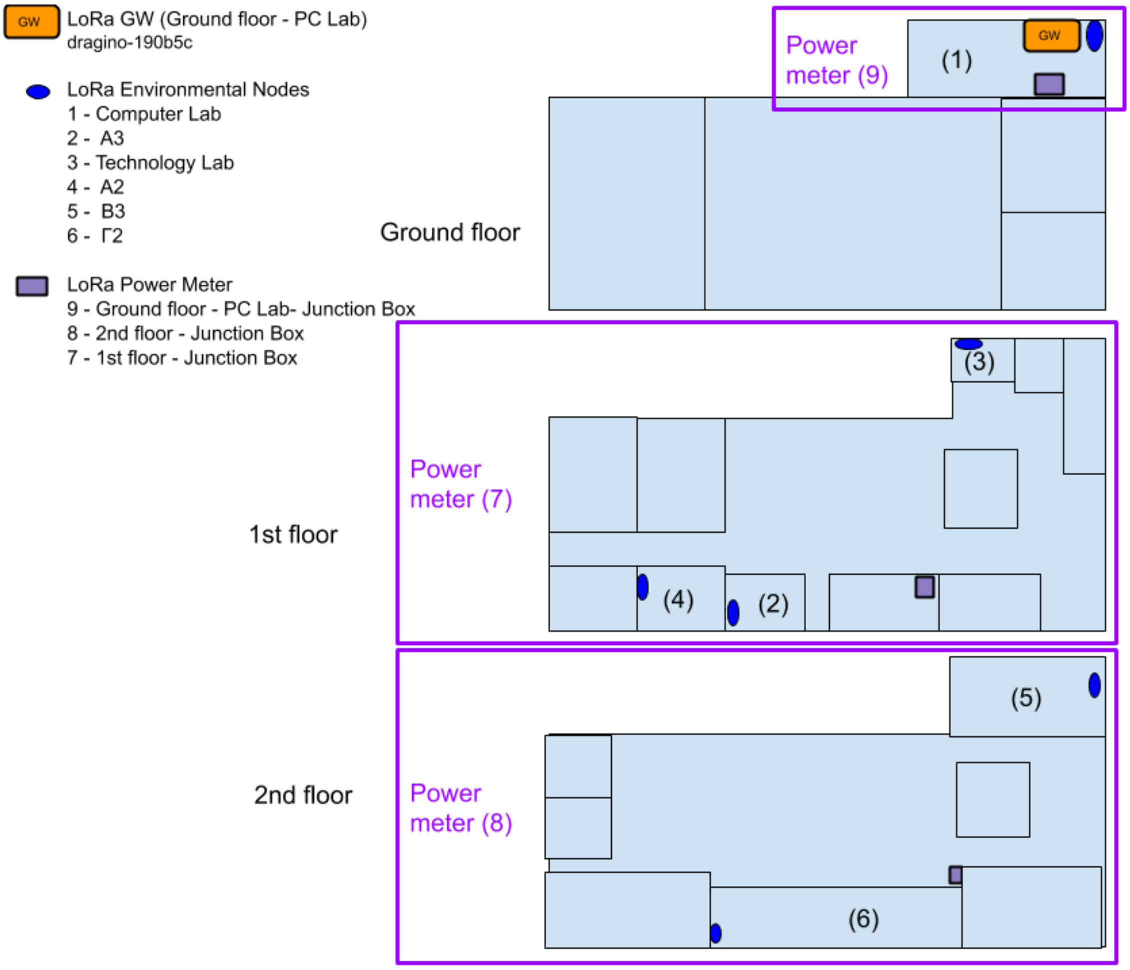


Figure 4 Diagram of GAIA installation in the school building of the 8th Junior High School of Volos

Talos Robotics School, University of Thessaly, Greece (GR26)

The TALOS team of the University of Thessaly is activated from 2016 in the field of STEAM and Makerspace activities with children. It comprises a team of educators and researchers and is actively supported by the University of Thessaly, as well as a team of faculty members with a lot of experience in STEM-related matters. It also has a large and high-quality set of makerspace equipment. The building is located at the center of the city of Volos, and is used by both TALOS staff and students, as well as university students, having a large amphitheater at the ground floor of the building, and a number of laboratory rooms. The building is used mostly during weekends for educational activities by TALOS students.

Teacher Name	Subject	Classes	Total students
Proias George	IT and Makerspace, PhD	Primary and Junior High School students	30 Directly Involved
Kourias Spyros	IT and Makerspace, PhD		

The infrastructure on this school was installed on October 2018. The list of the GAIA infrastructure in the building is as follows:

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	6
Weather Station	No	-

Atmospheric Conditions Unit	No	-
Power meter	Yes	2
CO_2 Sensor	Yes	2
PM Sensor	Yes	2

The diagram of the GAIA installation inside the building is as follows. The areas of the school building monitored for power consumption are included within the purple boxes.

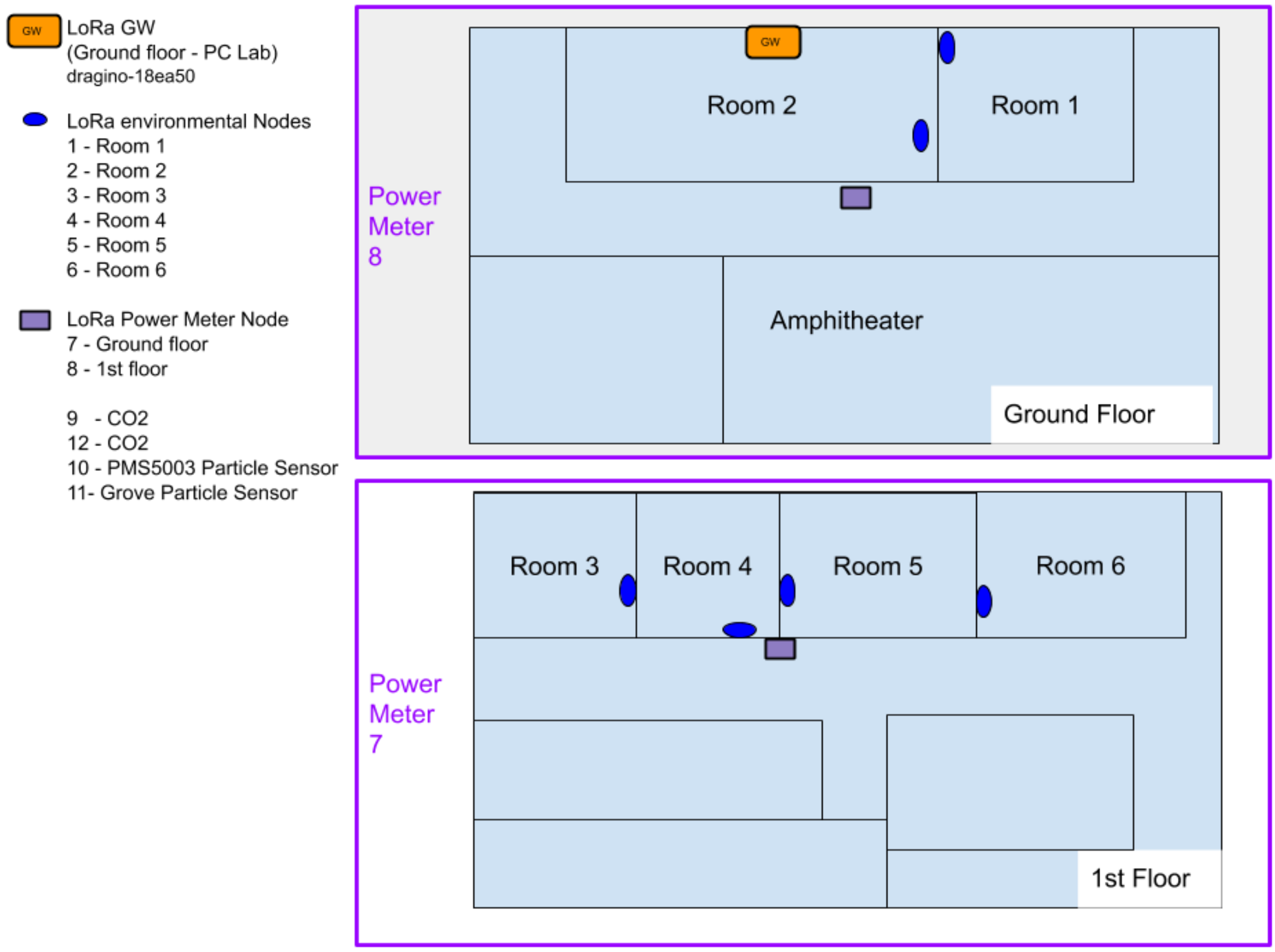
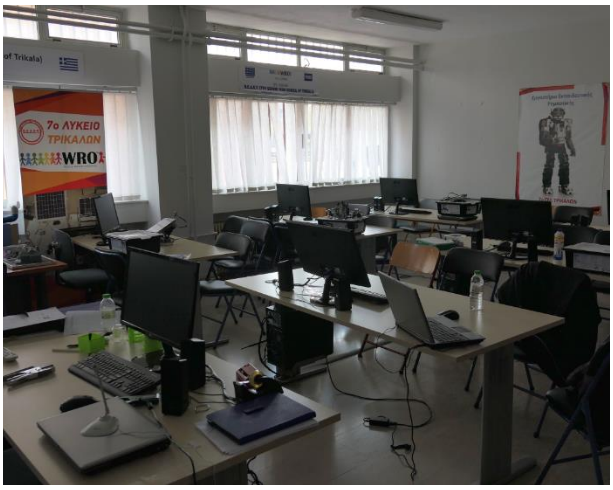


Figure 5 Diagram of GAIA installation in the school building of the Talos Robotics school

7th High School of Trikala, Greece (GR27)



This is a public school, with its building located at the outskirts of the city of Trikala. It is one of the most active schools in Greece in terms of educational activities related to technology, having won awards at a number of national and global robotics championships. The school has also one of the best robotics labs among Greek schools because of these activities.

Headmasters: Agathoklis Azelis

Teacher Name	Subject	Classes	Total students
Spachos Vasileios	IT Teacher	1st, 2nd Grade	68 Directly Involved
Zygouris Vasileios	Sociologist		
Karamitrou Aristea	Fitness Trainer		
Kliafa Victoria	English Teacher		

The infrastructure on this school was installed on October 2018. The list of the GAIA infrastructure in the building is as follows:

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	6
Weather Station	No	-
Atmospheric Conditions Unit	No	-
Power meter	Yes	3

The diagram of the GAIA installation inside the building is as follows. The areas of the school building monitored for power consumption are included within the purple boxes.

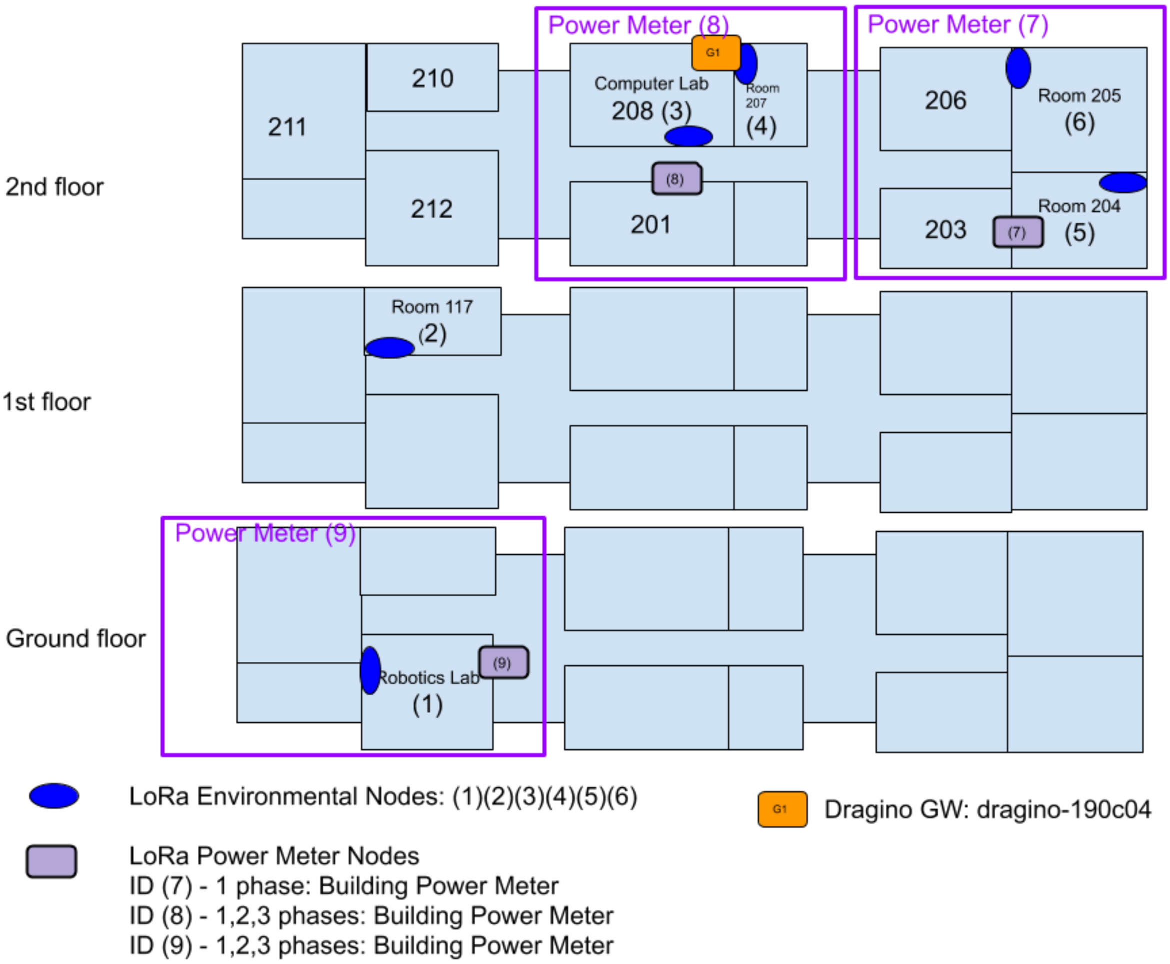


Figure 6 Diagram of GAIA installation in the school building of the 7th High School of Trikala

8th Junior High School of Korydallos (GR28)




This is a public school located at the city of Korydallos, inside the metropolitan area of Athens. The school has been hosting a robotics club for a number of years and has cultivated a culture of participating in technologically –oriented extracurricular activities. It is also one of the schools in GAIA with the most diverse composition of students in terms of cultural background.

Headmasters: Alexandridis L.

Teacher Name	Subject	Classes	Total students
Papadimitropoulos Nikolaos	Chemist	2nd and 3rd Grade Classes	25 Directly Involved

The infrastructure in this school was installed on September 2018. The list of the GAIA infrastructure in the building is as follows:

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	5
Weather Station	No	-
Atmospheric Conditions Unit	No	-
Power meter	Yes	1

The diagram of the GAIA installation inside the building is as follows. The areas of the school building monitored for power consumption are included within the purple boxes.

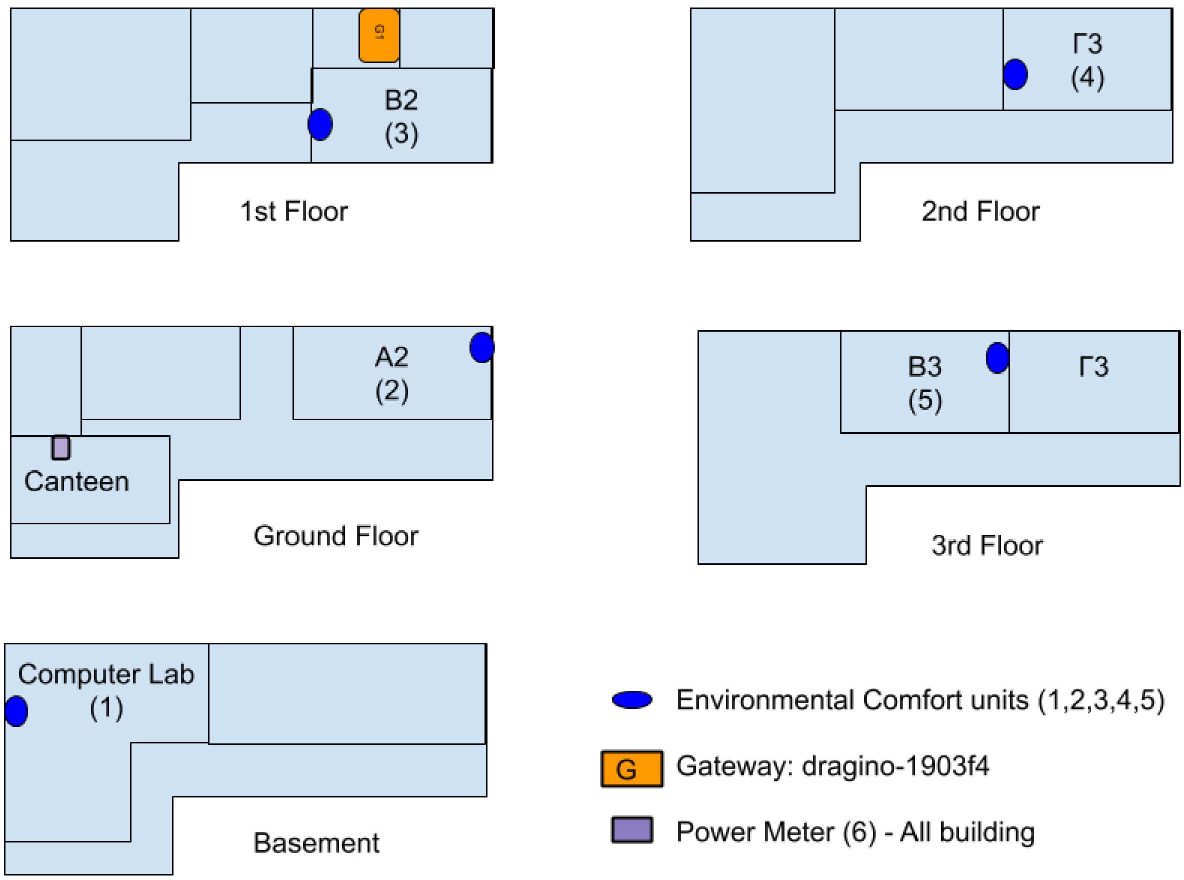


Figure 7 Diagram of GAIA installation in the school building of the 8th Junior High School of Korydallos

4. Overview of the trials and other trial-oriented activities

In this chapter, we describe the activities that have taken place between spring 2018 and summer 2019, essentially covering 2 school year periods. This period is the one referenced in this document as the main trials period for the project. As a reminder, a set of "mini" trials in selective schools was realized during the period April 2017 – June 2017. During that period, the GAIA team had the opportunity to collect valuable feedback on the applications from the final users, to test the ideas of scenarios, as well to introduce teachers and students in GAIA philosophy. That set of activities was described in detail in deliverable D4.2.

In deliverable D4.2 ("Final Trials Documentation"), the consortium has also defined an overall planning and implementation strategy for this trials period. However, during this period many changes took place in the composition of the list of GAIA schools, especially with 7 new schools being added to this list. Changes in the project consortium also had as a side effect restructuring certain trials activities and balancing the focus between other activities. Findings from the mini trials and the initial months of the trials had also an effect on both the application set and the trials design: on both the Challenge and the BMA, we made changes to accommodate requests by the users (discussed in Chapter 13). We also restructured parts of our monitoring strategy and introduced the GAIA methodology (discussed in the next chapter), in order to simplify the process of planning and reporting energy-saving activities. With respect to the actual implementation of the trials' activities, in the rest of this document we focus only on the 25 schools with GAIA IoT infrastructure installed in the respective buildings, leaving out the 2 schools without IoT infrastructure.

In Table 2, which summarizes the trials activities reported in the following pages, we have included all the important aspects of the trials:

- Participation in Lab Kit activities in school year 2017-18 and 2018-19.
- Participation in the GAIA Challenge.
- Use of GAIA's methodology.
- GAIA contests.
- Energy savings achieved.
- Type of activities implemented.

As an overall comment on the trials participation of the schools, apart from the overall impressive results of the project in terms of student numbers (see Chapter 2), the consortium has **managed to mobilize** the majority of the **schools** for almost **all the different aspects of the project**. Given the constraints placed on the project by having such a large number of different schools and end-user groups, the motivation of the schools, the teachers and the students themselves to participate in GAIA, has proved to be a major catalyst in the success of the trials as a whole.

Taken as a whole, this table shows that the schools almost in their entirety played the Challenge. Moreover, in at least one of the two school years almost all schools hosted some lab kit activities, while 18 out of 25 utilized the GAIA tools, planning and methodology to implement energy-saving activities. Out of all the schools, most actually succeeded in realizing energy savings for some periods, while two of the schools (Experimental High School of the University of Patras, 2nd Primary School of Paralia, Patras) chose to focus more on aspects related to retrofitting energy-efficient infrastructure. The latter school contacted the local municipality in a successful attempt to replace the school's external lighting with an efficient LED installation.

We now comment using a bit more detail on Table 2 regarding the abovementioned aspects, with deeper analysis included in the respective following chapters of this document.

Participation in Lab Kit activities during school years 2017-18 and 2018-19: The educational lab kit proved to be a successful proposition to introduce GAIA to the participating schools and students, together with the Challenge. CTI in particular has made considerable effort to visit a large number of schools and implement such activities in as many schools as possible. However, this was not feasible due to schools like Kastelorizo being in very remote places, or schools that joined the consortium in autumn 2018 not having enough time to dedicate for such activities. Thus, the N/A (not available as an option) values in Table 2 for these schools. Such aspects are discussed in more detail in Chapter 15.

Participation in the GAIA Challenge: as mentioned earlier, the GAIA Challenge has been a massive success with the students in all 3 countries. Essentially all the schools of the project have adopted it as an introduction to sustainability and energy, except from the Sapienza University in Rome. However, this was more or less expected, since the design of the Challenge was focused on much younger students. Such aspects are discussed in more detail in Chapter 13.

Use of GAIA's methodology: as explained in the next chapter, the methodology was a tool to simplify the implementation and monitoring of the progress of the energy-saving activities in the schools of the project. The schools also seemed to agree that it was a useful tool, since 18 out of the 25 schools used it to a certain degree.

GAIA contests: there were two GAIA contests during the previous 2 school years. There was a lot of interest from the schools regarding this specific aspect of the trials, and it helped to engage the schools and increase their interaction with the project in a very quantifiable manner. Such aspects are discussed in more detail in Chapter 14.

Energy savings achieved: as can be seen in the respective column of Table 2, a number of schools achieved energy savings in the range of 15-20%, which is compatible with results in related previous work in the field. Other schools that focused on very specific issues had much more impressive results, while other ones were below 10%. The results mentioned in this table apply to the time periods in which the schools implemented the energy-saving activities, i.e., mostly during spring 2019. In several instances, we also refer to the energy that can be influenced by users. As also explained in the GAIA methodology chapter, school buildings have the characteristic that their operation is hard to change. In many cases, some parts of the energy consumption profile of a school simply cannot change without having a serious effect on its operation; e.g., in Söderhamn, air ventilation is a large part of the energy consumption of the building but cannot be turned off. In Prato, heating is handled by the municipality and cannot be affected directly by changes in the behavior of students and teachers.

Type of activities implemented: Regarding type of energy-saving activities implemented by the schools, the vast majority of the schools chose to focus on lighting. It is a recurring theme, especially in Greek schools, that lighting operation is sub-optimal, although it is a big part of the power consumption in school buildings. The other popular area chosen by the schools was teaching equipment and electrical appliances in schools. Three schools chose to explore some aspects related to heating, while more schools were interested in seeing thermal comfort issues in practice. There was one school (the Experimental Primary School of the University of Patras) that explored indoor noise levels, which was a standout activity for the consortium members.

Table 2 Overview of school activities during GAIA's main trials period.

School	Lab Kit 2018	Lab Kit 2019	Played Challenge	GAIA Methodology	Participated in contests	Energy Savings Achieved During Activities	Type of activity
Staffangymnasiet, Söderhamn	N/A	N/A	Yes	Yes	No	9% total, 22% of the energy affected by users	Total electricity consumption, appliances
Gramsci Keynes School, Prato	N/A	Yes	Yes	Yes	Yes	41.4% (1st year), 37% (2nd year)	Lighting in school corridors, equipment/appliances
Sapienza University, Rome	N/A	Yes	N/A	Yes	N/A	8.7% (lighting), 2.6% (total)	Lighting and total
Ellinogermaniki Agogi, Athens	Yes	Yes	Yes	Yes	No	54% (lighting)	Lighting
Exp. Primary School - Patras University	N/A	Yes	Yes	Yes	Yes	20,99% (total)	Lighting, total power consumption, noise
Exp. Junior High School - Patras University	N/A	Yes	Yes	Yes	Yes	16.13% (total)	Total electricity consumption, lighting, thermal comfort
Exp. High School - Patras University	N/A	Yes	Yes	Yes	No	Studied external lighting issues and compiled report	Lighting, external lighting
Exp. High School - Laggouras, Patras	Yes	Yes	Yes	No	Yes	18.21% (year-round electricity consumption at GAIA monitored classrooms)	The school did not implement structured energy saving actions in 2018-19, although they had strong participation previously. By comparing 2018-19 with 2017-18, we saw 18,21% energy savings at a part of the building where GAIA classes had lectures.
46th Primary School, Patras	Yes	Yes	Yes	Yes	Yes	19.1% total	Total electricity consumption
2nd Primary School of Paralia, Patras	Yes	Yes	Yes	Yes	Yes	Studied external lighting and heating issues, compiled report	Lighting, external lighting, heating
EPAL/Lab Center Patras	Yes	Yes	Yes	No	Yes	-	-
8th Junior High School, Patras	Yes	Yes	Yes	Yes	Yes	6.1% total, 13% on the energy affected by users	Total electricity consumption
Ekpedeftiria Panou, Nafpaktos	N/A	Yes	Yes	No	N/A	-	-

1st Junior High School of N. Filadelfeia, Athens	Yes	No	Yes	No	Yes	8.24% (year-round electricity consumption at the 2nd floor of the school)	The school did not implement structured energy saving actions in 2018-19, although they had strong participation previously. By comparing 2018-19 with 2017-18, we saw 8,24% of energy savings at the 2nd floor of the school.
6th Primary School of Kaisariani, Athens	Yes	Yes	Yes	Yes	Yes	52.5% on the energy affected by users	Total electricity consumption
5th Junior High School of Nea Smyrni, Athens	Yes	No	Yes	No	Yes	-	-
1st Junior High School of Rafina, Athens	Yes	No	Yes	No	No	-	-
8th Junior High School of Korydallos, Athens	N/A	Yes	Yes	Yes	Yes	Studied heating issues and compiled report	Heating consumption
1st Primary School of N. Psychiko, Athens	Yes	Yes	Yes	Yes	Yes	7.57%	Total electricity consumption
8th Junior High School, Volos	N/A	N/A	Yes	Yes	No	34.22% on the energy affected by users	Total electricity consumption, lighting, appliances
TALOS Robotics School, Volos	N/A	Yes	Yes	Yes	No	31,07% total, 71% on energy affected by users	Total electricity consumption, lighting, appliances
7th High School, Trikala	N/A	No	Yes	Yes	Yes	37.9% (total electricity)	Total electricity consumption, lighting, appliances
Junior High School of Pentavryso, Kastoria	Yes	Yes	Yes	Yes	Yes	52.88% (total electricity)	Total electricity consumption, heating, thermal comfort
Primary School of Lygia, Lefkada	Yes	Yes	Yes	Yes	Yes	21.4% of the energy affected by users	Total electricity consumption, lighting, thermal comfort
Primary School of Kastelorizo	N/A	N/A	Yes	No	Yes	-	-

Contribution by educators to GAIA's educational material

Throughout the trials, there have been a number of educators in Greece, Sweden and Italy, which have contributed to a certain degree to the production of GAIA's educational material, or they have contributed by producing other types of material, e.g., videos for explaining their energy-saving activities. Such contributions were made by:

- I. Nesi and G. Simoni, from the Gramsci Keynes school in Prato.
- J. Gunneriusson and F. Lindqvist, from the Staffangymnasiet in Söderhamn.
- Greek teachers I. Markelis (Ekp. Panou, CTI), N. Papageorgiou (EA), D. Karantzis (6th Primary School of Kaisariani), C. Tziortzioti (EKFE N. Filadelfeias, CTI), A. Apostolidou (2nd Junior High School of N. Ionia), G. Proias (Talos).

On the YouTube channel[1] of the project, a number of videos produced or co-produced by the schools of the project have already been uploaded. Other videos by the schools have been uploaded to third channels, e.g. the video[2] by the Gramsci Keynes School in Prato. Some of these videos were produced as part of the participation of the schools in the GAIA contests, while others as part of GAIA workshop presentations.

We should also mention that members of the GAIA consortium had the opportunity to co-author a number of scientific publications with a number of these educators, since they provided useful input and participated in the shaping of the GAIA activities at several schools. Such publications include the following:

- G. Mylonas et al. "An Educational IoT Lab Kit and Tools for Energy Awareness in European Schools", in International Journal of Child-Computer Interaction, Elsevier.
- C. Tziortzioti, I. Mavrommati, G. Mylonas, A. Vitaletti, I. Chatzigiannakis, "Scenarios for Educational and Game Activities using Internet of Things Data", IEEE Conference on Computational Intelligence and Games (CIG18), Maastricht, Netherlands.
- G. Mylonas, et al., "Using an Educational IoT Lab Kit and Gamification for Energy Awareness in European Schools", in Proceedings of the Conference on Creativity and Making in Education (FabLearn Europe'18), ACM, 30-36.
- G. Mylonas, D. Amaxilatis, L. Pocero, S. Tsampas, J. Gunneriusson, "A Methodology for Saving Energy in Educational Buildings Using an IoT Infrastructure", submitted to the 10th International Conference on Information, Intelligence, Systems and Applications
- F. Paganelli, G. Mylonas, G. Cuffaro, I. Nesi, "Experiences from Using Gamification and IoT-based Educational Tools in High Schools towards Energy Savings", submitted to the Ambient Intelligence 2019 Conference.

---

[1] GAIA Project YouTube channel, https://www.youtube.com/channel/UC6BA2B6FMNE83-UFZw34gZA/

[2] Gramsci-Keynes, Progetto GAIA "Green Awareness In Action", https://www.youtube.com/watch?v=eWWkP8IadSM

Preparatory, Organizational and Dissemination workshops with educators

In this section, we briefly describe some activities targeting the educators participating in the GAIA trials, as well as the overall educational community. These activities have all been conducted after the release of deliverable D4.2, "Final Trial Documentation". The list in this chapter does not include the numerous informal visits and meeting with educators for the trials' organization and synchronization.

Workshop with teachers at Gramsci Keynes School

Date and place	7 March 2018, Prato, Italy
Number of participants	4

In the framework of the third GAIA Workshop at Gramsci-Keynes school, 4 new teachers took part to the discussion, showing interest in taking part in our project. After a very brief introduction about the project, we started showing them the practical activities they can do with their students: how to play with the Gaia Challenge, how to monitor the data collected from the sensors in the school with the BMS and we helped them giving some example of formative activities built on purpose for the Gramsci-Keynes school. At the end of the meeting, we encouraged all the teachers to promote GAIA and its activities within their colleagues.

Seminar in Prato

Date and place	24/05/2018, Florence
Number of participants	50

OVER's Energy Manager had a seminar about energy topics with the aim to increase energy awareness in students of Prato and propose possible activities to save energy acting on the own behavior. The seminar was divided in two parts; the first, where we presented general concepts about energy such as the way in which electricity is produced and, the concept of carbon cycle. Practical examples, like the convenience of the electrical car or a comparison among national electricity mix emission factors have been explained. The second part of the seminar covered more specifics topics for the two different participating curricula. For the Surveyor, class a more in-depth explanation was performed about energy efficiency in buildings (i.e., thermal transmittance), whilst for scientific curricula initial concepts about heat pumps have been treated.

Contest Prize announcement to students

Date and place	8 June 2018, Prato, Italy
Number of participants	40

On Friday, June 8, the last day of school, the ceremony for the Italian schools took place at the Gramsci-Keynes school in Prato. Classes 1 ELS, 2 DLS and 1 EE finished first in both CONTEST 1 for the best energy reduction result and CONTEST 2 for Best Portfolio together with the Pentavrysso School. They won a tablet and a Raspberry Pi with a sensors kit. The ceremony took place in the auditorium of the school; the students also received a certificate of participation to the GAIA activities.


GAIA Summer school 2018

Date and place	July 2018, Pallini, Greece
Number of participants	25

The consortium, and in particular EA and CTI, have initiated the organization of a summer course during 2018, aimed towards educators from all the countries participating in GAIA. This will the second summer course organized by the consortium and will aim for a much larger participation than the first one, since the consortium will have already built a large network of collaborators through the trials phase of the project. More details regarding this summer course can be found at the website for this action (http://play-create-learn.ea.gr/), as well as the respective section for GAIA (http://play-create-learn.ea.gr/GAIA).

Figure 8 A scene from the Play-Create-Learn event

Workshop with the 3DLab project

Date and place	September 11, 2018, Patras, Greece
Number of participants	14

GAIA project was presented at the 3rd project meeting of the 3DLab Making with Brain, Technology and Hands (Erasmus+ project). The presentation of the GAIA was focused on the GAIA Lab kit and how it was applied to school community the last school year and the goals for the school year 2018-2019.

Awarding students with Contest Prizes

Date and place	25 October 2018, Prato, Italy
Number of participants	20

GAIA awarded the school with the prizes gained within the GAIA Contest 2018 (one tablet and one sensor kit). The prizes have been given to the school principal with the participation of a delegation of students and teachers. We then had a meeting with four teachers to propose and discuss GAIA educational activities to be carried out this school year. Hereafter a list of proposals:

- Participation of new classes to the GAIA Challenge.
- Preparation of new content for the GAIA Challenge.
- Monitoring and experimentation activities using GAIA sensors (e.g. energy saving in the school hall and monitoring devices' energy consumption behavior in the PC laboratory).
- Hands-on activities with the Sensor Kit.
- Build your IoT application in GAIA with Node-RED (https://nodered.org/) to support energy-saving class activities.

Figure 9 Students receiving their awards

Workshop with educators from schools in Western Greece

Date and place	02/11/2018, Patras
Number of participants	18

CTI and EA organized a workshop for educators at schools from the Western Greece area, and mainly from Patras. The topic of the workshop was the organization and implementation of educational and energy-saving activities during the 2018-19 school year, after having the experience of implementing several activities during the previous school years.

Workshop in the Gramsci Keynes School in Prato with students

Date and place	13 February 2019, Prato, Italy
Number of participants	30 students

CNIT organized a seminar held by OVER in the Gramsci Keynes school in Prato. Two classes of the Scientific Lyceum participated to the seminar. The seminar introduced main concepts related to energy and energy efficiency and carbon footprint. The students were also given some data on carbon footprint of different transportation means and the average carbon footprint of European countries. Finally, some data on the energy consumption of the school in Prato were provided to promote their awareness and their intervention in the daily life. The second part of the workshop was devoted to introducing the ICT tools provided by GAIA, and how they can use them to implement energy-saving activities.

Presentation of GAIA projects to students, University of Florence

Date and place	24/05/2018, Florence
Number of participants	25

CNIT and OVER made an introduction to the Internet of Things, Architectures, Architecture of the GAIA platform as an example of IoT architecture, adoption of related software patterns and REST architectural style. The audience consisted of students of the School of Engineering at the University of Florence. Students had the opportunity to play with the GAIA technologies presented in the workshop, while the consortium received feedback on its software lineup.

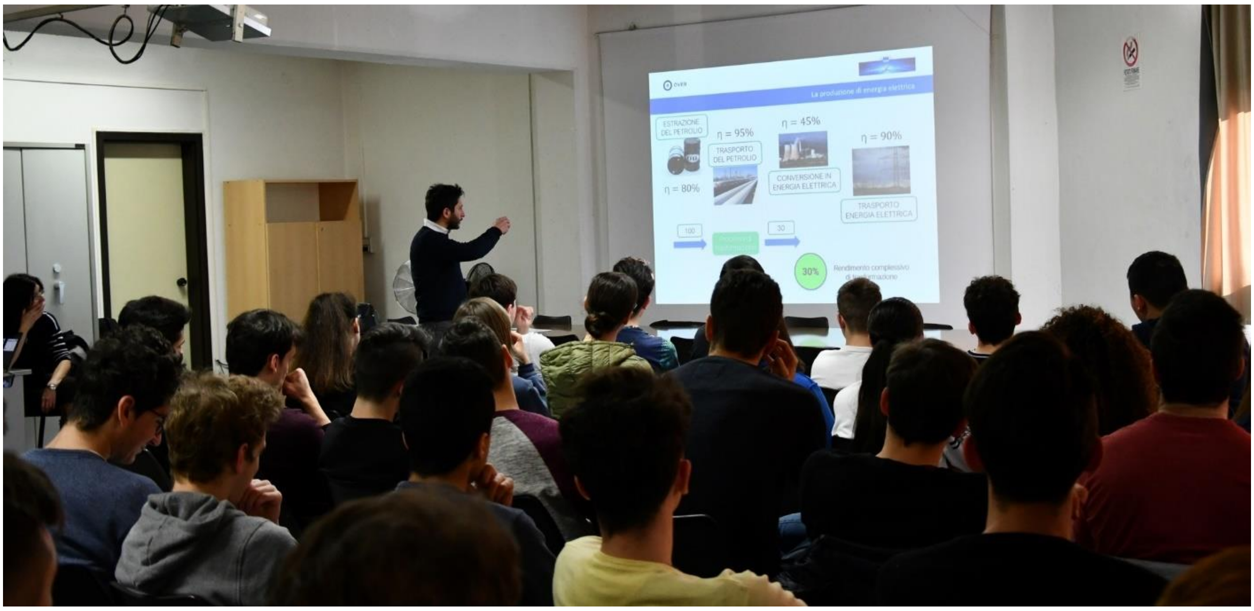


Figure 10 Scene during a presentation of GAIA by OVER

Workshop in Sapienza

Date and place	May 2018, Rome
Number of participants	60

During the month of May 2018, OVER held a workshop in the Department of Computer, Control, and Management Engineering Antonio Ruberti of Sapienza, University of Rome. The seminar has been organized in more days and three modules have been treated. The workshop has been structured in a similar way to what we did in the first edition, held in May 2017. In the first two modules, we discussed about theoretical aspects, presenting an outline of the project along with its objectives and introducing the software infrastructure in all its components. In the last module of the workshop, students had a view of applications deployed focusing more on the technical aspects (API interfaces among them). At the end of this part, three project proposals have been discussed with the attenders inviting them to join the GAIA community contributing to the development of new functionalities using GAIA existing API and its dataset. Several project proposals were presented and were implemented during the respective semester. For each project, students presented an archive with all the produced material and a brief report explaining the work and the obtained results. Furthermore, one of the students who has worked in one of these projects is now part of OVER's Research and Development Team.

Final Consortium Meeting and Workshop with teachers

Date and place	28/05/2019, Athens
Number of participants	23

The final consortium meeting of GAIA took place in Athens, at the premises of EA. It was combined with a workshop with teachers from the GAIA schools, that shared their experiences through short presentations with the rest of the consortium. It was also an opportunity for reflection and discussion of the project's overall approach, its wins and shortcomings, and on how the teachers felt that future projects would benefit from it.

Other important elements of the trials

Survey detecting behavioral change

As stated in previous deliverables, there is an existing body of evidence in academic literature, demonstrating the potential for energy savings due to measures targeting behavior change. Through the trials, the GAIA project can help generate goals and provide feedback to individuals to facilitate behavior change. Involving people in GAIA activities, instead of holding theory-only lectures, could potentially have tangible positive results. Building users, key management personnel, teachers and students were invited to participate in an online survey for detecting the current environmental awareness. In certain cases, we have conducted also interviews with school principals and selected teachers, which were discussed at the last consortium meeting. We present in detail surveys regarding sustainability awareness and as evaluation of the educational lab kit in Chapters 16 and 17 of the present document.

Monitoring trials and the GAIA Methodology

As mentioned, the participating schools did not follow a common plan, or the exact same educational scenarios and material during the trials of GAIA. For this reason, several ways for monitoring trial activities will be implemented. First, the GAIA application set provided useful information regarding its use from the users. Tools for tracking users' activity were set up for GAIA Challenge and the Building Manager Application, which were the main software parts of GAIA used by the schools. A lot of information for the users were extracted by Matomo[3], which is integrated to the GAIA application. For any other extra information, database extraction was used.

Apart from these monitoring tools, we originally set up a set of forms to be filled in by dedicated teachers from each participating school, reporting activities and evidence, e.g., photos during the activities. However, this method was not utilized by certain schools during the activities, and we resorted to keeping activity logs by members of the consortium on a number of occasions. As part of the implementation of the trials in the project, we designed the GAIA methodology that is explained in detail in the following chapter. It was essentially an attempt at answering some initial questions and establishing probes for the trials monitoring. It provided a template/framework for schools to work with during the trials, making it easier for both the consortium and the school to report energy-saving activities. Detailed examples of its application are included in Chapters 6-10 of this document, where we essentially include the reports produced by the participating schools.

[3] Matomo web analytics platform, https://matomo.org/

5. The GAIA Methodology

In this section, we provide a detailed description of the methodology we proposed to the participating GAIA schools, for integrating energy saving activities into the daily life of a school that has installed an IoT infrastructure in its building to monitor certain parameters, such as its overall power consumption. Its design follows the overall philosophy of the GAIA project, but is not limited to GAIA's implementation or specific hardware/software used in the project. In general, in order to change the behavior of students and teachers in terms of energy consumption and achieve sustainable results, GAIA utilizes a loop-based approach focused around three pillars: raise awareness, support action, and foster engagement. In the context of the proposed methodology, this could be 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 a 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 activities that are not in some way tied to a specific lecture or learning outcome; 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 in the sample activity regarding the methodology: awareness, observation, experimentation and action. A final step suggests staying focused and monitoring progress.

Steps of the GAIA Methodology

Step 1 – Awareness and Preparatory steps

This step can be done either in parallel with Step 2, or before Step 2. Schools should create a general profile for 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 refrigerators.
- Equipment used for teaching purposes like PCs, lab equipment, smart boards, 3D printers, etc.

The timetable of the school regarding the following aspects should be 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 is the energy consumption of the building 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

Measure what the energy consumption is during a period of a “normal” week, i.e., a week where no major schedule disruptions take place. E.g., no excursions or other changes to the schools take place, and during which the students and teachers have lectures 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 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 period during this step should be at least a week long, and could take into account the data already available in the 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 school, which we can influence without affecting its orderly operation.

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

During a period of at least a week, the school should implement the actions scheduled by the educators to tackle energy consumption, with respect to each cycle of activity chosen by the school. E.g., when the lighting thematic cycle is active, students should 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 weekly the respective measurements and reward students and classes based on their progress. Another way is through competitions, e.g., by organizing teams in your school to compete with each other in different parts of the school building. Schools should also have in mind that such aspects are supported within the GAIA competition for this school year.

Application of the methodology

As mentioned in the previous chapter, 18 out of the 25 schools of the project to a certain extent utilized this simple tool. Some of the schools more or less followed the approach proposed to them, while others chose to follow a looser version of it. The issue that sparked the generation of the methodology was essentially the scarcity of time, from the side of the schools and the educators. One aspect of this was that, on the one hand, educators needed a more specific set of guidelines on how to report their activities, and on the other one, from the consortium's side, we tried to be more specific in what type of "output" was expected from the schools. This could also help the educators to adjust their planning in terms of timing in an easier manner.

The methodology had already been tested in Prato and Söderhamn before handing it over to the rest of the school to use it as a tool. Thus, when it has handed to schools it was generally well received, and seemed to benefit the teachers a lot in terms of their preparations before the activities, as well as reporting after the activities. It also provided a set of information for each school's activities so that the consortium would be able to verify whether certain parameters of the activities were correctly reported, or whether issues related to energy consumption were correctly identified by the educators and the students at the end of the trials period.

In the following chapters, we have structured the reporting of energy-saving activities of the schools based on the GAIA methodology template, in order to provide a uniform way of describing these aspects.

6. Educational and Energy Saving Activities in Söderhamn (SE19)

Educational activities in Söderhamn

Staffangymnasiet is the Upper Secondary School of the Municipality of Söderhamn. The number of students is approximately 750 every year and 800 has been directly affected during this period, that consists of two academic years. The number of staff is approximately 100, while 80 of them have been directly affected to some degree, and about 30 have been very actively involved in the GAIA trials and the project overall.

Educational activities overview for the academic year 2017-18 and 2018-19

Every student has been invited to participate in GAIA Challenge at Staffangymnasiet. Almost all classes had the opportunity to start the challenge in class at school every time we participated in the challenge. In connection to the challenge, the teachers raised the question what you as a student can do and how you can engage your family and the local society.

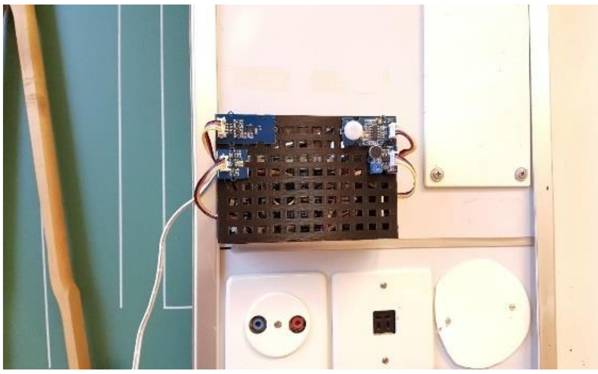
Raspberry PI was assembled and set up by the electricians' program at our school. As a part of a course, they ordered the components online, assembled it and set it up by using the provided software from GAIA, 30 students were involved in the process. The students studied the programming language of the PI and wrote their own programs for the PI. The placement of the Raspberry PIs was done by our technical students after having some theoretical review about the sensors and their functions and performance. 30 students were involved.

Activities with the BMS system and Raspberry PIs was used in cooperation to collect data, analyze it and explain the results as a part of a physics course. The electricians used the BMS and the Raspberry PIs as a part of a course in building management, together with the school building's manager. Some of the students in Staffangymnasiet participated in the scavenger hunt held by EDOC, with about 60 students participating in these activities.

During school year 2018-19, the educational activities were largely similar to the ones during the previous school year, with some variations in the actual content and the number of students and teachers participating, i.e., during the last period more students participated in the energy saving activities.

We now continue with a more detailed description of the abovementioned educational activities.

Title: 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 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.

Title: 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: 1-2h of lecture 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, we have performed this task four times during the GAIA-project and it has involved exactly 300 students. It has been a lot of green cake!

Title: 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 behavior regarding their showering.

Time spent for this subject: 1-2h of lecture 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 liter 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 made the same reduction?

Presentation: 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.

Title: Temperature inside classrooms

Goal: To make students aware of temperature regulation in 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 behavior of the system to reduce energy consumption.

Time spent for this subject: 1 h 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, you must create an account here:

https://sso.sparkworks.net/aa/gaia/registration?redirect_uri=http://bms.gaia-project.eu

When you log in, you will get a list of all schools connected to GAIA - 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.

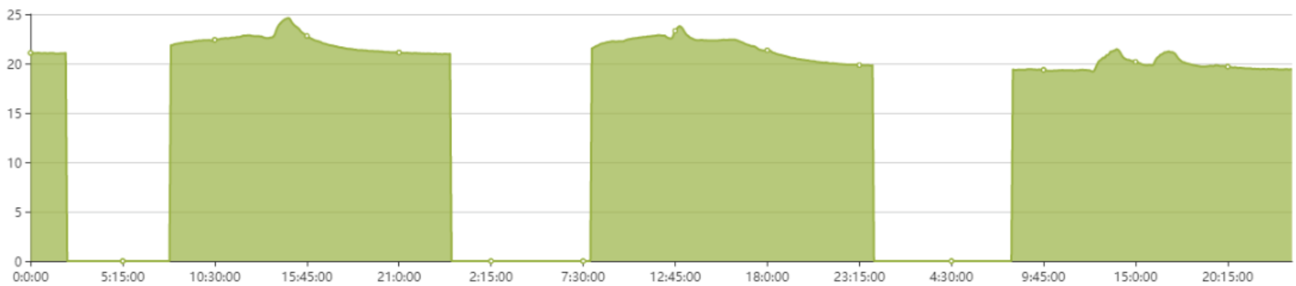
In order to save energy, the heating system should lower the temperature in the classrooms during the afternoon and night, and warm them up to 20 degrees in the early morning.

Study measurement data from Room 222 to determine how well the temperature control works.

Presentation: A short report with suggestions for changes to save energy. Screenshots showing the measurement data that 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.

Title: 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 h 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?

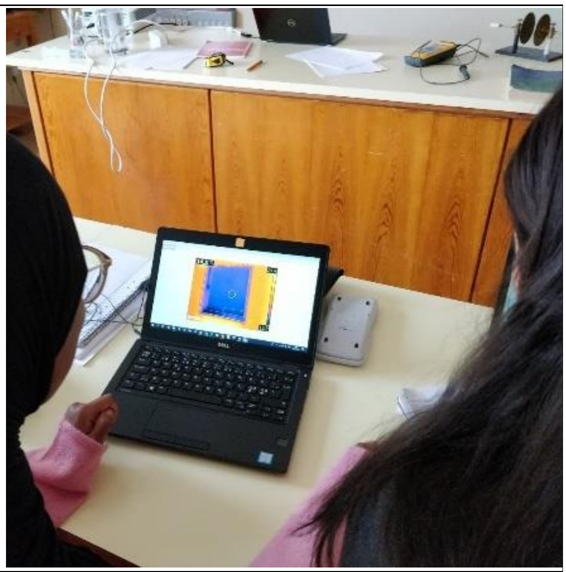
b) How much would it represent for all the school classrooms if we assume they are used in the same way as this room?

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. Therefore, the students did exactly this, as you can see in the following pictures.

Title: Checking the insulation at Staffangymnasiet, Söderhamn

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 our 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.



A complete run of the 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 because 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.

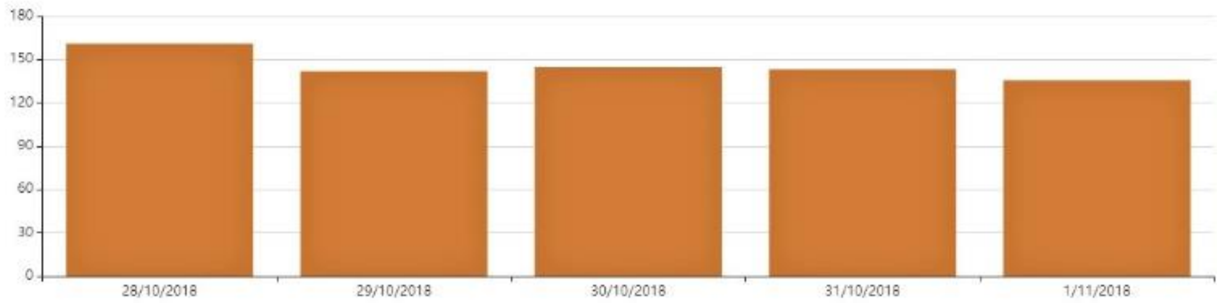


Figure 11 Electric energy consumption week 44, the baseline week.

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:

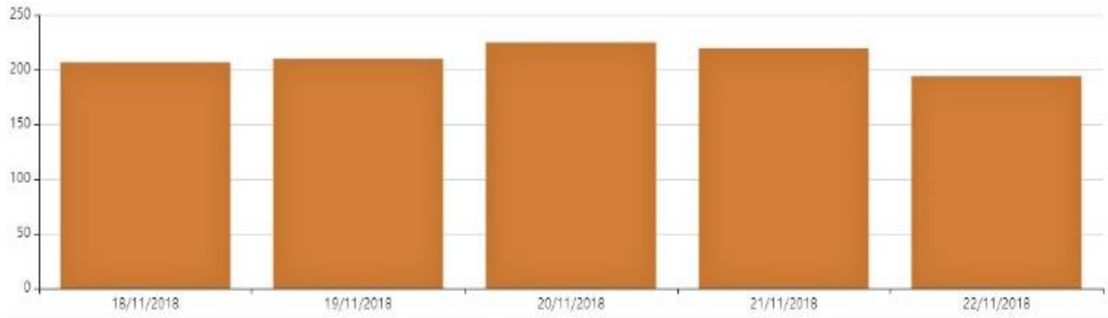


Figure 12 . Electric energy consumption during week 47, the comparison week.

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.

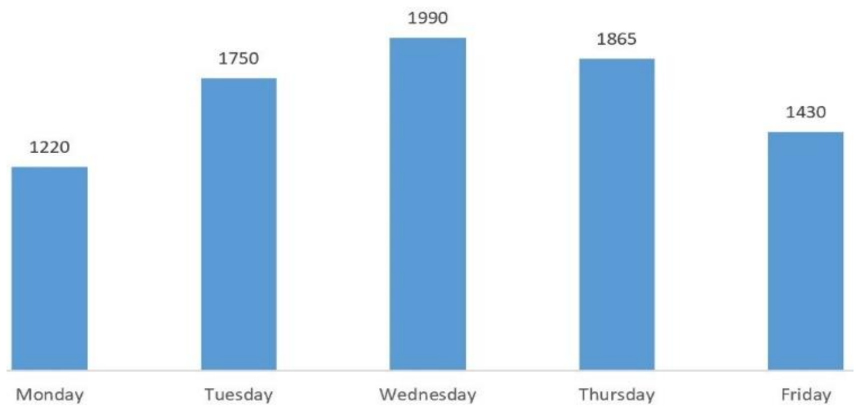


Figure 13 Room usage during week 47 (minutes)

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:

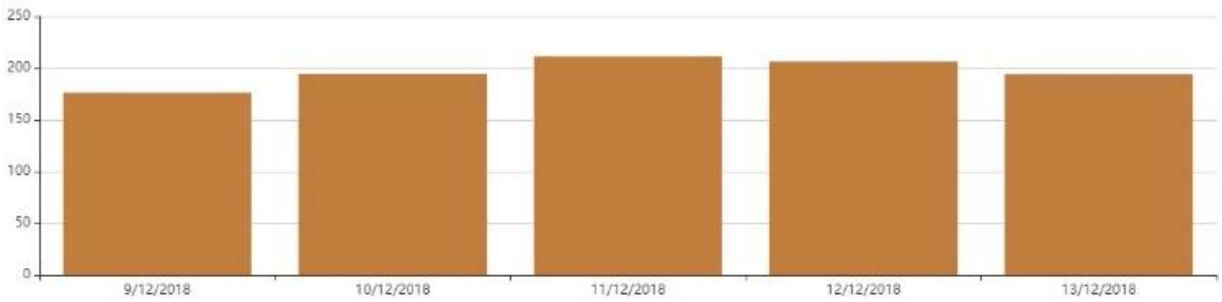


Figure 14 Electric energy consumption during week 50, the energy saving week

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 between this and 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.

Table 3: 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

Energy Aspects Report

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 is 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 consumption 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.

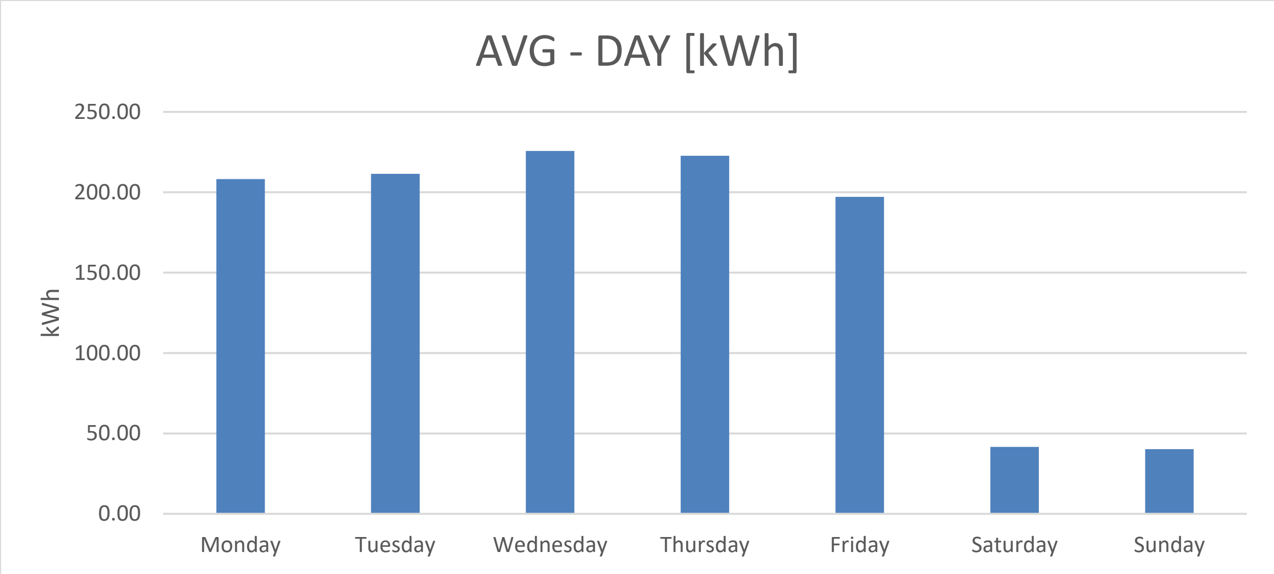


Figure 15 - Daily average energy consumption into the school. Period 19th of November 2018 - 25th of November 2018

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

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.

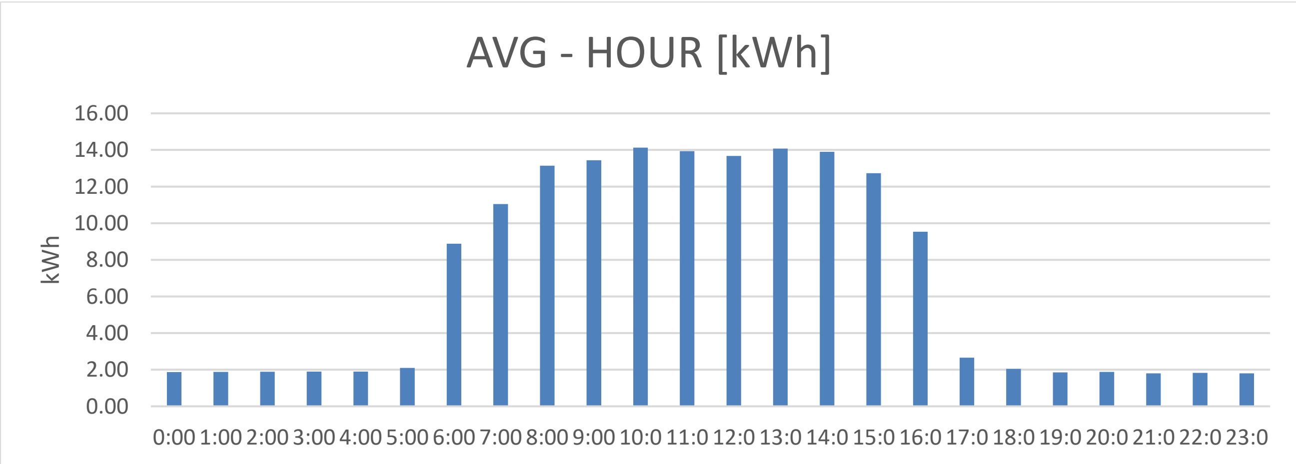


Figure 16 - Hourly average energy consumption into the school. Period 19th of November 2018 - 25th of November 2018

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 until 15:00. In the afternoon, the energy consumption begins to decrease until 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.

Normalization Index

Overall Consumption – full year forecasting: 438.749 kWh from energy bill during the year 2016 only for electricity (no heating)

29,2 kWh/m^2 8,1 kWh/m^3 438,7 kWh/person involved

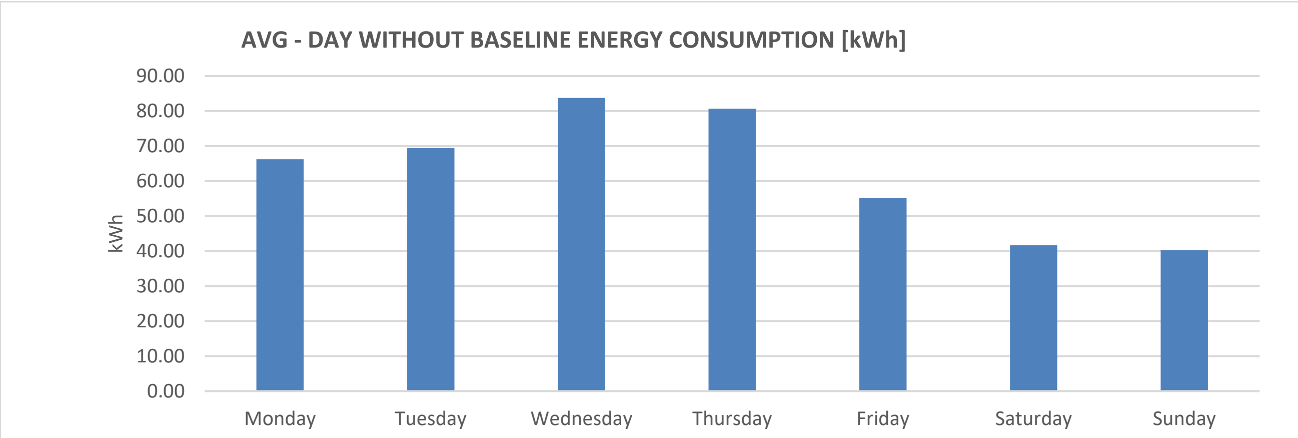


Figure 17 - Daily average energy consumption into the school subtracting the baseline energy consumption *Period 19th of November 2018 - 25th of November 2018*

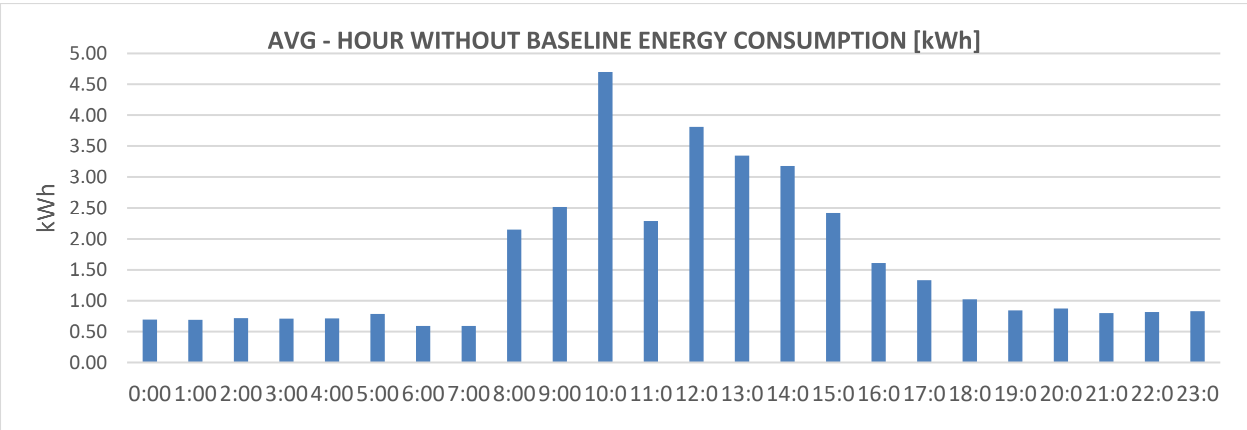


Figure 18 - - Hourly average energy consumption into the school subtracting the baseline energy consumption
Period 19th of November 2018 - 25th of November 2018

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 replaced with LED-based ones. 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 it is calculate as **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.

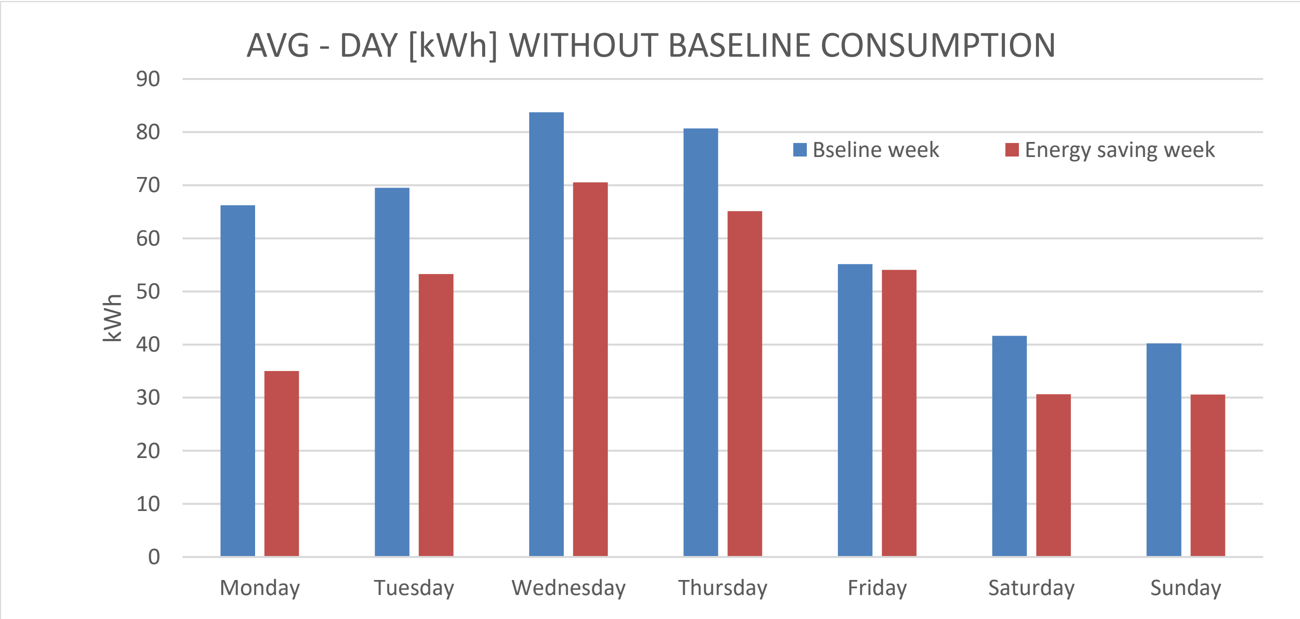


Figure 19 - Daily average energy consumption – Comparison
Baseline week: 19th -25th of November 2018; Energy saving week: 10th – 16th of December 2018

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.

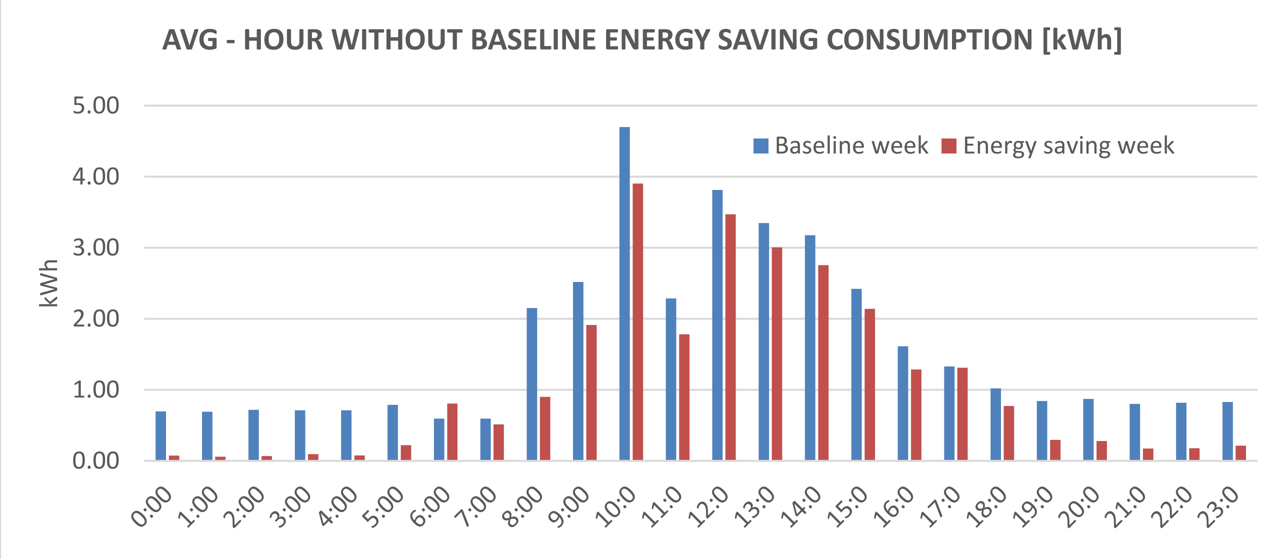
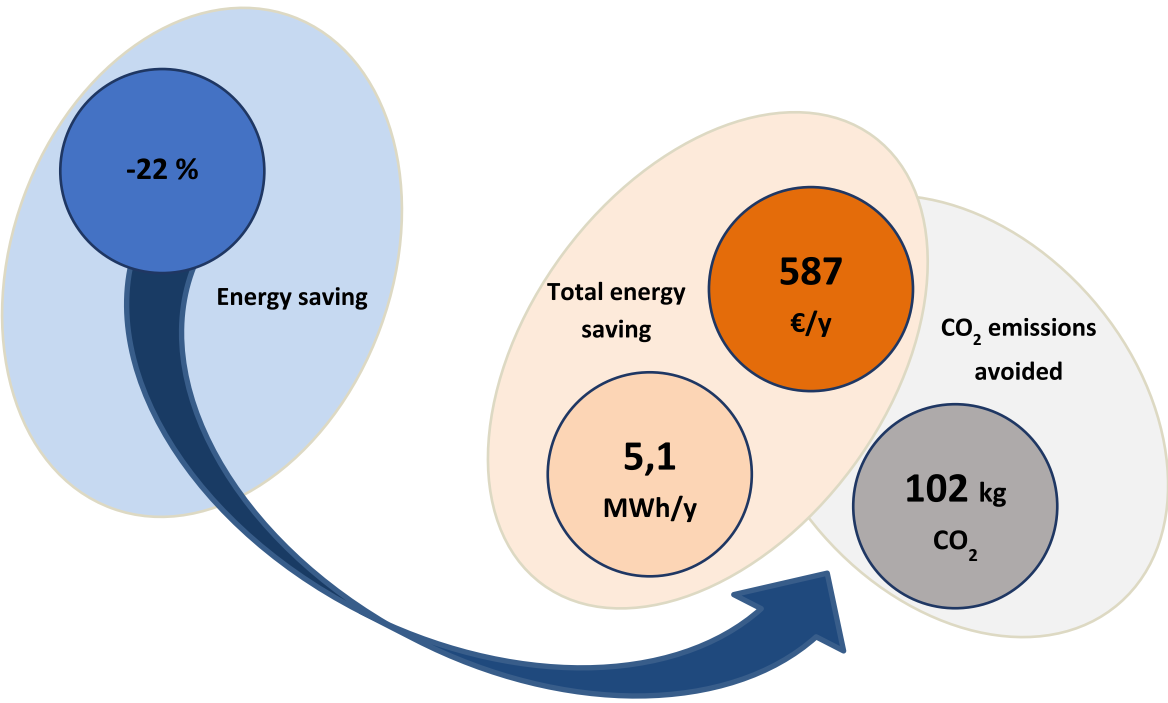


Figure 20 - Hourly average energy consumption – Comparison
Baseline week: 19th -25th of November 2018; Energy saving week: 10th – 16th of December 2018

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.



ACTIVITY 2 – LIGHTING CHANGE

To understand the energy savings related to this activity, we need to use energy consumption of the last period because the activity is still in progress.

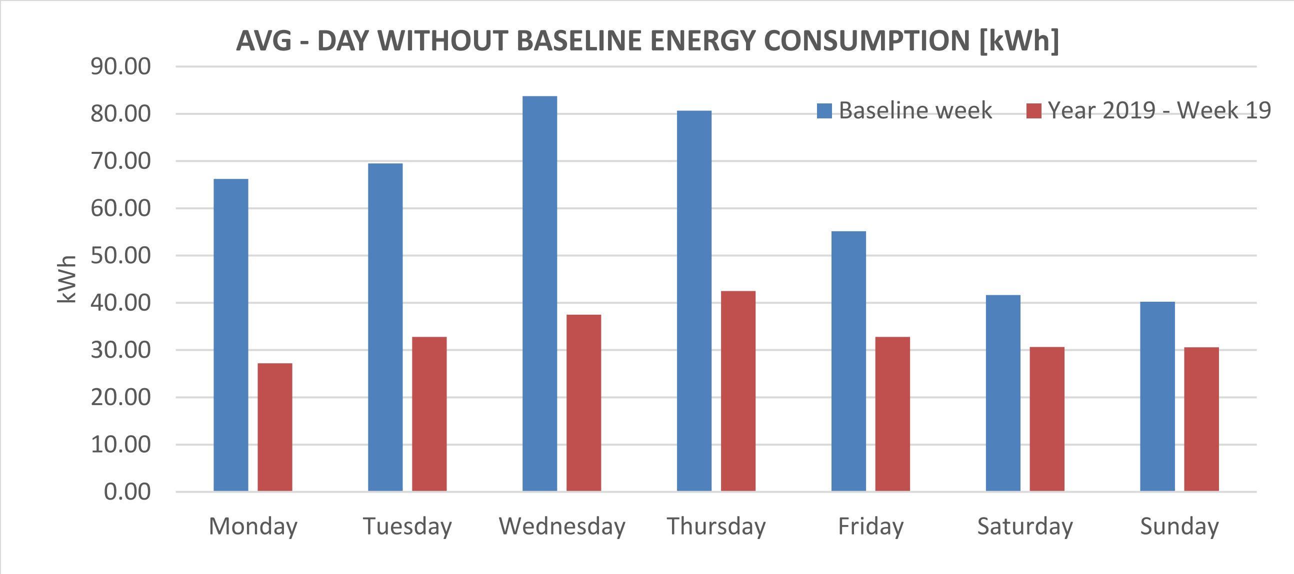


Figure 21 - Daily average energy consumption – Comparison
Baseline week: 19th -25th of November 2018; Week 19: 6th – 12th of May 2019

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. By analysing the hourly chart, it is possible to understand better how the energy savings result was achieved.

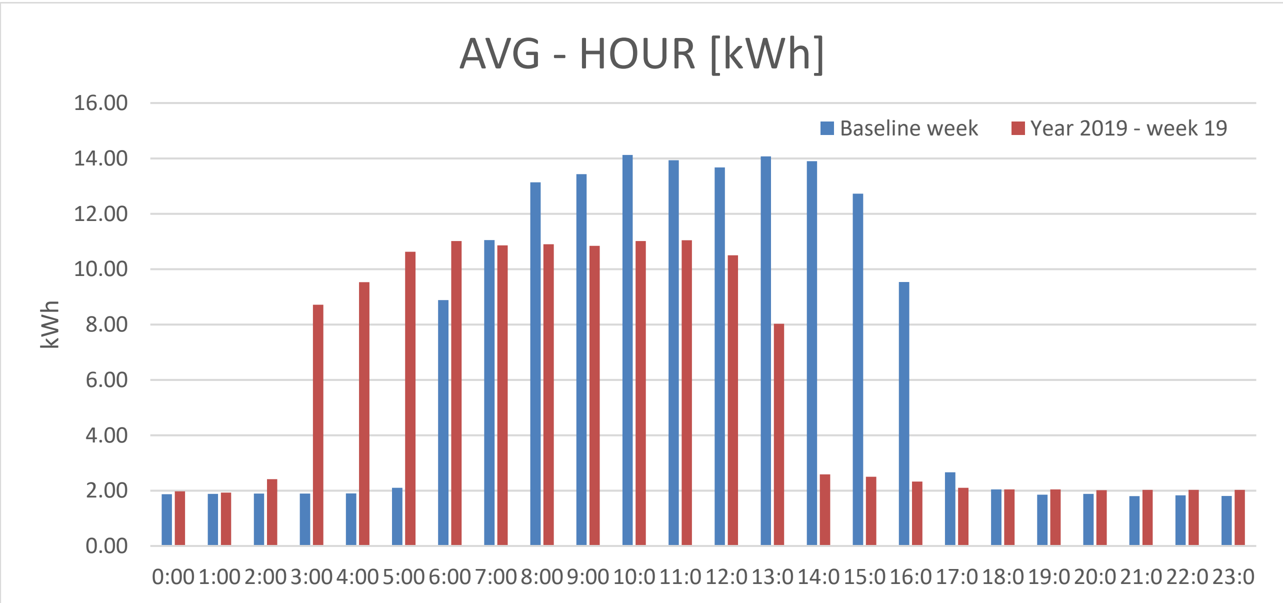
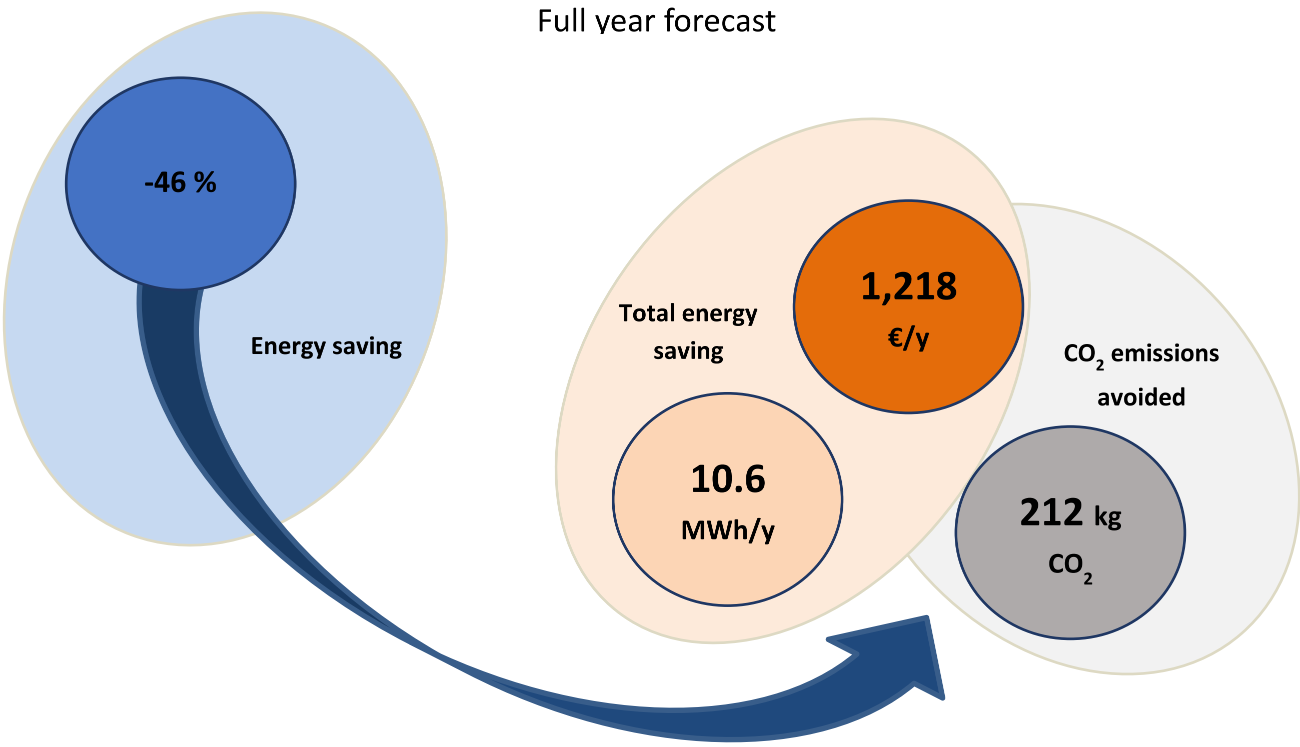


Figure 22 - Hourly average energy consumption – Comparison
Baseline week: 19th -25th of November 2018; Week 19: 6th – 12th of May 2019

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.



Comparison

In the following table, there is the comparison about the energy consumption between the baseline week and the energy saving week for both energy saving activities.

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)

7. Educational and Energy Saving Activities in Prato (IT17)

School year 2017-18

In 2017 and first months of 2018 several workshops have been organized with teachers to explain GAIA objectives and involving them actively in designing and performing GAIA activities with their students. Three classes have been actively participating in the GAIA Contest and performed activities following the GAIA educational methodology, including participation to the GAIA Challenge, observation of GAIA sensors' measurements and energy saving activities, while other 5 classes participated mainly to the GAIA Challenge. Two teachers have coordinated the activities of these classes.

Hereafter we 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.

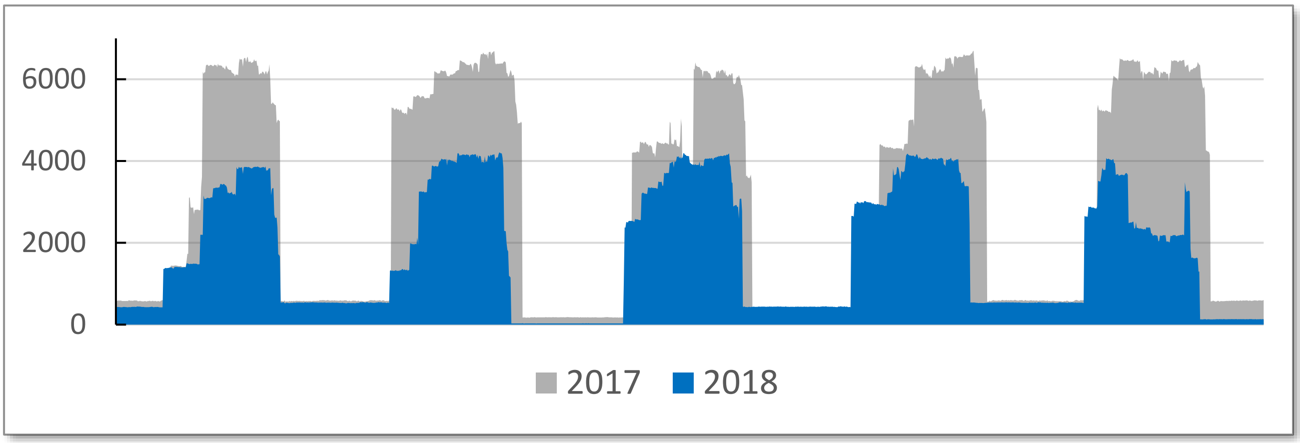


Figure 23 Active Power (W). Weekdays only, 8-12 May 2017 vs 7-11 May 2018 as a sample

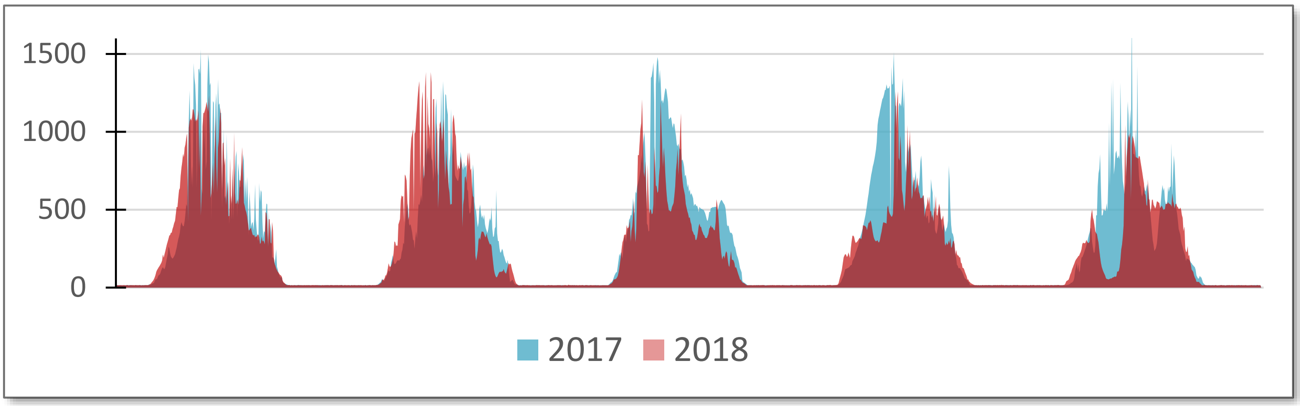


Figure 24 Luminosity in the hall (lux). Weekdays only, 8-12 May 2017 vs 7-11 May 2018 as a sample

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°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 couldn’t 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.

DATE	HOURS	ACTIVITY DESCRIPTION	TOOLS
15/02/2019	1	Introduction to the Internet of Things. Examples from web sources.	Web browser
20/02/2019	1	Introduction to Node-RED and to the paradigm of Flow-based programming. Introduction to the notion of node, flow and deployment in Node-RED. Inject and debug nodes	Node-RED Documentation at the nodered.org web site. Video tutorial by GAIA consortium: Video tutorial 1
22/02/2019	1	Some basic flow examples. Use of the GaiaNode plugin for accessing GAIA resources and measurements (e.g., LatestValue node). Creation of an account on the bms.gaia-project.eu site for each student.	Node-RED Documentation at the nodered.org web site. http://bms.gaia-project.eu BMA web site Video tutorial by GAIA consortium: Video tutorial 2
27/02/2019	2	Planning and editing of a plan of activities towards the Gaia Contest. Organization of the work into teams. Each team has a task and has to document this task.	Documentation provided
01/03/2019	1	Configuration of Raspberry and temperature sensor. Creation of a GAIA virtual sensor and related Node-RED flow to deliver measurements to the BMS (PushValue node).	Node-RED
06/03/2019	1	Dashboard produce through Node-RED: management of tabs, gauge, chart and text nodes.	Node-RED Video tutorial by GAIA consortium: Video tutorial 3
08/03/2019	1	Additional tools provided by Node-RED: use of the switch node to filter out out-of-range measurements; use of the trigger node to create a mechanism analogous to 'watchdog timer'; use of nodes supporting the use of the http protocol.	Node-RED
13/03/2019	1	Discussion to prepare the interview to the School principal. A team collects the ideas and organize	-

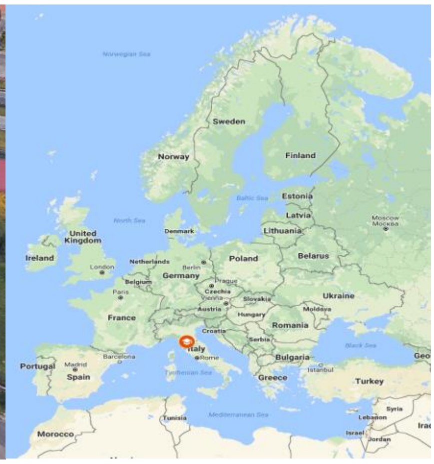
		and make the interview to the principal (they also record the interview).	
15/03/2019	1	Teamwork	-
20/03/2019	1	Teamwork	-
22/03/2019	1	Teamwork	-
27/03/2019	1	Exam	-
TOTAL	**15**		

Educational objectives:

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.
Plugin GaiaNode	Understand how relevant is extending Node-RED with new nodes. Usage of main GAIA nodes.
Use of virtual sensors	Understand the role of temperature, humidity and luminosity sensors. Learn how to manage GAIA sensor measurements retrieved via GAIA services. Analyze and process data through a spreadsheet.
Web dashboard	Familiarize with HTML language. Design and realize a small widget to visualize acquired data.
Energy consumption awareness	Observe and detect critical situations in the school concerning energy wastage. Understand how Node-RED and the GAIA plugin may help monitoring and taking decisions towards energy saving.

Energy Aspects Report

BUILDING DESCRIPTION



List of sensors and meters installed

Inside the school building, the following equipment is 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.

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

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 until 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 consumption before energy efficiency solutions - Hall – Common Area

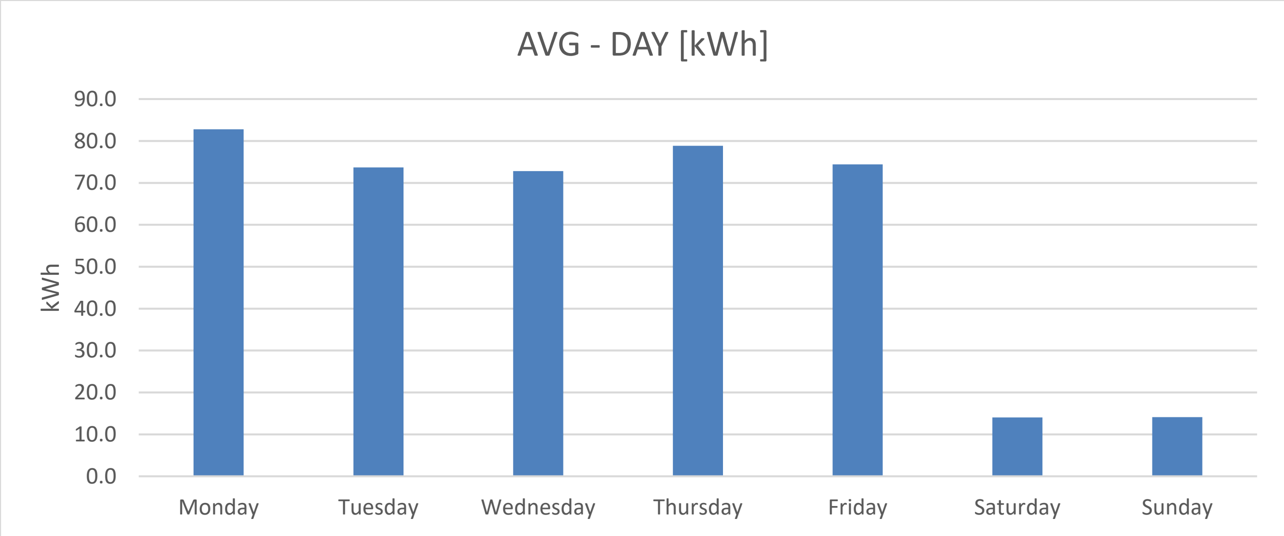


Figure 25 - Daily average energy consumption in the common area. Period 1st of May 2017 - 15th of May 2017

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.

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

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.

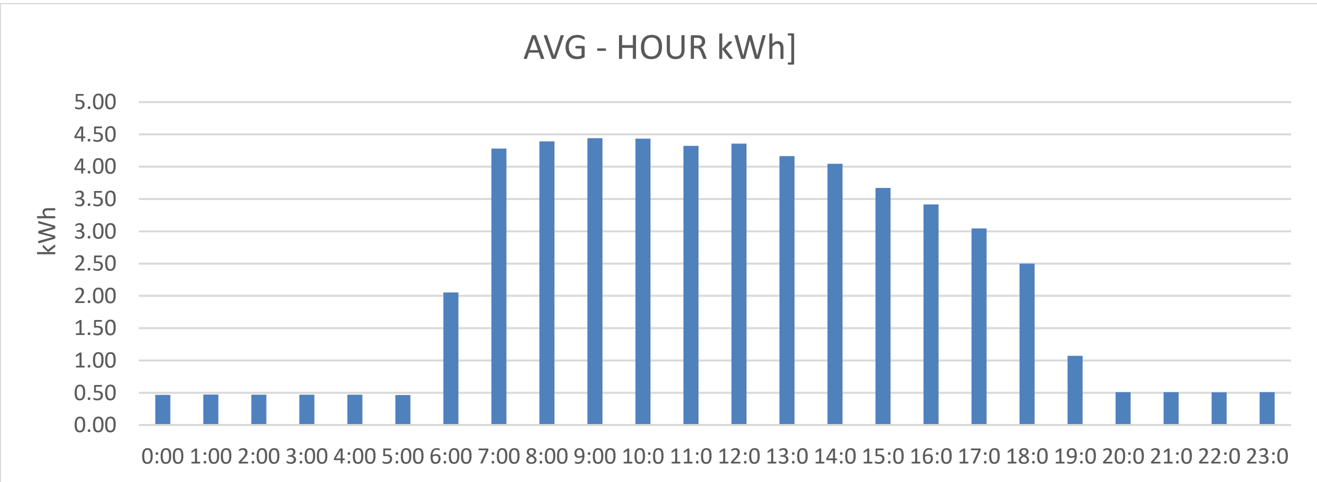


Figure 26 - Hourly average energy consumption in the common area. Period 1st of May 2017 - 15th of May 2017

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. To understand the energy efficiency of the building and compare the results to other buildings we will use the KPI kWh/m^2 and kWh/m^3. The KPI kWh/person involved is not useful in this case.

Normalization Index

Overall Consumption – full year forecasting: 116 MWh

13,2 kWh/m^2 2.83 kw/m^3 65,4 kWh/person

Notes

Surface monitored: 8.780m^2 Volume monitored: 41.000m^3 No HVAC consumption

In order to try to reduce energy consumption and increase the energy efficiency of the building, the following activities were undertaken.

ACTIVITY 1 – EXPLOIT NATURAL LIGHT

Students were 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 on 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 were 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 was 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. The weekly energy savings amounted to 170 kWh that in terms of money is 32 €/week. Calculation has been done considering periods longer than a week. For the average baseline week, the period from the 1st of May 2017 to the 15th of May 2017 was considered; for the average energy saving week, the period from the 6th of May 2018 to the 19th of May 2018 was considered.

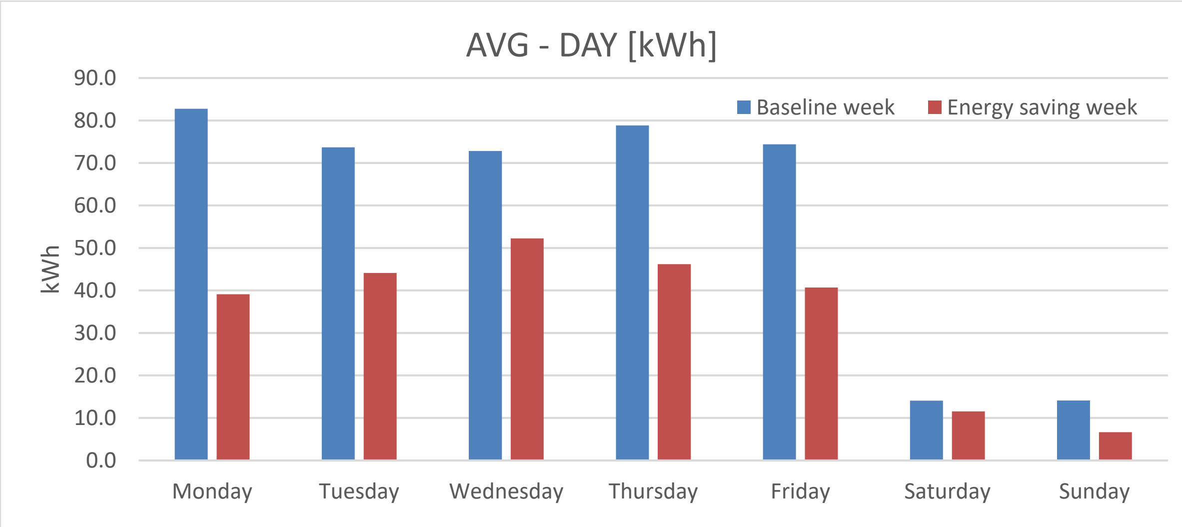


Figure 27 - Daily average energy consumption in the hall – Comparison. Baseline period: 1st -15th of May 2017; Energy saving period: 6th – 19th of May 2018

The energy saving is present during the whole week, with the best performances on Monday and Friday. During the weekend, we have little energy saving because of the 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.

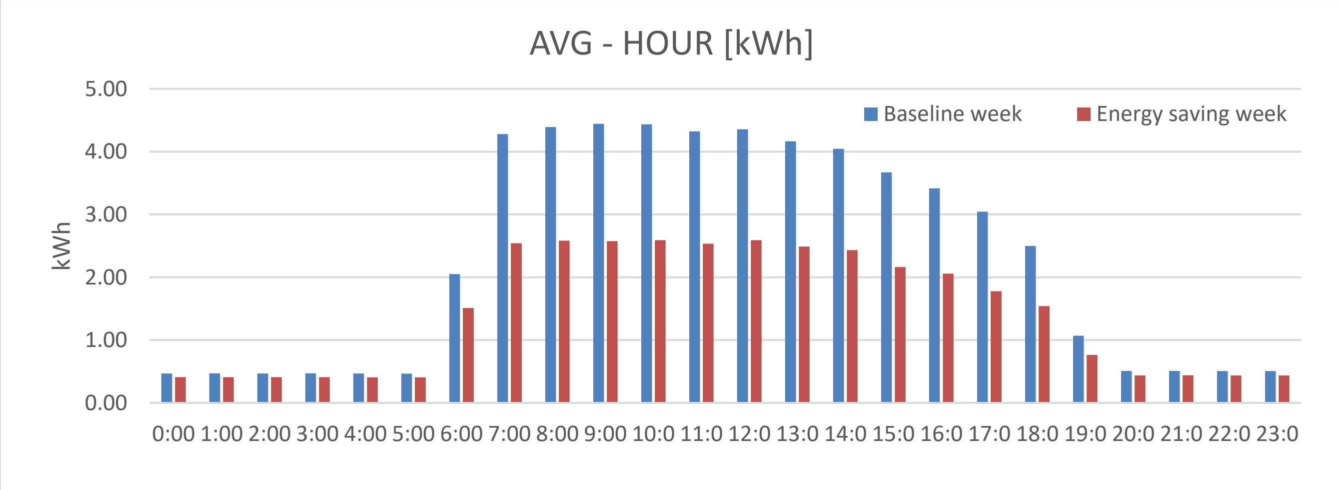
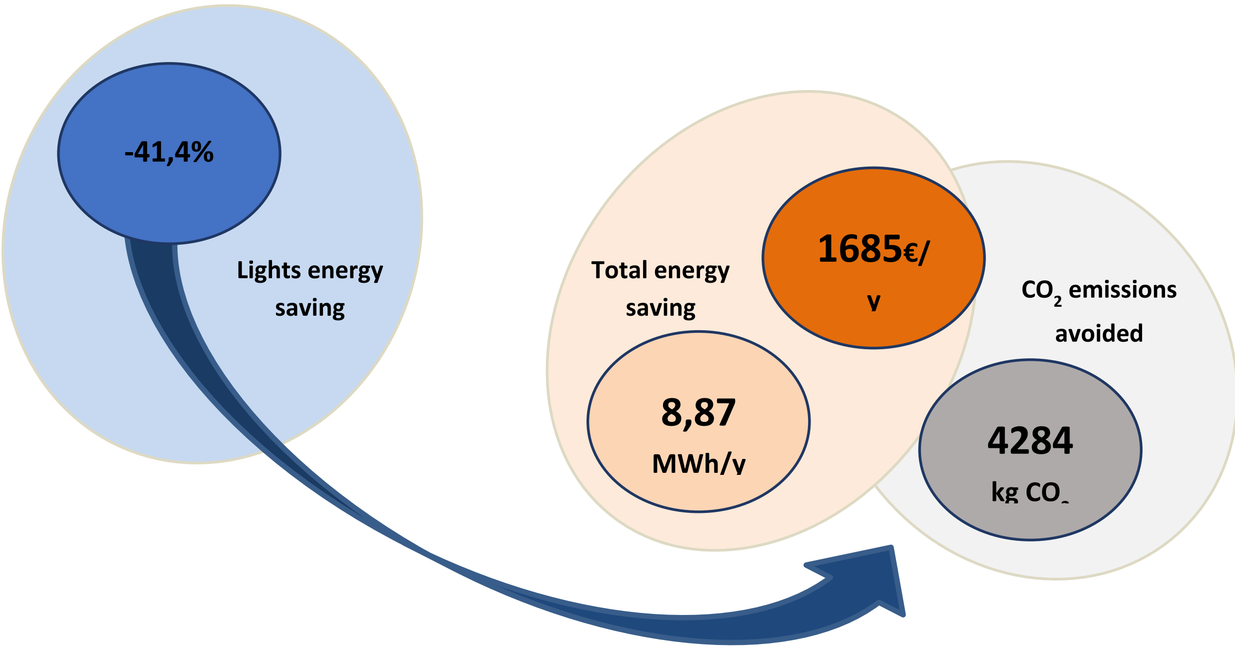


Figure 28 - Hourly average energy consumption in the hall – Comparison. Baseline period: 1st -15th of May 2017; Energy saving period: 6th – 19th of May 2018

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 kg CO_2.



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 $kgCO_2/kWh$

8. Educational and Energy Saving Activities in Sapienza (IT18)

OVER have been involved in the organization of trial activities within the Sapienza University of Rome and in particular within the Department of Computer, Control and Management Engineering Antonio Ruberti. In order to involve as many students as possible, the GAIA educational Framework has been revised to make it compatible with the characteristics of the university students of the Department.

The main difficulties we found, in comparison to other schools in GAIA, was to handle *(i)* a different target in terms of age and interests, and *(ii)* a lack of stability due to the different occupancy and use patterns of classrooms, which frequently change during the year and having students following different classes with different time constraints. Moreover, Sapienza is a university and it is a mixture of workers and students. Some of the buildings have e.g., only workers as tenants (this is the case of the Orthopaedics Building).

In this context, we had to revise the original GAIA framework to find something more attractive for this end-user group. On the other side, however, we had the opportunity to work at a more technical level with the students, since they follow a technical curriculum that was well suited to programming activities and mostly, each of these students was equipped with their own device with a good Internet connection.

We decided that the best way to let the students join the GAIA community was to propose projects exploiting the GAIA infrastructure, in order to design new software modules and implement new functionalities. Besides the department, we also worked, especially in the first part of the project, with the Orthopaedic Building where we tried to implement practical energy-saving activities, such as turning off the lights during the closing office hours. Everything was reported on a technical document, and we used the data and savings produced with these actions to push additional initiatives and installations of the infrastructure in other facilities. In this section, we describe first an overall schedule activity, which led us to the conception and realization of the projects, and then we continue with an in-depth presentation of the implementation and outcomes reached.

Overall Schedule

In the following, we show a more detailed table, grouping the main trial activities we performed during the second part of the project. We have inserted in the table only the main events, avoiding listing every call and meeting we had inside Sapienza to prepare the workshops and the projects.

DATE	Event Description
24/04/2018	Internal meeting on general organization - time, number of modules, duration for each module, location, teachers and student target
07/05/2018	Internal meeting about Workshop Contents Definition for each module and project proposals
18/05/2018	Internal Meeting for revising material to show during the workshop
22/05/2018	GAIA Workshop – Second Edition, First Module
25/05/2018	GAIA Workshop – Second Edition, Second and Third Module

About 60 students attended the workshop, which was organized by Over with the collaboration of Prof. Massimo Mecella. The seminar has been organized in more days and three modules have been treated (each lasting three hours). The workshop has been structured in a similar way to what we did in the first edition, held in May 2017. Each module was organized as follows:

- *Module One*: The GAIA project was first contextualized introducing the research and innovation funding programmes (Horizon 2020) and the related EU work programme challenges. After this first introduction, a more in-depth explanation was given about its general objectives, the trial Buildings, the educational and didactics approach and the educational serious game. The first module ended with a brief depiction of the then status of the project in terms of software infrastructure implemented and trial activities carried out.
- *Module Two*: A more detailed view about software modules was covered. For each module, an accurate explanation has been given about its functionalities and their API. The module of Data Acquisition, Data Storage, Building Knowledge Base, Analytics and Recommendation Engine along with all the WP3 application has been discussed.
- *Module Three*: After having analyzed in detail each module, we gave examples of their use. All the WP3 applications were shown and we explained how an energy manager usually looks at energy data in order to figure out how and how much a facility is consuming. Finally, we presented the three project proposals, inviting the attenders to join GAIA community through the implementation of both their own projects and/or those ones proposed.

In the next section, we discuss the projects proposals, explaining the work performed by the students.

Project Proposals

Students were invited to participate to the development of new functionalities using GAIA existing API and its dataset. OVER supported the students through face-to-face meetings and asynchronous communications. The following table contains a list of these activities.

DATE	Event Description
12/06/2018	Meeting with a first student to define how to realize project proposal N°1
26/06/2018	Meeting with the student to configure Spark account and to clarify some aspects related to the API to use
02/07/2018	Discussion of the project proposal N°1
03/07/2018	Discussion with a second student to define how to realize project proposal N°3
10/07/2018	Meeting with the student to configure Spark account and to clarify some aspects related to the API to use
24/07/2018	Discussion of the project proposal N°3
17/09/2018	Start-up meeting of the project proposal N°2. Set up of the project and high-level overview of its main objectives

30/08/2018	Additional explanation about similarity functionality of clustering module. Discussion about work progress status.
14/11/2018	First Beta Release with suggestion on how to improve and do bugs fixing
30/11/2018	Stable release and final discussion of project proposal N°2

For each project, students produced a report and released the relevant code. Moreover, for two of the three projects, a Jupyter[4] Notebook was realized too. We outline now the project requirements proposed to the students and a brief description of the work done by them.

Project Proposal N° 1

The aim of this project was to design and implement a standalone module to cluster building consumptions using a different approach than the one employed in the Analytics Module. The module has to be designed so that the analysis could be replayed at any time but must be triggered manually. The new module will offer two main functionalities: a) clustering all the buildings in the platform given their consumptions; b) clustering days given a single building intra-day consumption. In both cases, considering the time-series nature of consumption data, K-Shape algorithm has to be used to perform time-series data clustering. The dataset has to be built interacting with the API offered by the GAIA platform over a fixed period and the outcome of the analysis has to be properly presented and commented.

The analysis has been made on data collected from May 31, 2017 to May 31, 2018 with the objective to cluster buildings among each other's based on the energy yearly consumptions. First, student understood if the K-Shape technique was influenced by noises (e.g. sensors failures, sensor shut down etc.). At this aim, data cleaning techniques have been applied to the data set, such as remove building with most zero-values or cutting all values (outliers) which are "far" from the median. Through these improvements, quality score of the cluster got some enhancements. After many trial-and-errors, in the end the value of three was identified as the best clustering number.

Project Proposal N° 2

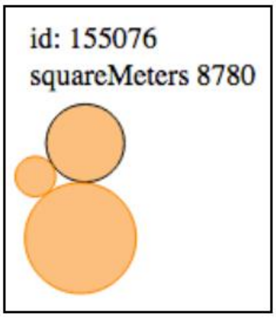
The aim of this project is to develop a graphical user interface component to showcase the result of a clustering analysis performed by the Analytics Module. The component will be built using an appropriate tool that will allow its integration by an external website and its capabilities will be properly documented.

The component will be able to plot the clusters, together with the items they are made of, and will allow a user to interact with them in order to retrieve information about them and the different elements they contain. The user will be also able to search for a specific building or select two buildings and compare them.

Ad hoc visualizations were designed to be applied to the energy and structure clusters, with the aim to create a comparative visual analysis. Several graphical metaphors have been utilized to make this task easier. In the image below, we can see how it is easy to understand the general composition of the existing clusters, where the numbers represent the total amount of buildings inside each of them.

[4] Project Jupyter: https://jupyter.org/

Users could explore the clusters by means of two operations, click and mouse over. By clicking a point, it was possible to view all the attributes related to the building. With the mouse over, it was possible to see the id of the building, and, if an attribute was selected from the menu dropdown, the value related to that attribute for the specific building (image below).



Another interesting visualization allowed comparing buildings among each other, depending on the value of an attribute. By using the menu, it was possible to select specific attributes, and, after this choice, the radius and the color of the point changed accordingly. There was also the possibility to visualize the similarity between one specific point and all the others. The user could select the similarity from the relative checkbox, causing the points to change their position with respect to similarity measure.

Project Proposal N° 3

The aim of this project is to evaluate different approaches and techniques to perform forecasting of consumption data. Algorithms such as SVR, Multilinear Regression and Neural Networks will be employed and compared in order to understand if and how they can be tweaked to obtain predictions in the context of energy consumption. The module will be designed so that the analysis could be replayed at any time but must be triggered manually. The dataset will be built interacting with the API offered by the GAIA platform over a fixed period of time and the outcome of the analysis will be properly presented and commented.

In this project, the students created, by utilizing building and dataset of GAIA Infrastructure, three forecasting models to predict the energy consumption of the next 24 hours. An SVR model, a Multilinear Regression model and an Artificial Neural Network model were designed, each of them using different input vectors to train and to test these algorithms.

The SVR model used a Radial basis function kernel, or *rbf kernel*, to predict the future consumption values for a given date and building. The Multilinear Regression model was exactly as a normal Linear Regression model, but it took more variable, and not just one, as input. The Artificial Neural Network model was composed by 14 neurons as input, one hidden layer with 10 neurons that used a *ReLu* function as activation function and 1 single neuron for the output layer, which gave us the predicted value. Finally, the student has evaluated the three models through the mean accuracy with a confidence interval and the root mean squared deviation.

Energy Aspects Report

Total people:	40
People directly involved:	2
Square meters:	1.500m^2
Volume:	4.500m^3
Working schedule	60h/week

Inside the building, the following infrastructure is installed:

- 2 three-phase meters
- 8 single-phase meters that permit to monitor 40 single-phase power lines.

Energy consumption before energy efficiency solutions

The average – day chart shows the energy consumption during a week; it is almost constant during the first 4 work weekdays (Monday to Thursday), with a daily consumption of about 235 kWh per day. During Friday, the energy consumption begins to decrease and during the weekend, there is a minimum of consumption with a value of 132 kWh per day.

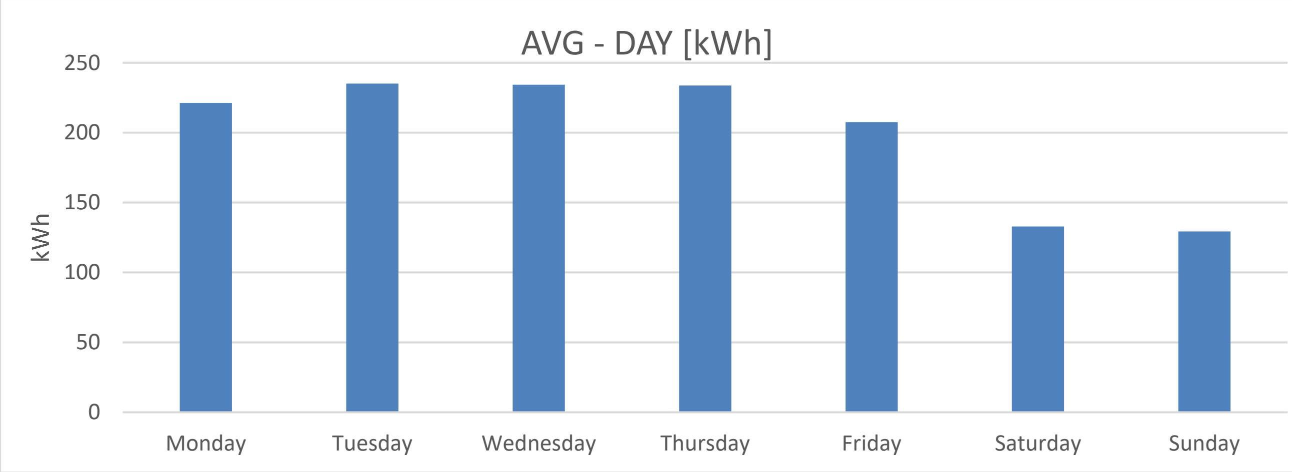


Figure 29 - Daily average energy consumption into the school. Period 31st of October '16 - 30th of October '17

Days of the week	Average energy consumption [kWh]	Delta [%]
From Monday to Friday (workweek)	226,4	-
Weekend	131,1	-42,1%

The work activities determine more energy consumption for 95,3 kWh/day equal to 42,1%. In terms of money, we are talking of 19 €/day.

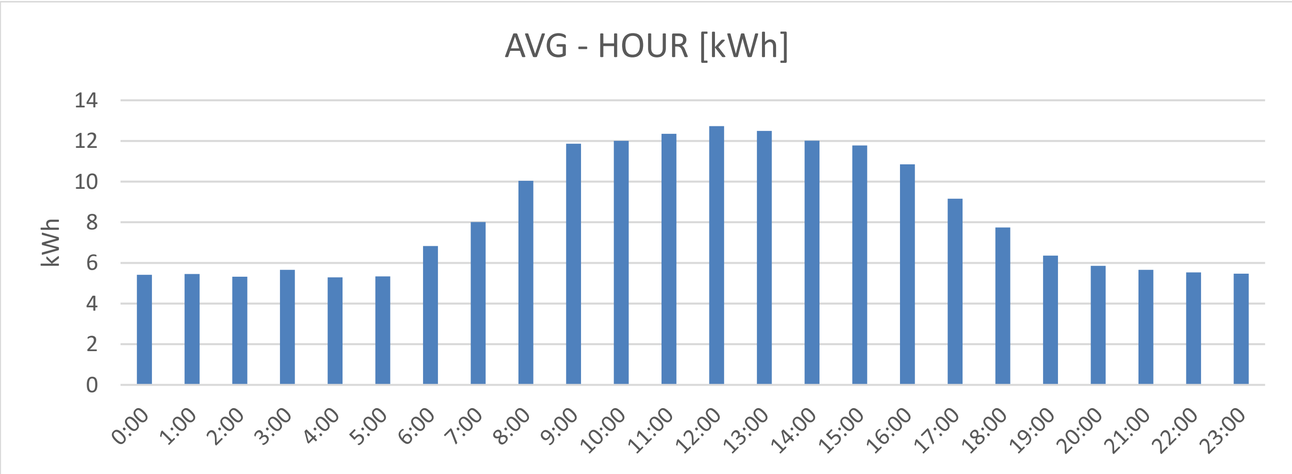


Figure 30 - Hourly average energy consumption into the school. Period 31st of October '16 - 30th of October '17

The average – hour chart shows the typical daily trend of a workday. You have the maximum energy consumption at midday with 12,7 kWh. This value is almost constant from 09:00 to 15:00. That means that the energy consumption is strongly influenced from the work activities. During the closing hours the energy consumption is constant and equal to 5,4 kWh.

Hours of the day	Average energy consumption [kWh]	Delta [%]
From 09:00 to 15:00 (peak)	12,7	-
Off-peak	5,4	-57,5%

The difference between peak and off-peak hours is of 7,3 kWh per hour that means 1,5 € per hour. This can be supposed to be the activities energy cost.

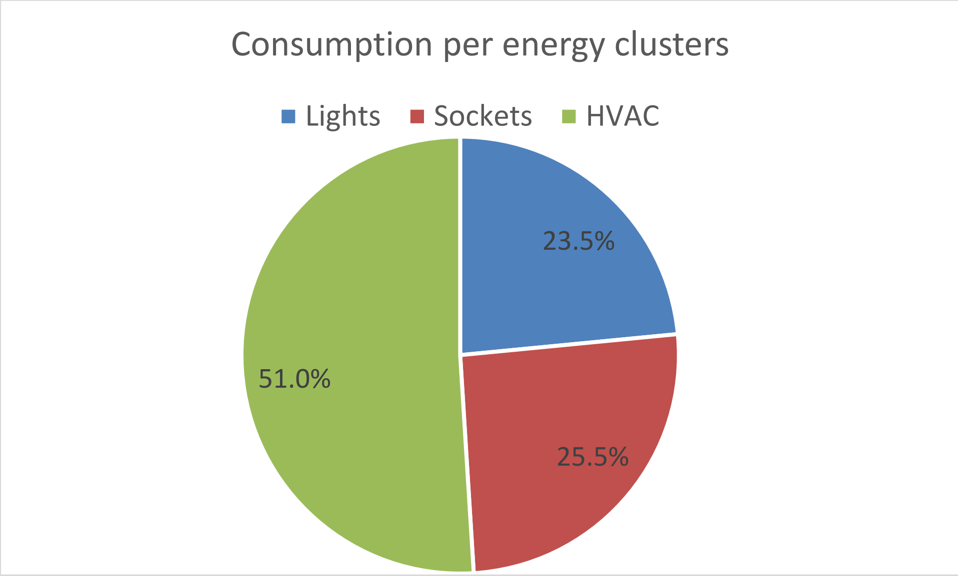


Figure 31 – Energy consumption – energy cluster classification

In the chart above, Monthly consumption shows how energy is used inside the building. Lights and sockets represent per each month almost the same amount of consumption, except for the month of August. The difference between General and the sum of Light and Socket is HVAC consumption. To understand the energy efficiency of the building and compare the results to other buildings, we use the KPI kWh/m^2 and kWh/m^3. The KPI kWh/person involved is not useful in this case.

Normalization Indexes		
Overall Estimated Consumption: 72 MWh	48 kWh/m^2	16kWh/m^3

In order to try to reduce the energy consumption and increase the energy efficiency of the building, the following solution was implemented.

ACTIVITY 1 – SWITCH OFF LIGHTS

This solution provides to switch off the lights in the evening and during the weekend; the analysis was carried out over a week. The activity has involved all the lights present into the floor building, so that the obtained energy saving is the maximum we could obtain. The energy saving has been of 8.7% of the energy consumption associated with the lighting cluster, equal to 2.6% compared to the total consumption. Numerically, the weekly energy saving amounted to 26 kWh.

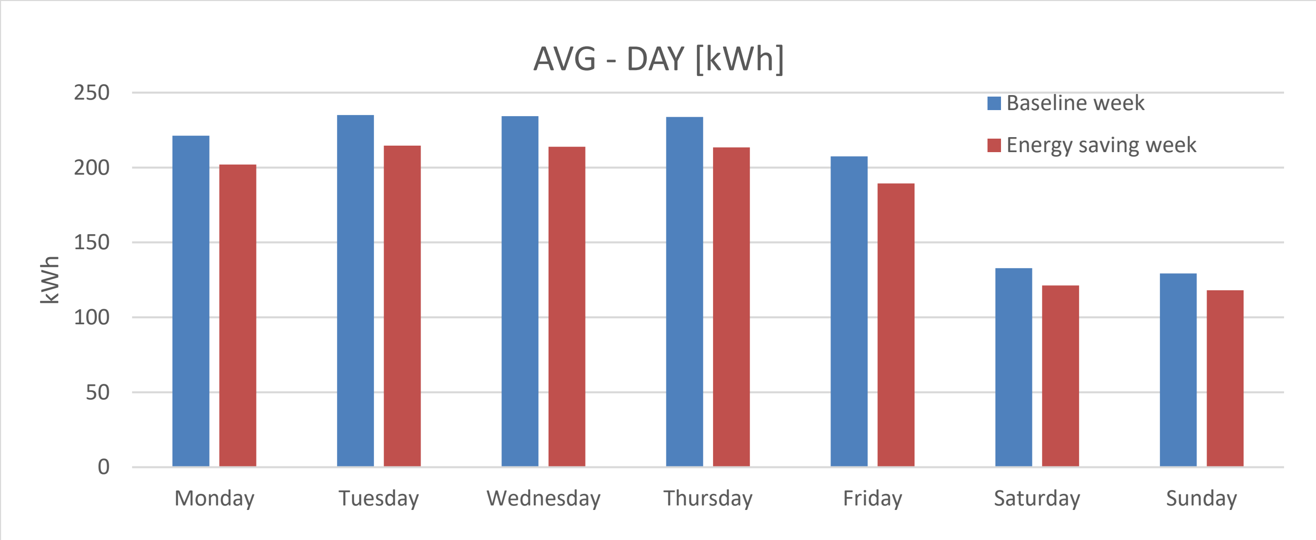
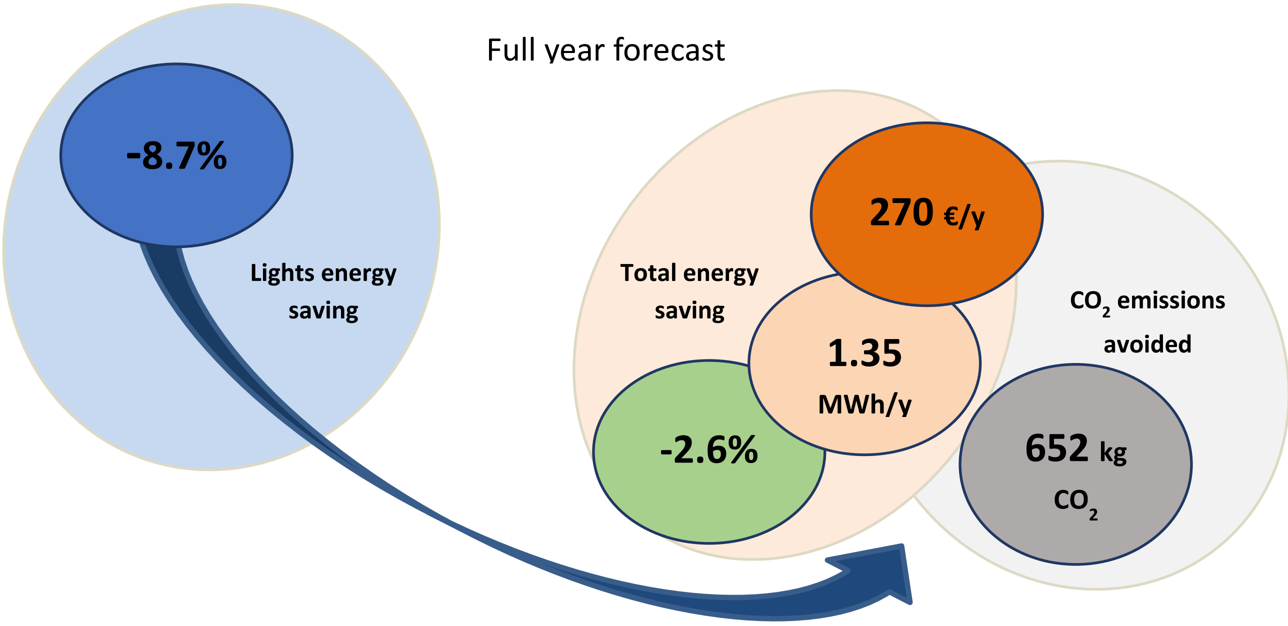


Figure 32 - Daily average energy consumption – Comparison. Baseline period: 31st of October '16 - 30th of October '17; Energy saving period: the 1st of November '17 – the 30th of November '17

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 1,350 kWh/year, equal to 652 kgCO_2.



In the following table, there is the comparison between the baseline week and the energy saving week.

Week	Consumption [kWh/week]	Difference with baseline [kWh/week]
Baseline week	296,5	0
Energy saving week	270,7	25,8

NOTES: Electricity cost: 0,2 €/kWh National emission factor: 0,483 kgCO_2/kWh

9. Educational and energy saving activities in Ellinogermaniki Agogi (GR14)

Educational Activities

Within the project, Ellinogermaniki Agogi systematically monitored the consumption of electricity in seven classrooms of the 6th grade in its primary school. One of the thematic areas chosen by the school focused on the consumption of electricity, mainly from the lighting used during lecture time.

1st Step- Sensitization and preparation

The part of the building utilized in the project includes seven classrooms, which are monitored by the GAIA infrastructure. The teachers 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.

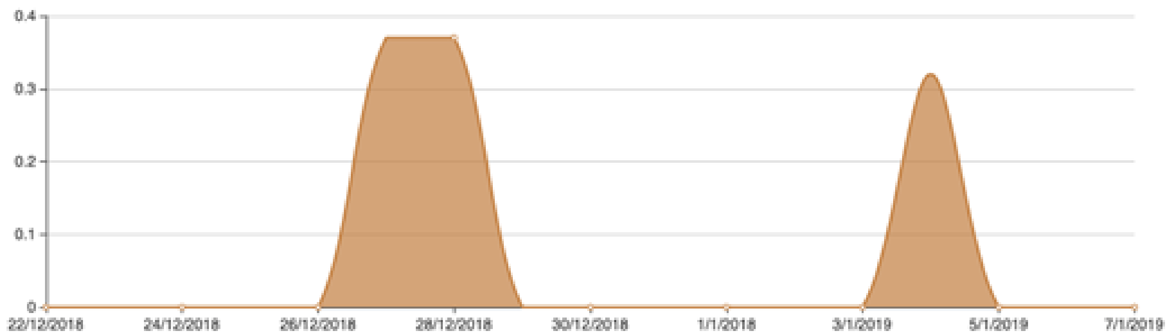


Figure 33 Current consumption in the last week of the year and the first week of the New Year

The average value for this period was 0.35 kWh per day. This was considered as the basic energy consumption for these halls, i.e., consumption that is inelastic (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:

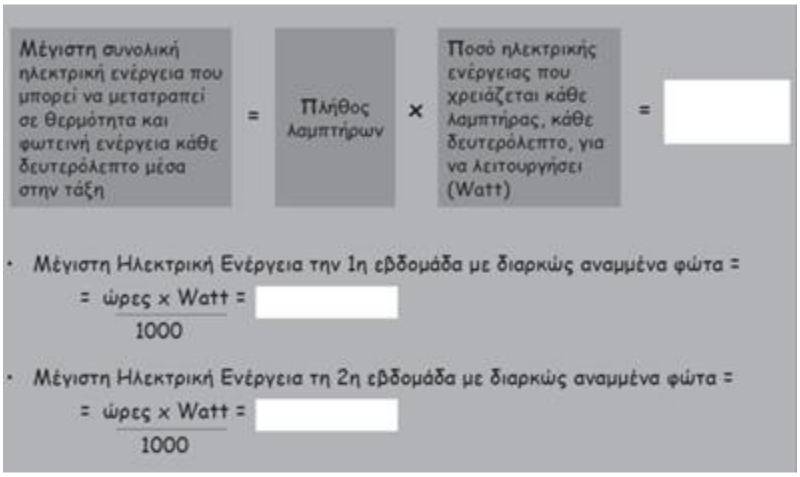


Figure 34 Calculating energy consumption by students - the comparison interval

Figure 35 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 seven 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, teachers asked the students 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 i) lessons outside the classroom, ii) during the breaks, and iii) during lessons when the weather is comfortable, helps the students to focus better during lessons on the board. After completing the recording week, the pupils summed up the time intervals where the 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:

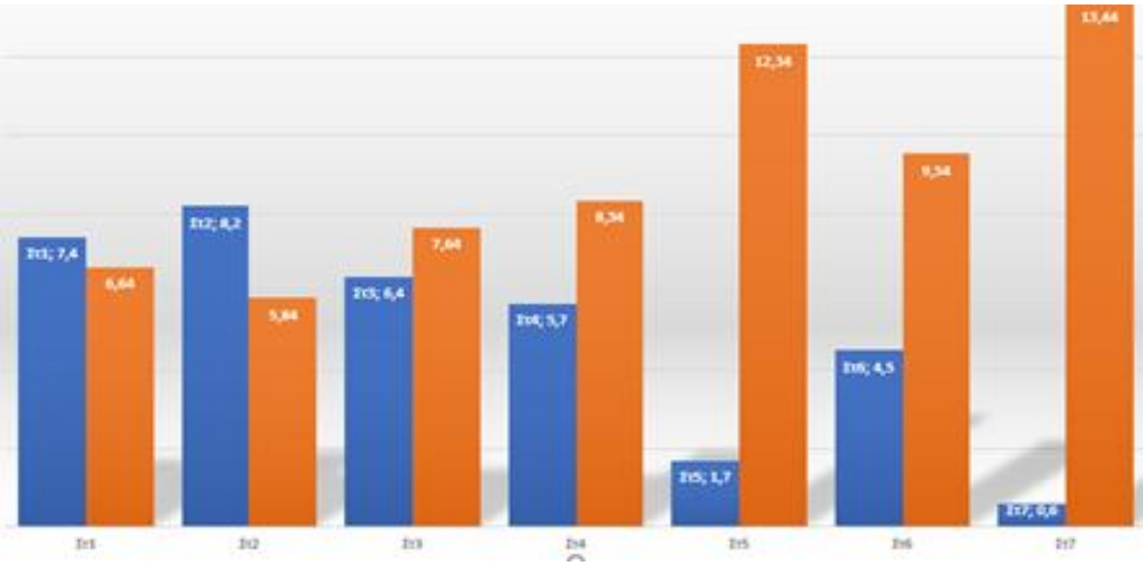


Figure 36 Presentation of results (blue column) and savings (orange column) of energy per segment

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:

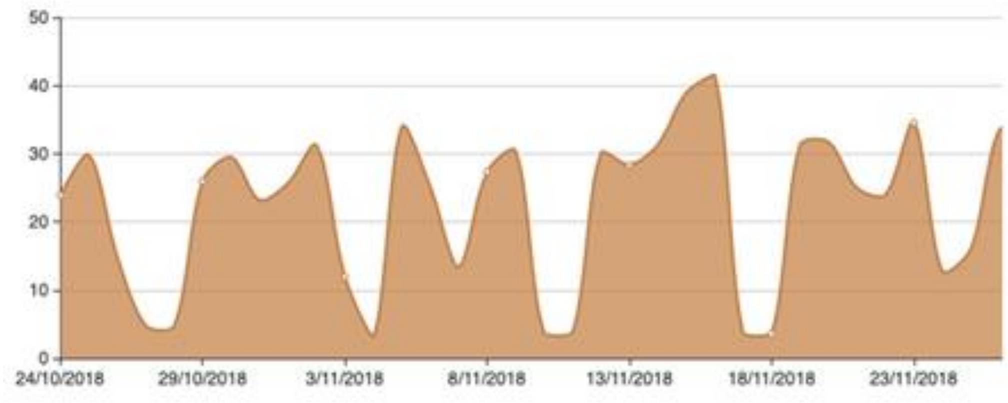


Figure 37 Total energy consumption in kWh.

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:

Figure 38 Student observations after comparing their calendars (a).

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

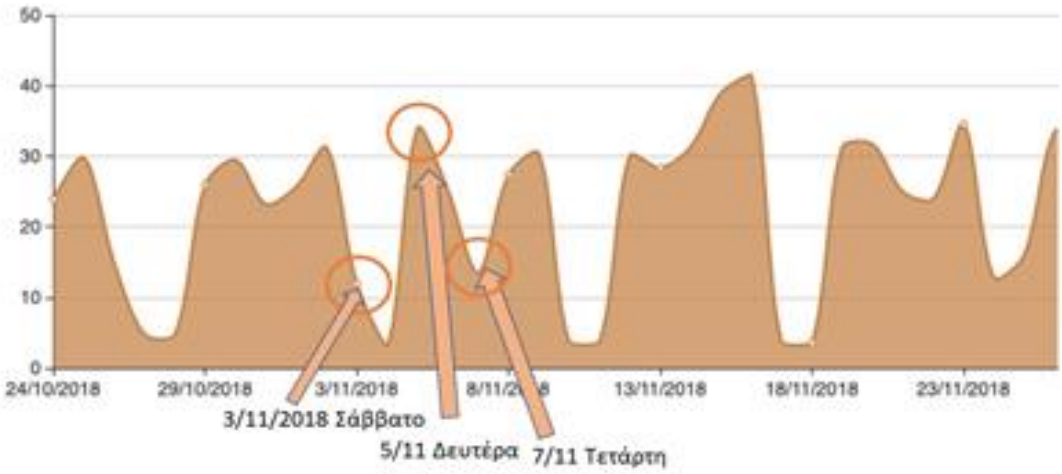


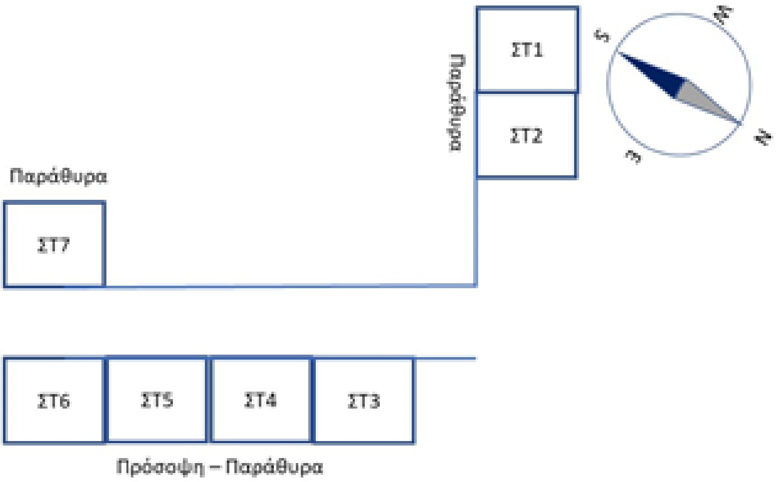
Figure 39 Student observations after comparing their calendar (b).

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 on 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. However, very quickly they realized this was a day during which they did not have lecture time. Moreover, fortunately they did not forget to turn off their lights before they left.

Then the debate returned to the "comparison" between the two classes, 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 classrooms and how these are oriented within 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 found that the orientation of their classes is such that:

- Northeast-oriented sections (ST3-ST6) need their lights after 11 after the sun is then almost above the building,
- Southwest orientated sections (ST1-ST2) need their lights from morning until noon, just out of their windows there are trees (olives) and opposite the windows there is the building of the high school,
- West-facing section F7 needs its lights only in the morning as the whole day is illuminated by the sun.

The discussion of the energy savings achieved by each department as well as the correlation with the direction of the class gave rise to the question of whether a department "stole" 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 bar graphs, the discussion arose in all parts of the F where the same questions were formulated which the students responded using all 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.

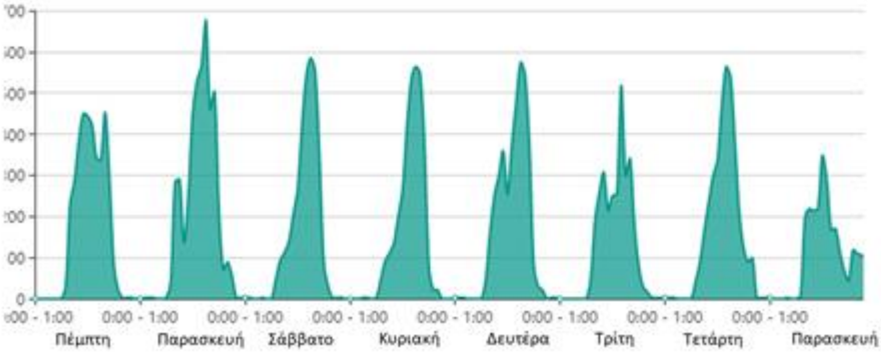


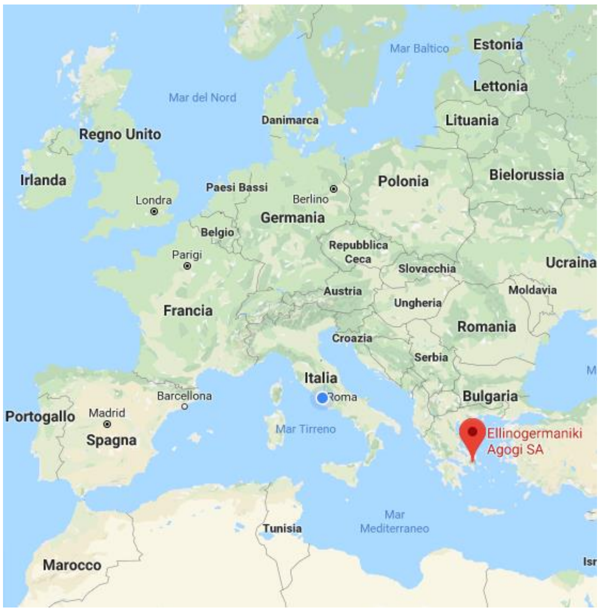
Figure 40 Brightness recording of the segment that managed to save all the electricity needed for the lights of the order.

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. The students eventually verified that F7 did not "cheat" to produce their results, but that Sections 1 and 2 used more energy than the ones that saved. A lesson emerged as follows: a) all of the classes in the 6th grade managed to save energy, and b) that the big savings of 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.

Energy Aspects Report



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

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

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 average daily consumption in the workweek days (from Monday to Friday) is about 26 kWh per day. During the weekend, there is a minimum 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.

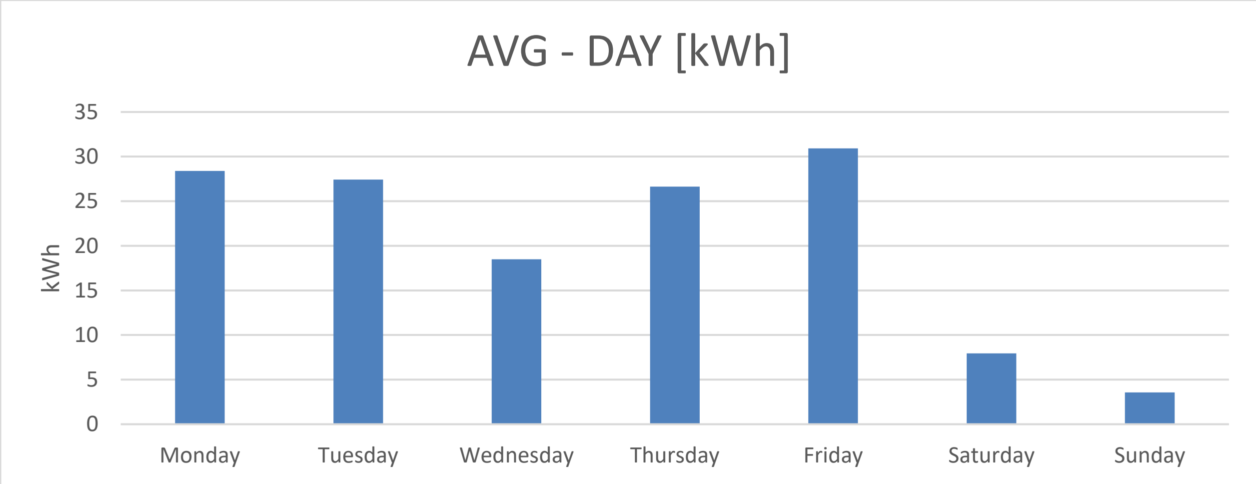


Figure 41 - Daily average energy consumption into the school. Period 29th of October 2018 - 11th of November 2018

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

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.

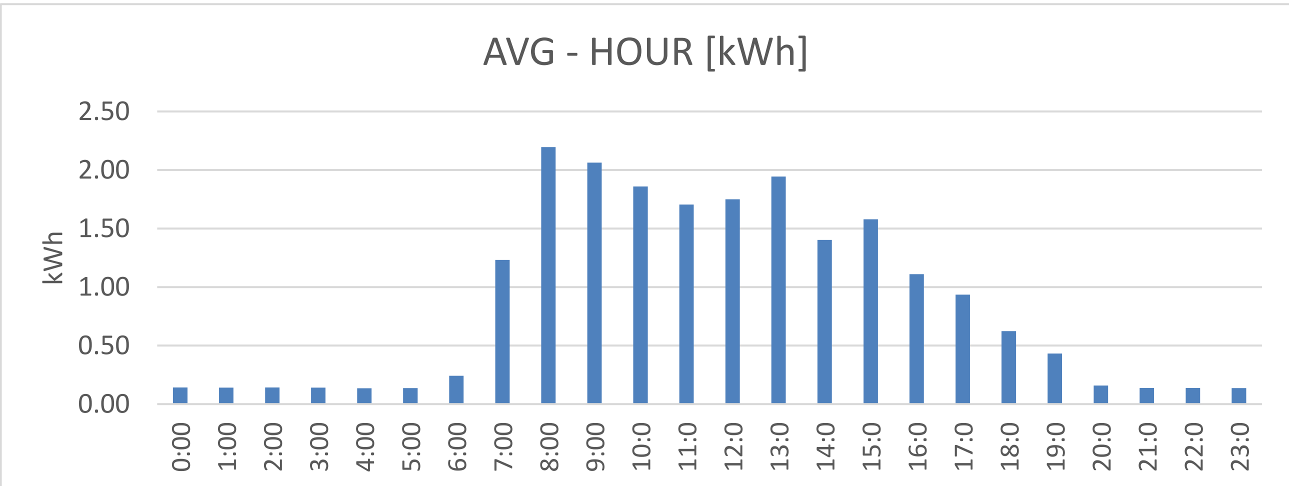


Figure 42 - Hourly average energy consumption into the school (October 29th 2018 - November 11th 2018)

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 until 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 has involved 7 classrooms (ST1, ST2, ST3, ST4, ST5, ST6, ST7). In each classroom, there are 24 lamps of 18 Watts each; thus, the electrical power related to the activity is just above 3kW. 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.

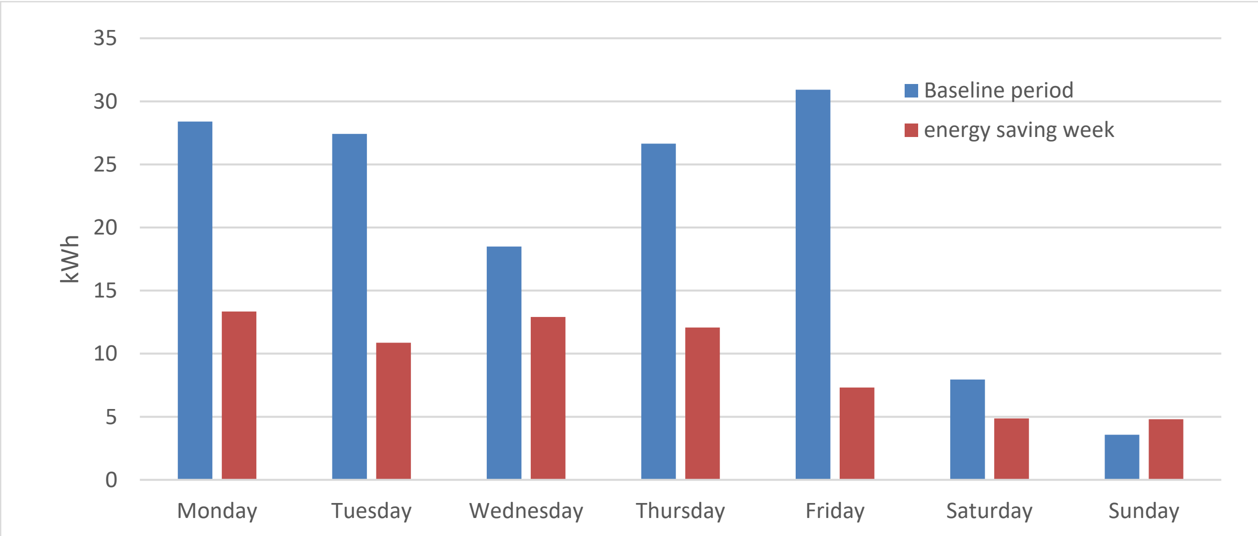


Figure 43 - Daily average energy consumption – Comparison
Baseline period: 29th of October -11th of November 2018; Energy saving week: 8th – 14th of October 2018

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 saving is less because of 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.

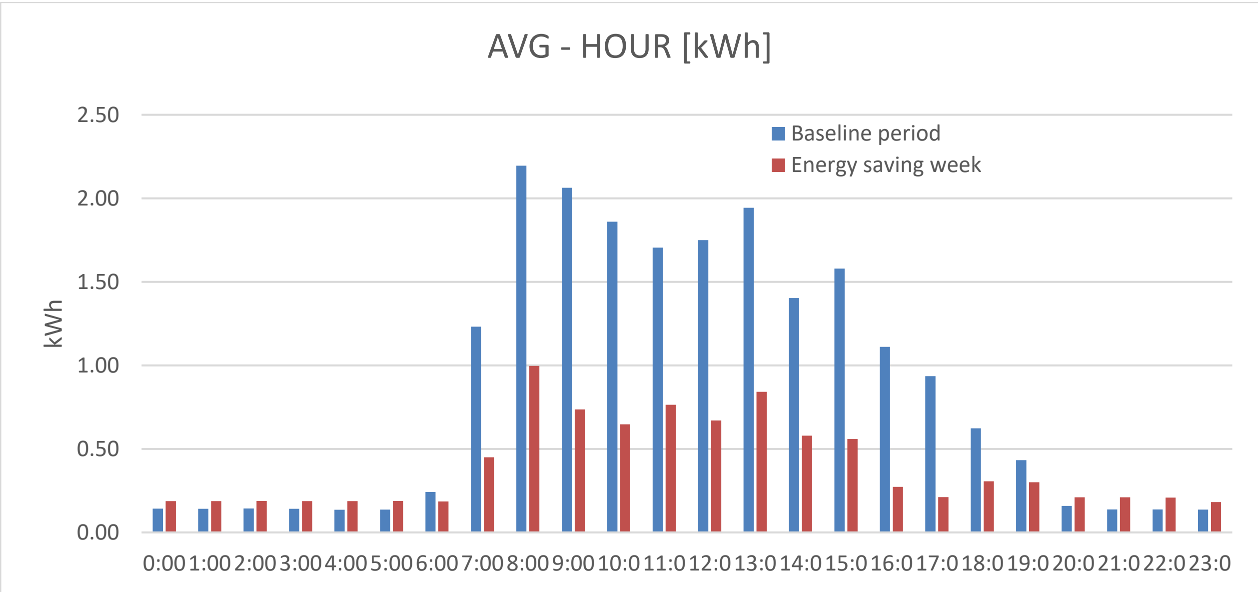
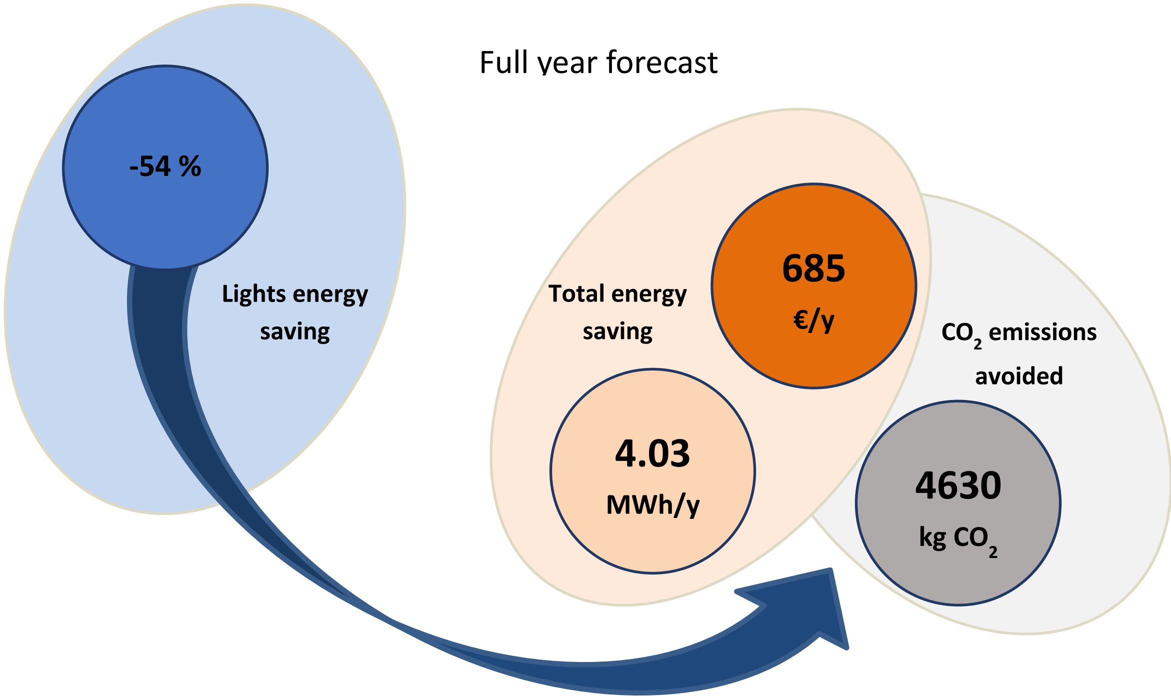


Figure 44 - Hourly average energy consumption – Comparison
Baseline period: 29th of October -11th of November 2018; Energy saving week: 8th – 14th of October 2018

It is interesting to see how the energy saving has been achieved during the whole working day except for the closing 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.



In the following table, there is the comparison about the energy consumption between the baseline week and the energy saving week for both energy efficiency activities.

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

10. Energy saving activities in Greek schools

Overview of the Greek schools' activities during the trials

As described in Chapter 2 of this document, we had 21 schools in Greece with IoT infrastructure, and 2 without one, participating in GAIA. These schools have in their vast majority collaborated with us in a professional manner, and have dedicated lots of time and effort to implement energy-saving and sustainability awareness initiatives. We have opted to include Ellinogermaniki Agogi in the previous chapter as a separate school and not this one, due to its participation as a consortium member in the project, so the activities described here refer to the rest of the Greek schools.

During the trials period, we had very good levels of participation from the majority of the schools in Greece that participated in GAIA's activities, and here we include some examples of success stories that stood out during the trials period:

- The 6th Primary School of Kaisariani (GR12) was one of the schools with the highest level of interaction with the project, while also being one of the schools that participated in almost all educational aspects of the project. The teachers of the school produced their own material to complement GAIA's activities, while they also produced a video overview[5] of the school's participation that has been uploaded to GAIA's YouTube channel.
- The Experimental Primary school of the University of Patras (GR22) was another highlight in terms of original educational material produced by the teachers of the schools, while also being the only school that completed an activity focusing on noise levels inside their school building.
- The 46th primary school of Patras (GR10) was another school that participated in almost all of the activities of the project,
- The Junior High School of Pentavrysso (GR06) was one of the most enthusiastic schools to participate in the project. Even though it is located in a rural area, it has a culture of participating in such activities and was able to compete with other schools for the best contributions in both of GAIA's contests.
- The Experimental Junior High School of Laggouras in Patras (GR23) was one of a few schools that have had the students grouped into different teams to compete with each other in energy savings, and to produce videos documenting their participation in the project.
- The 7th High School of Trikala (GR27) 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.
- Finally, the 1st Primary school of Psychiko (GR15) and the 1st High School of Nea Filadelfeia (GR01) were two schools that participated in educational and technological exhibitions in Athens, together with the consortium, helping us to present our progress and results to a wide audience, e.g., during the Researcher's Night events.

We continue with overviews of the energy-saving activities in selected schools in Greece.

[5] https://www.youtube.com/watch?v=JsVxLcaUclg

6th Primary School of Kaisariani (GR12)

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

Students identified power consumption points for heating, lighting, refrigerators, microwaves, computers, printers, speakers, dishwashers, air conditioners, etc. The observations at the outset were general, concerning the entire school complex, and afterwards, more specific, and related to the part of the building monitored by GAIA. They created a school building profile and then produced a mobile measurement station. Afterwards, they appointed responsible students in order to control energy-intensive school points. With respect to the implementation of the activity, they tried to save energy by reducing unnecessary consumption during the energy-saving week from March 18, 2019 to March 24, 2019. This is the week used 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. The respective calculations were made considering the following periods: for the average baseline week, the week from March 11, 2019 to March 17, 2019 was considered, while the energy saving week was between 18th of March 2019 to March 24, 2019.

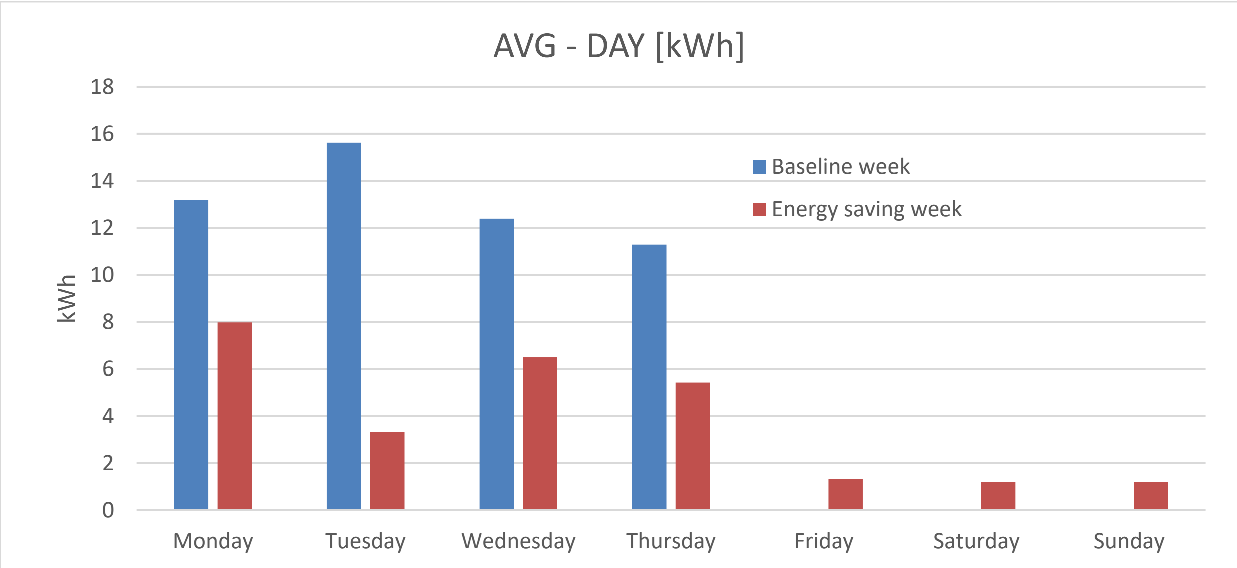


Figure 45 - Daily average energy consumption in second floor of the principal building. Period – Comparison Baseline period: 11th-17th of March 2019; Energy saving period: 18th – 24th of March 2019

The energy saving is present during the whole workweek, with the best performance on Tuesday. During Friday and the weekend, we did not 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.

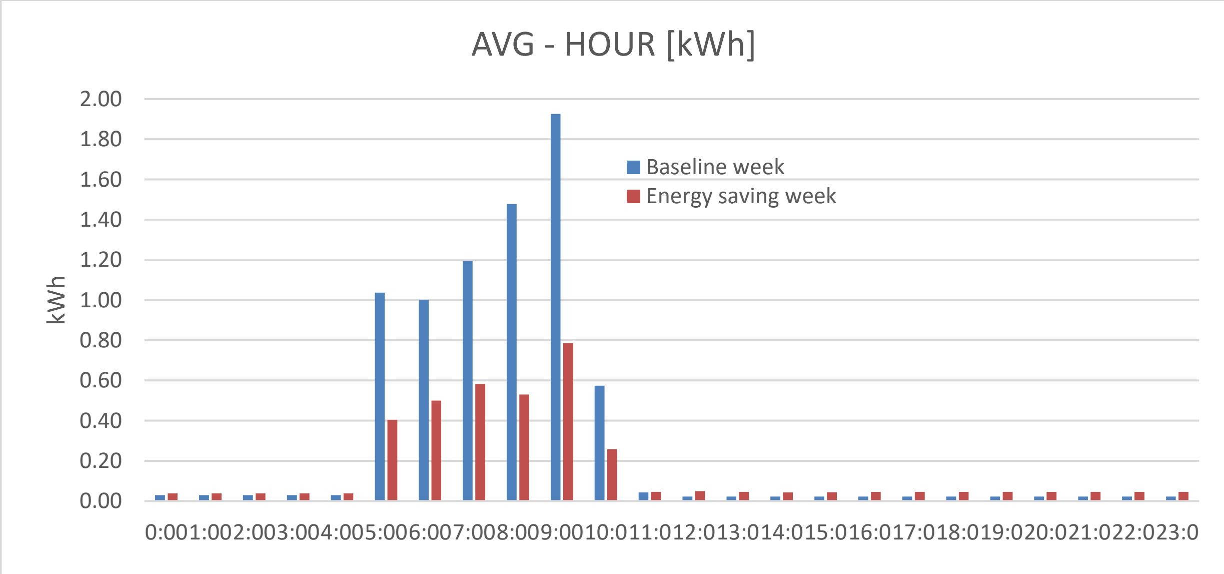
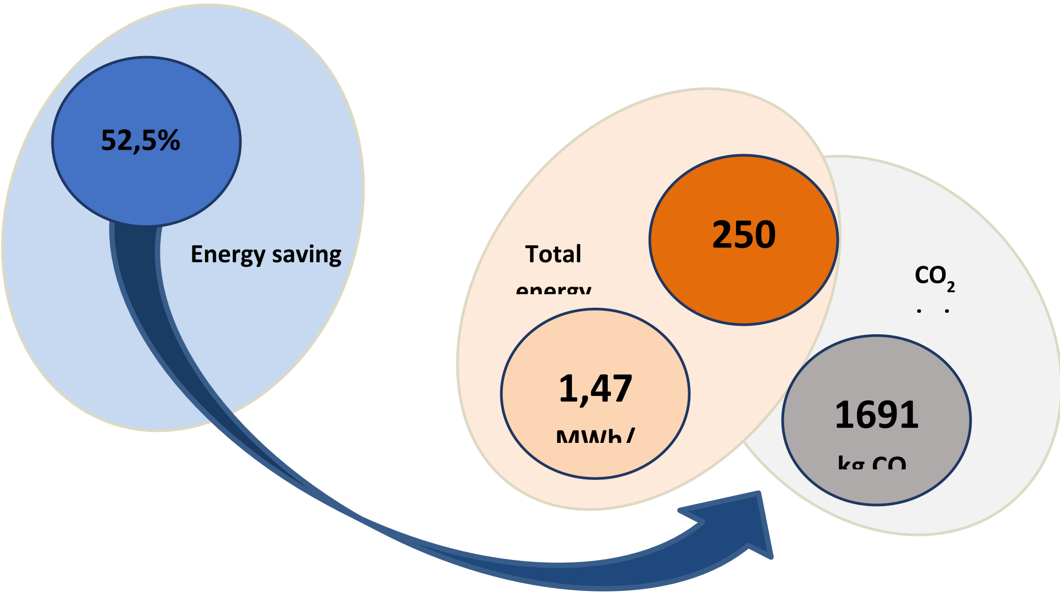


Figure 46 - Hourly average energy consumption in second floor of the principal building. Period – Comparison Baseline period: 11th-17th of March 2019; Energy saving period: 18th – 24th of March 2019

It is interesting to see how savings were achieved during the working hours, while during the closing hours the energy consumption was too low to have variations. To calculate a full year energy saving 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 1,332 kWh/year equal to 1,532 kg CO_2 avoided.



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

In this building, the installation's XBee network consists of four Arduino based environmental monitoring devices, one Arduino based electrical power meter and two Gateway devices with a total cost of 713 Euros. According to the estimated energy savings of 250 Euros per year, the cost of the installation in the school will be reimbursed in 2,85 years.

7th High School of Trikala (GR27)

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

Energy consumption before energy efficiency activity

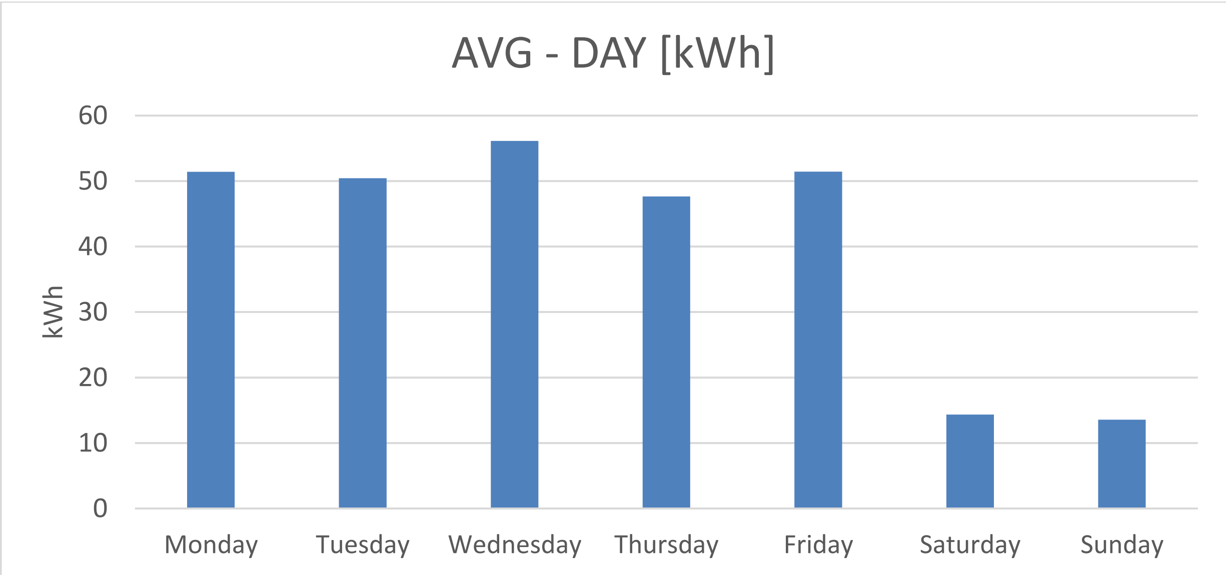


Figure 47 - Daily average energy consumption for the portion of the building monitored. Period 18th of February 2019 - 24th of February 2019

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.

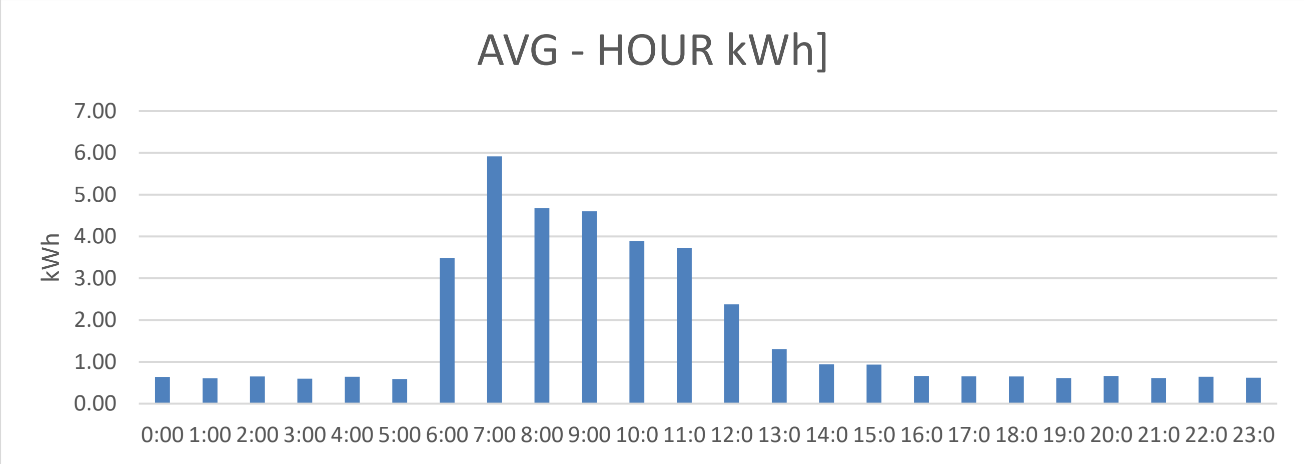


Figure 48-Hourly average energy consumption for the portion of the building monitored. Period 18th of February 2019 - 24th of February 2019

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 until 14:00. During the closing hours the energy consumption is almost constant of about 0,6 kW. In order to try to reduce the energy consumption and increase the energy efficiency of the building has been taken the following solution.

ACTIVITY – GENERAL CONSUMPTION REDUCTION

The activity comprised 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 we have 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. The 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.

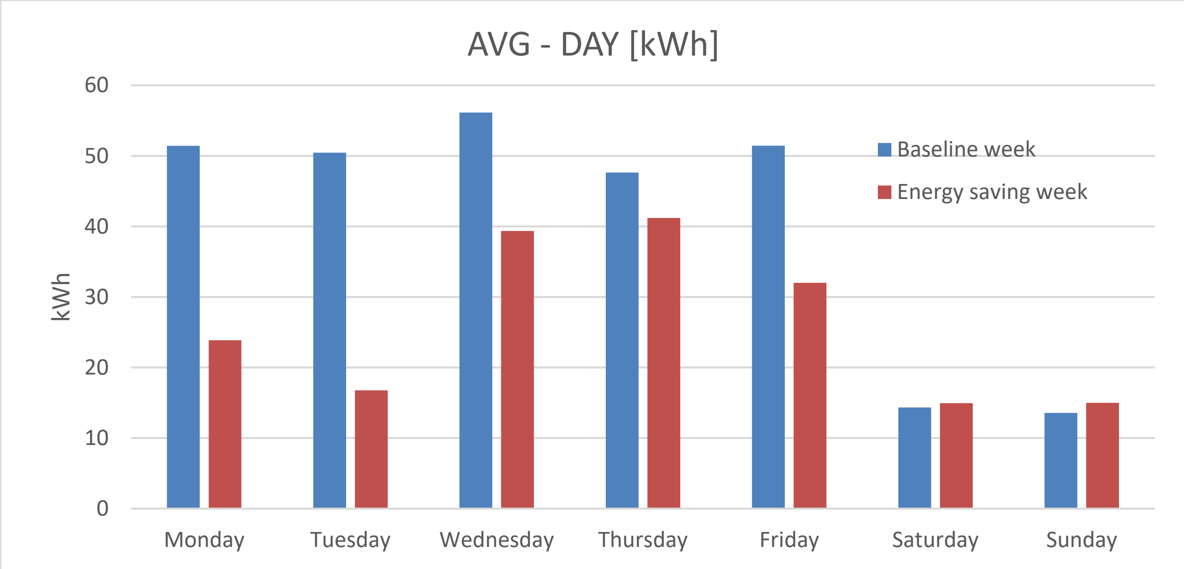


Figure 49 - Daily average energy consumption in portion of the building monitored. Period – Comparison Baseline period: 18th-24th of February 2019; Energy saving period: 4th – 10th of March 2019

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.

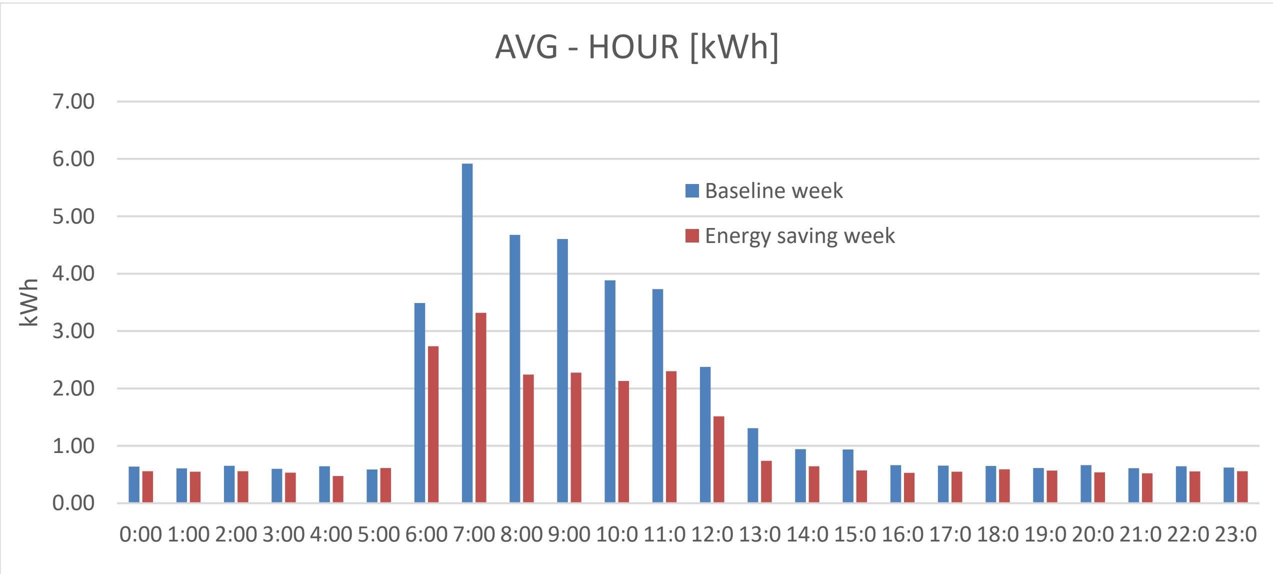
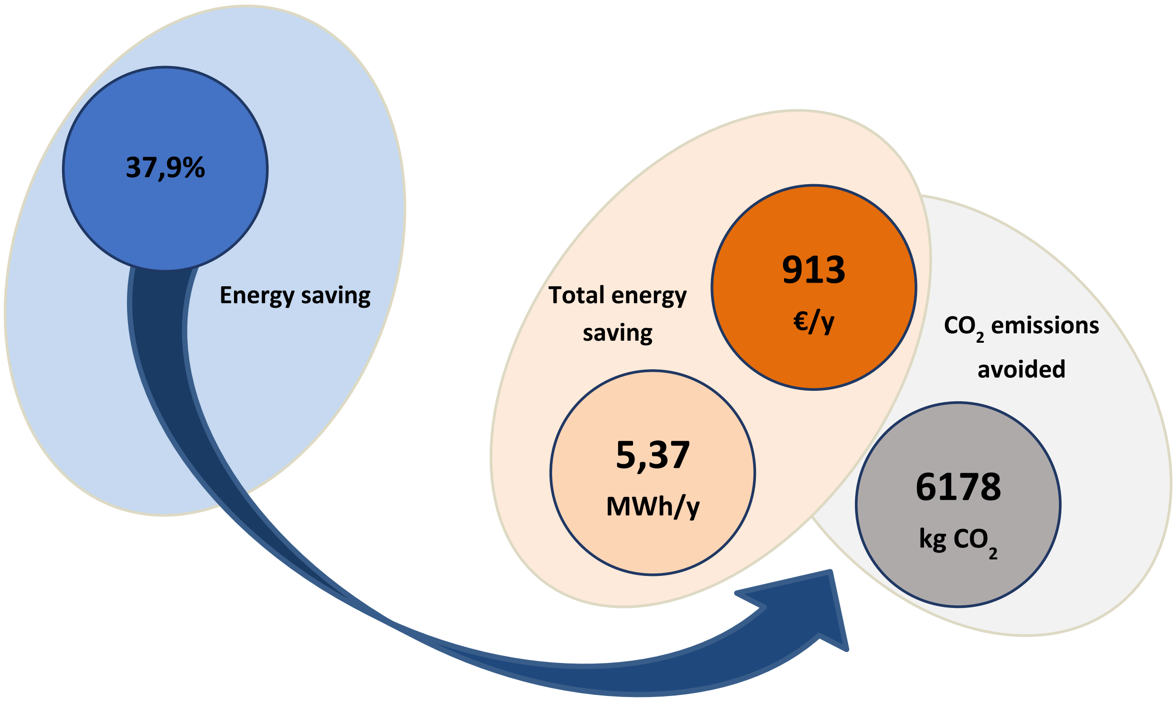


Figure 50 - Hourly average energy consumption in portion of the building monitored. Period – Comparison Baseline period: 18th-24th of February 2019; Energy saving period: 4th – 10th of March 2019

The energy saving has been achieved during the all day with no exceptions; we had the best performance during the working hours from 6:00 to 13:00. Students calculated also the energy saving separately for the ground floor and for the first floor. They obtained an energy saving of 33% for the ground floor and an energy saving of 60% for the second 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.



In the following table, there is the comparison about the energy consumption between the baseline week and the energy saving week for the energy efficiency activity.

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

In this building, the installation's LoRa network consists of six Arduino-based environmental monitoring devices, three Arduino-based electrical power meters and one Gateway device with a total cost of 826 Euros. According to the estimated energy savings of 913 Euros per year, the cost of the installation in the school will be reimbursed in 0,9 years.

Experimental Junior High School of the University of Patras (GR23)

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

Energy consumption before energy efficiency solutions

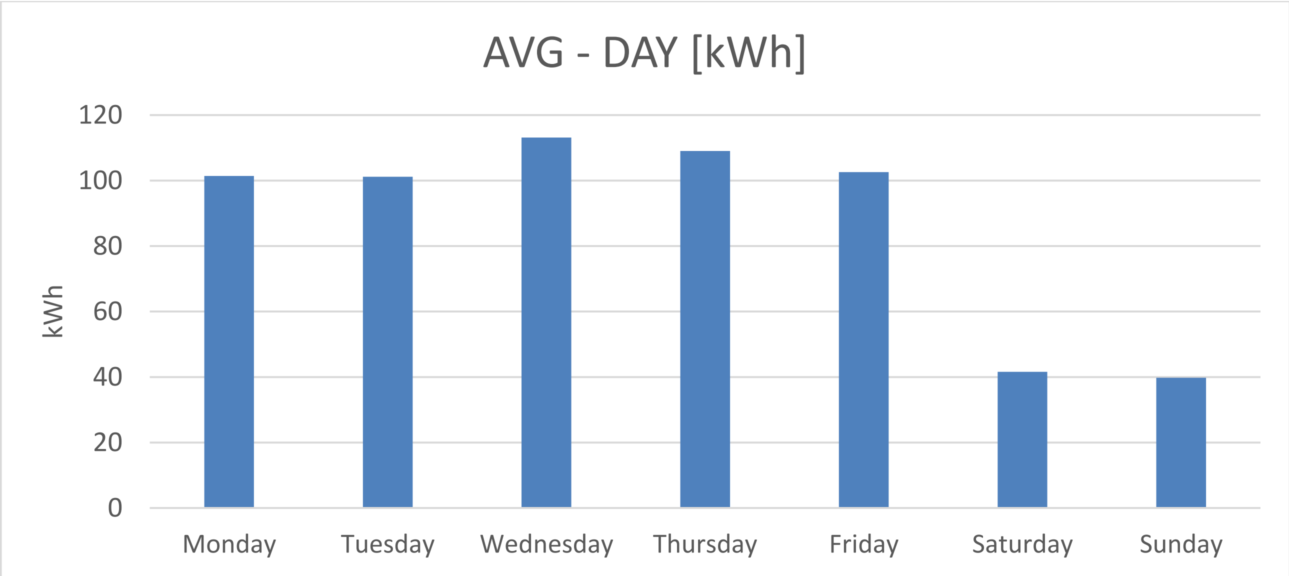


Figure 51 - Daily average energy consumption for the whole building.
Period 18th of February 2019 - 24th of February 2019

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 there is the minimum of the energy consumption with an amount of 40,7 kWh/day. The week 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, the energy consumption is 61,4% less than the energy consumption during the working days.

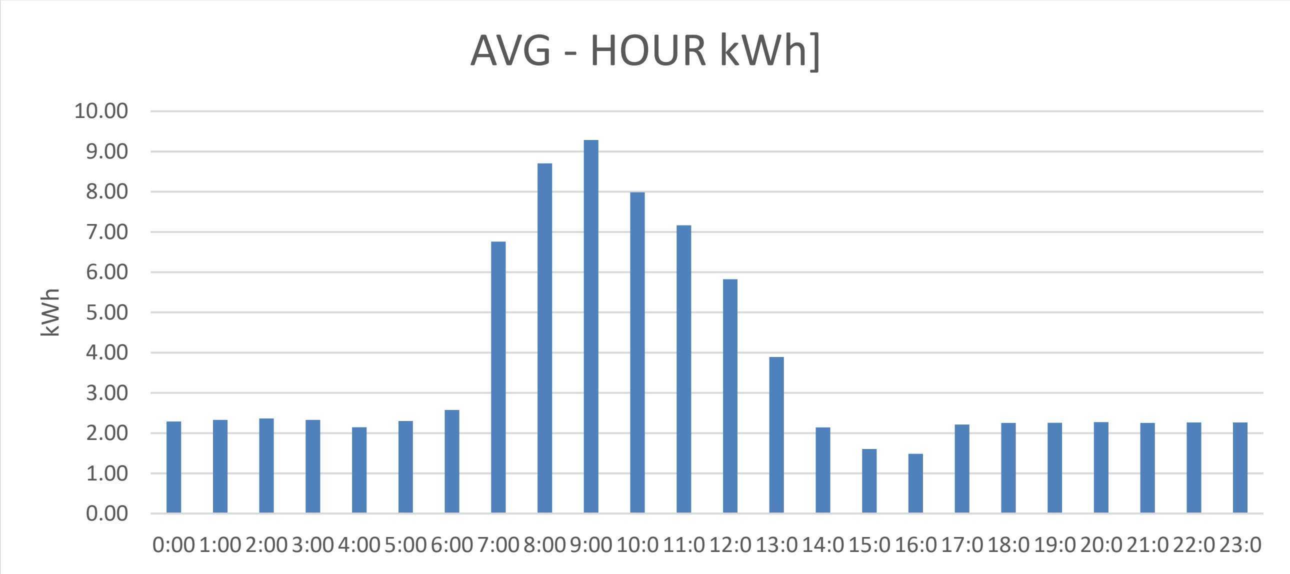


Figure 52-Hourly average energy consumption for the portion of the whole building. Period 18th of February 2019 - 24th of February 2019

In the average – hour chart you can see that the energy consumption grows during the morning to the maximum amount of 9,29 kWh at 9:00 in the morning. During the working hours, the energy consumption increases from 7:00 to 9:00 to decrease from 10:00 to 14:00. During the afternoon the energy consumption is low and constant to the amount of 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 following solution has been tested.

ACTIVITY – GENERAL CONSUMPTION REDUCTION

The activity comprised three phases:

- SENSITIZATION AND PREPARATION: student visited the interactive game 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 building by controlling lighting. For this reason, they have designated a guard 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 we have 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. The calculations concerned the following periods: for the average baseline week the week from the 18th of February 2019 to the 24th of February 2019 was used; for the energy saving week from the 26th of March 2019 to the 1st of April 2019.

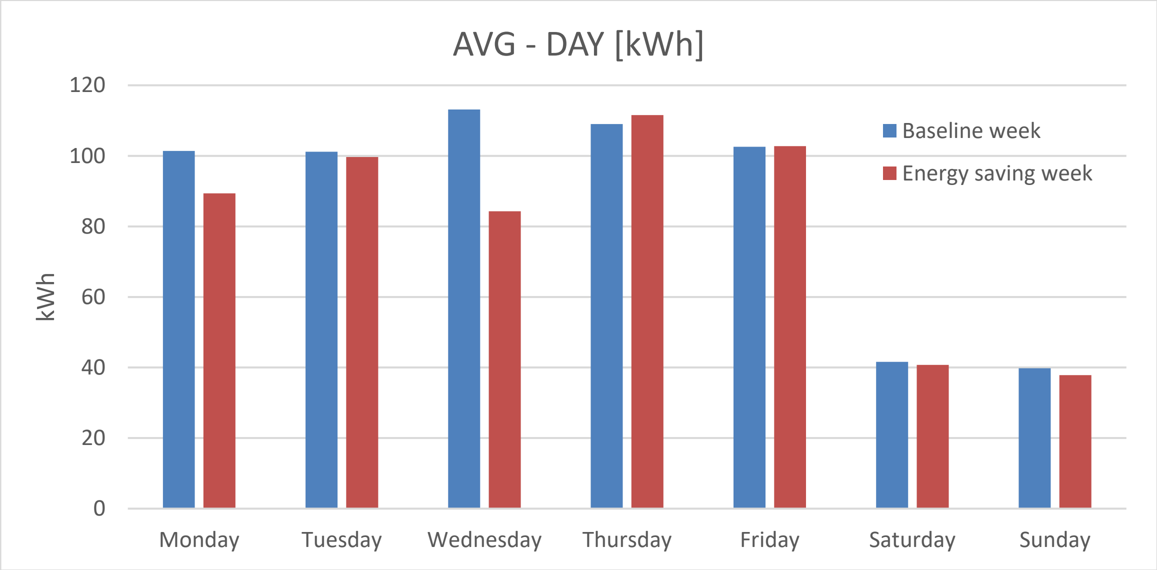


Figure 53 - Daily average energy consumption of the building – Comparison
Baseline period: 18th-24th of February 2019; Energy saving period: 26th of March – 1st of April 2019

The energy saving is most present on Monday and Wednesday, while is null on Tuesday and Friday. On Thursday the energy consumption during the energy saving week in higher than the baseline week, maybe because of special needs. The best performance has been done on Wednesday with a value of 25,5%. During the weekend, we had the same energy consumption with no energy saving. This means that the lights are well management into the school. 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.

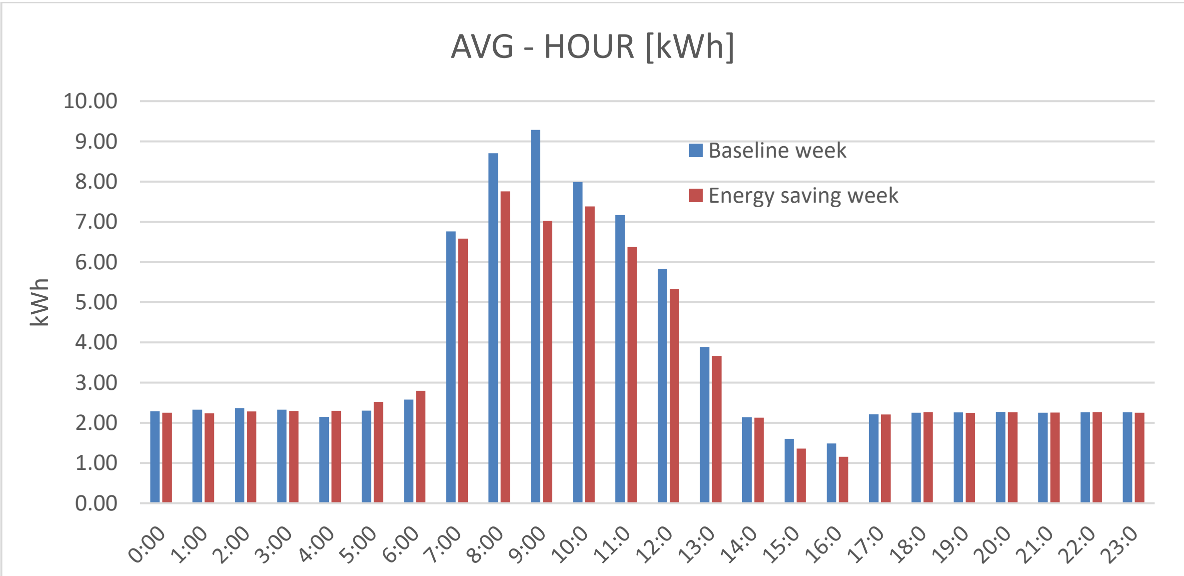
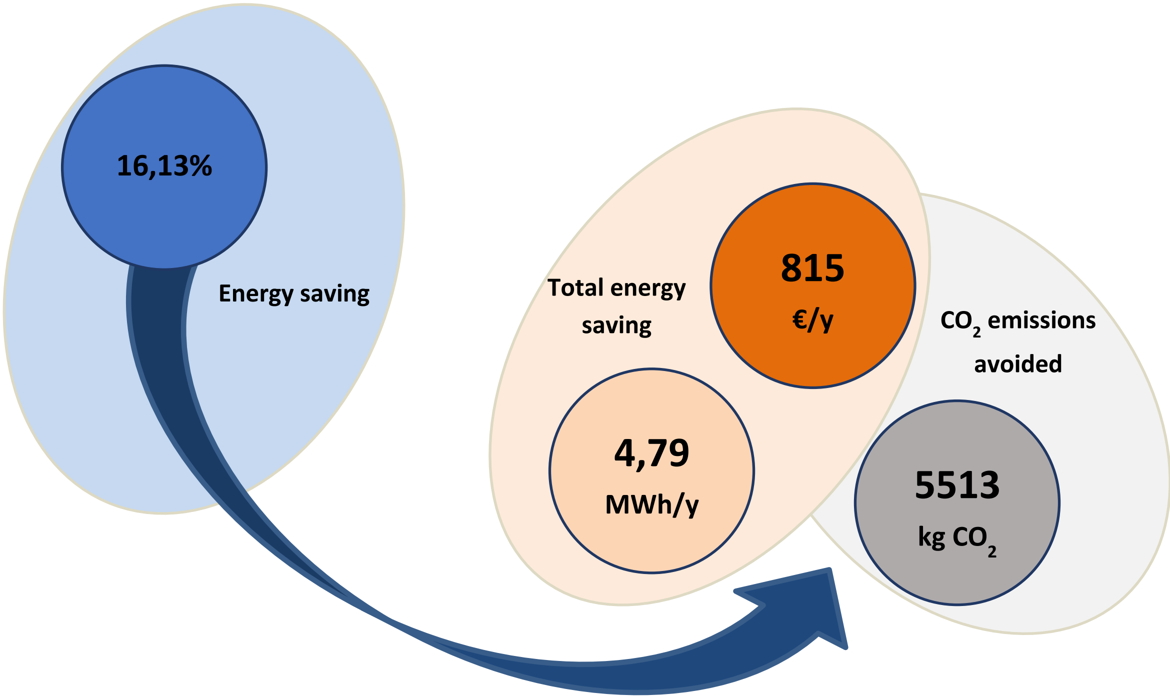


Figure 54 - Hourly average energy consumption of the building – Comparison
Baseline period: 18th-24th of February 2019; Energy saving period: 26th of March – 1st of April 2019

The energy saving has been achieved during the working hours; we had the best performances 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 2,547 kgCO_2 avoided.



In this building, the installation's LoRa network consists of six Arduino based environmental monitoring devices, one Arduino based electrical power meter and one Gateway device with a total cost of 658 Euros. According to the estimated energy savings of 815 Euros per year, the cost of the installation in the school will be reimbursed in 0,8 years.

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

Experimental Primary School of the University of Patras (GR22)

Total people:	210
People directly involved:	42
Square meters:	N/A
Volume:	N/A
Working schedule	30 to 45 hours/week

Energy consumption before energy efficiency solutions

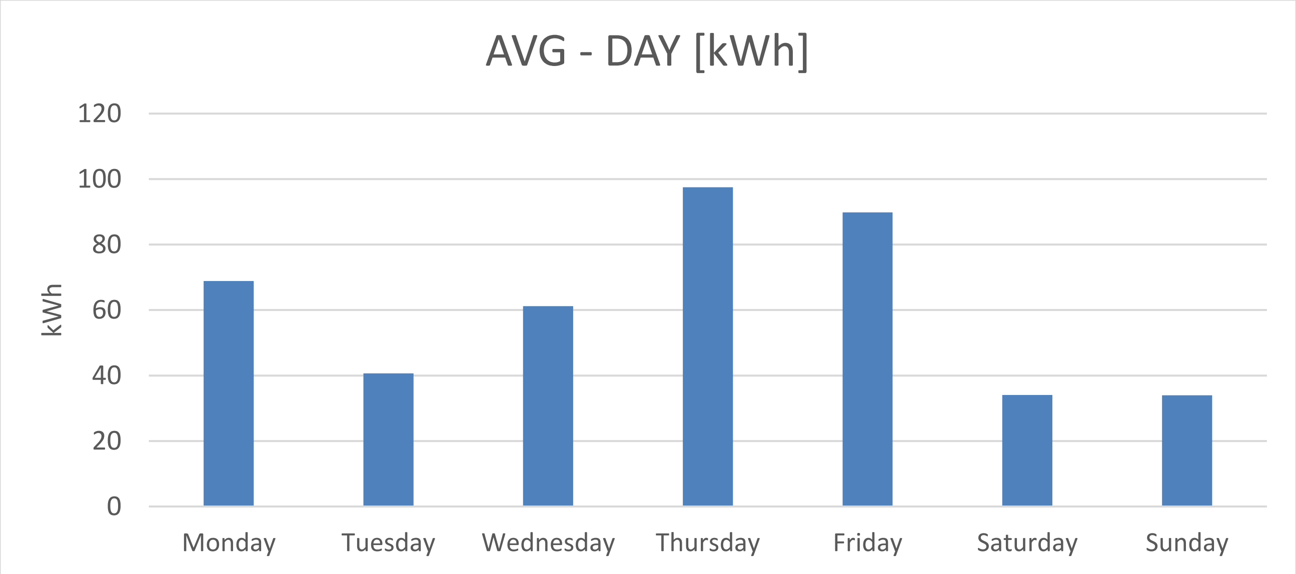


Figure 55 - Daily average energy consumption for the portion of the building monitored. Period 4th of February 2019 - 10th of February 2019

The average – day chart shows the energy consumption during a week for portion of the building monitored. It is different during the workweek days (from Monday to Friday) with a daily consumption of about 71,6 kWh per day. During the weekend, there is the minimum of the energy consumption with an amount of 34 kWh/day. The week average is 60,9 kWh/day and 426 kWh/week.

Days of the week	Average energy consumption [kWh]	Delta [%]
From Monday to Friday (workweek)	71,6	-
Weekend	34	-52,5%

When the portion of the building is not used, the energy consumption is the half of the energy consumption during the working days.

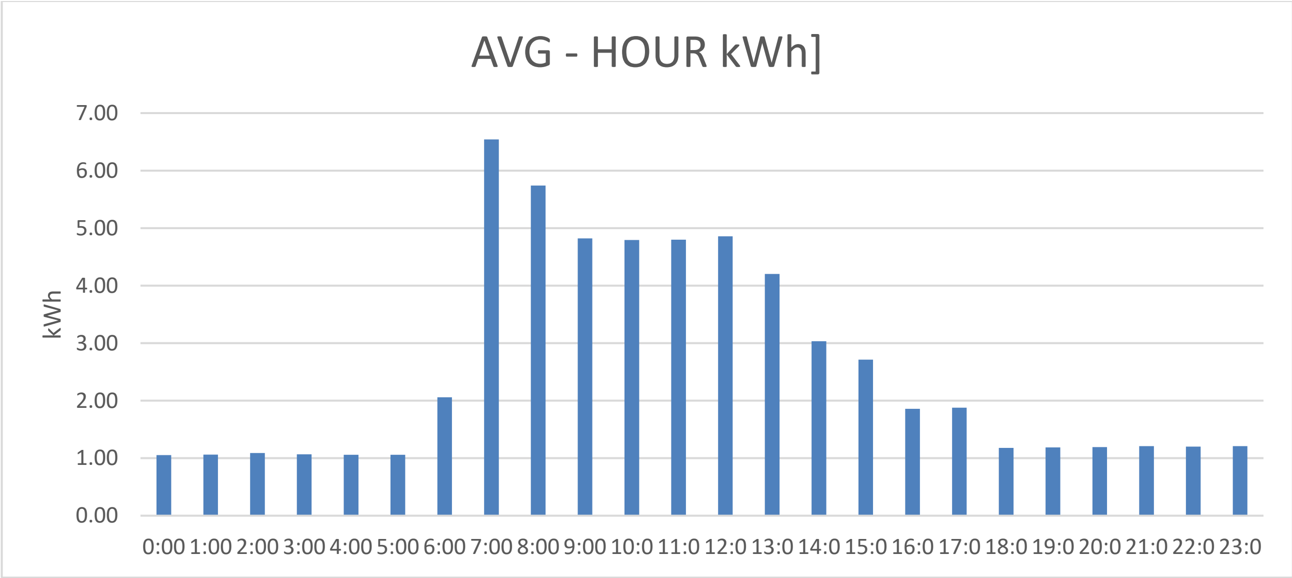


Figure 56-Hourly average energy consumption for the portion of the building monitored. Period 4th of February 2019 - 10th of February 2019

In the average – hour chart you can see that the energy consumption grows during the morning to the maximum amount of 6,54 kWh at 7:00 in the morning. During the working day, energy consumption remains almost constant and starts decreasing during the afternoon, until 17:00.

During the off hours, the energy consumption is almost constant of about 1 kW. In order to try to reduce the energy consumption and increase the energy efficiency of the building, the students implemented the following activity.

ACTIVITY 1 – GENERAL CONSUMPTION REDUCTION

The activity comprised two steps: first, students were invited to observe the school energy consumption with regard to lighting and heating in the various parts of the building. After the first step of observation, the students tried an action where the lights in the corridors, the classes, as well as the computers and the video projectors were closed. In a one-week period, 6 groups of students of the 8th grade switched off all the electrical devices in all classes and corridors each time a break took place. This week was from the 18th of February 2019 to the 24th of February 2019. 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.

The energy saving has been of 25,2% of the energy consumption for the part of the building monitored. Numerically, the weekly energy saving amounted to 107,5 kWh that in terms of money is about 18 €/week. Calculation concerned the following periods: for the average baseline week, they used the week from the 4th of February 2019 to the 10th of February 2019; for the energy saving week, from the 18th of February 2019 to the 24th of February 2019.

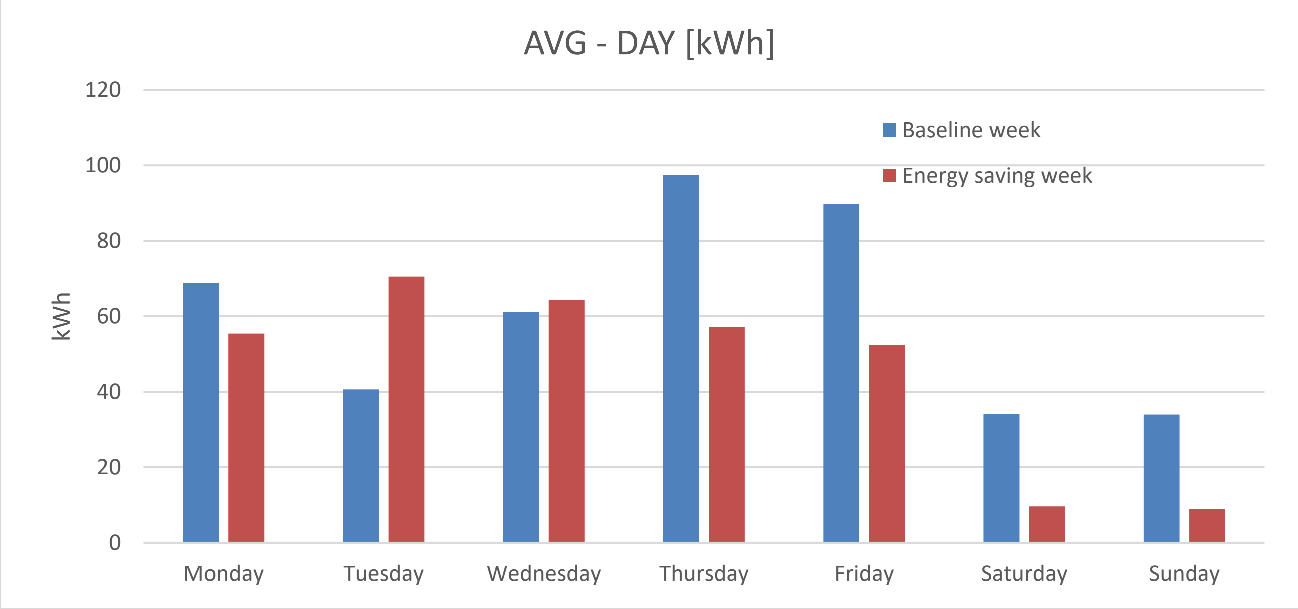


Figure 57 - Daily average energy consumption in second floor of the principal building. Period – Comparison Baseline period: 4th-10th of February 2019; Energy saving period: 18th – 24th of February 2019

The energy saving is present during the whole workweek, with the exception of Tuesday; the best performance has been on Friday. During the weekend, we had the best energy saving performance with a reduction of more than 70%. 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.

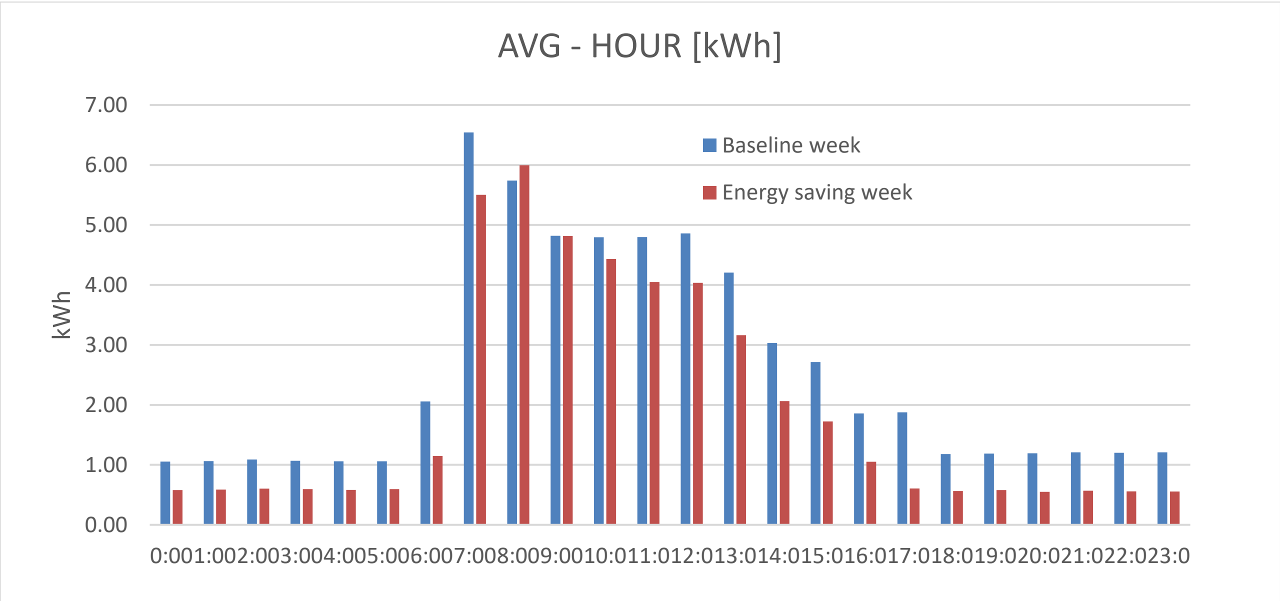
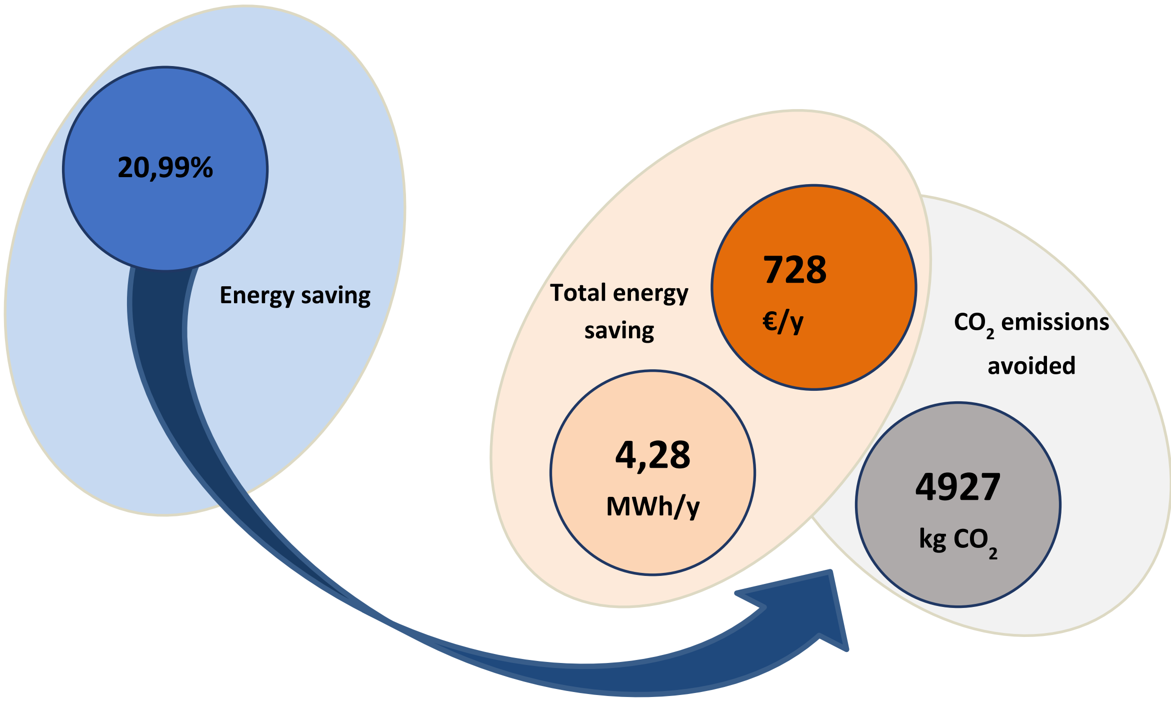


Figure 58 - Hourly average energy consumption in second floor of the principal building. Period – Comparison Baseline period: 4th-10th of February 2019; Energy saving period: 18th – 24th of February 2019

The energy saving has been achieved during the all day except the hours from 8:00 to 10:00, probably because all the utilities should be used and there was no space to reduce energy. 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 5,607 kWh/year equal to 6,449 kgCO_2 avoided.



In the following table, there is the comparison about the energy consumption between the baseline week and the energy saving week for the energy efficiency activity.

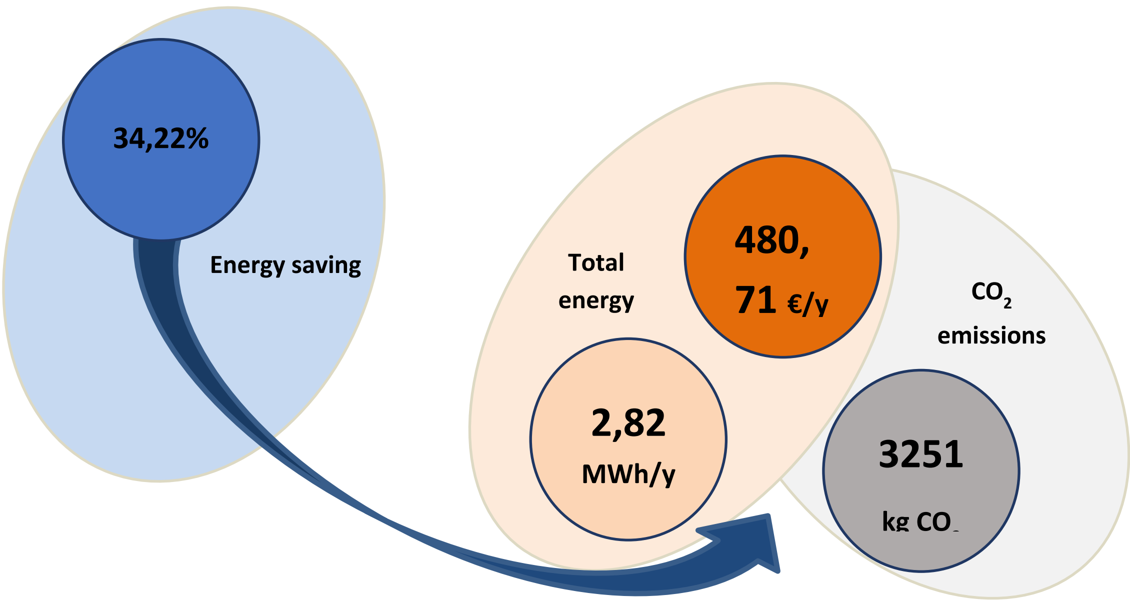
Week	Consumption [kWh/week]	Difference with reference [kWh/week]
Reference week	392,52	0
Energy saving week	310,12	82,4

In this building, the installation's LoRa network consists of four Arduino based environmental monitoring devices, two Arduino based electrical power meters and one Gateway device with a total cost of 571 Euros. According to the estimated energy savings of 728 Euros per year, the cost of the installation in the school will be reimbursed in 0,78 years.

8th Junior High school of Volos (GR25)

Total people:	198
People directly involved:	16
Square meters:	2453 m
Volume:	N/A
Working schedule	30 to 35 hours/week

To calculate the average energy consumption in the school, we analyzed the consumption during the week when the school was not operating due to Christmas holidays (inelastic consumption) and consumption during a regular week of school operation. Afterwards, we took the average of each week's consumption; we took the deduction to see net consumption (variable) on days of operation. We saw that during the period from 31/12/2018 to 5/1/2019 the consumption was 48,19 kWh in total and 9,64 kWh on average per day. During a typical school period from January 14 to 18, the consumption was 158.87 kWh. After that, the students performed some energy saving actions from 18/02/2019 to 22/02/2019 switching off the computers and turning off the lights in the classrooms and the corridors when there was enough natural light.



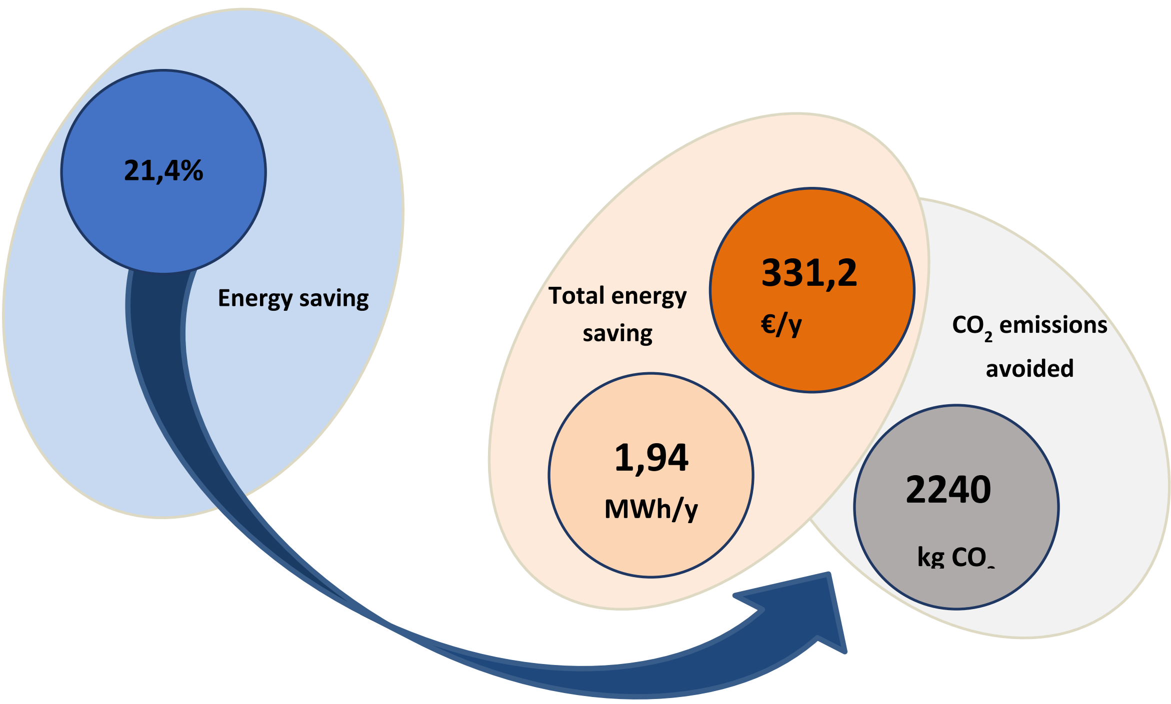
Week	Consumption [kWh/week]	Difference with baseline [kWh/week]
Reference week	158,87	0
Energy saving week	104,49	54,38

In this building, the installation's LoRa network consists of six Arduino based environmental monitoring devices, three Arduino based electrical power meters and one Gateway device with a total cost of 826 Euros. According to the estimated energy savings of 480,7 Euros per year, the cost of the installation in the school will be reimbursed in 1,71 years.

Primary school of Lygia, Lefkada (GR04)

Total people:	82
People directly involved:	48
Square meters:	1037
Volume:	9333
Working schedule	30 to 45 hours/week

The school measured consumption during a typical week with lessons. As the ideal week for this measurement, we thought it was the week following Easter holidays from 6/5/2019 to 12/5/2019. This week, all students were on school and there were no teachers' absences. During this period, the consumption was 175.09 kWh. Then the school through different energy saving actions reduced the consumption to 137.62 kWh.



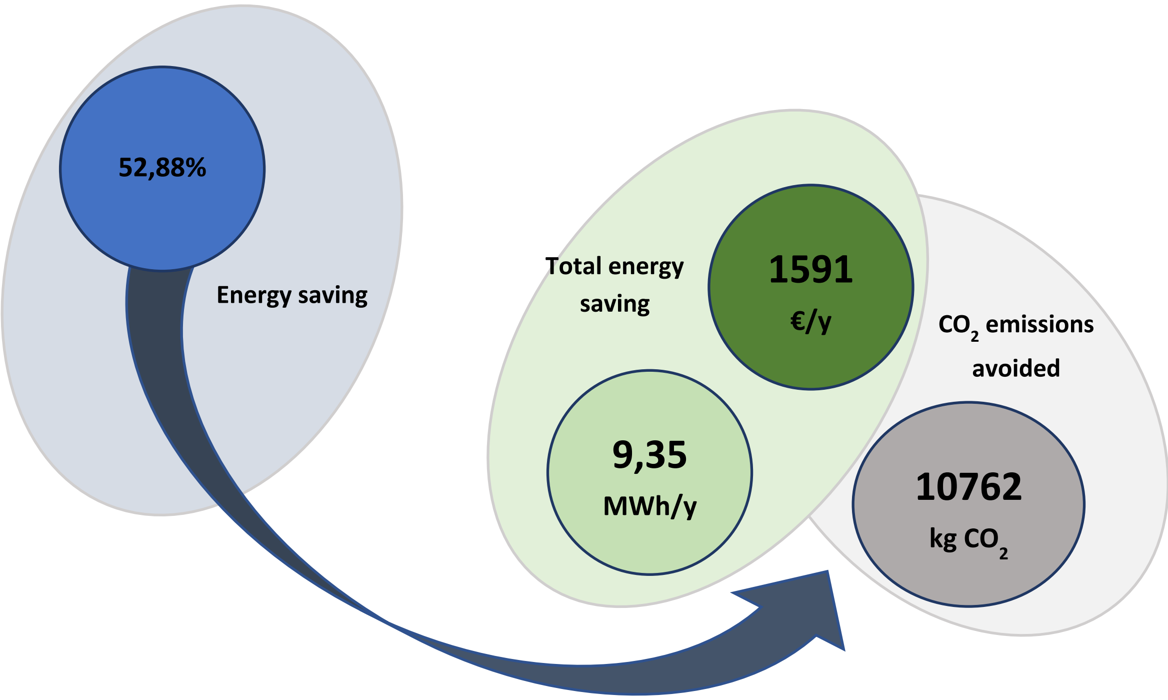
Week	Consumption [kWh/week]	Difference with baseline [kWh/week]
Reference week	175,09	0
Energy saving week	137,62	37,47

In this building, the installation's XBee network consists of five Arduino based environmental monitoring devices, one Arduino based electrical power meter and one Gateway device with a total cost of 769 Euros. According to the estimated energy savings of 331,2 Euros per year, the cost of the installation in the school will be reimbursed in 2,32 years.

Junior High School of Pentavryssos, Kastoria (GR06)

Total people:	46
People directly involved:	31
Square meters:	711
Volume:	4825
Working schedule	30 hours/week

The students from the Junior High School of Pentavryssos measured the average energy consumption of the building during a typical working week from 23/02/2019 to 01/03/2019. The average energy consumption for this week was 340.30 kWh. Moreover, from 02/03/2019 to 08/03/2019 was the period that started energy-saving actions in school. The average energy consumption through the action week was 160.32 kWh.



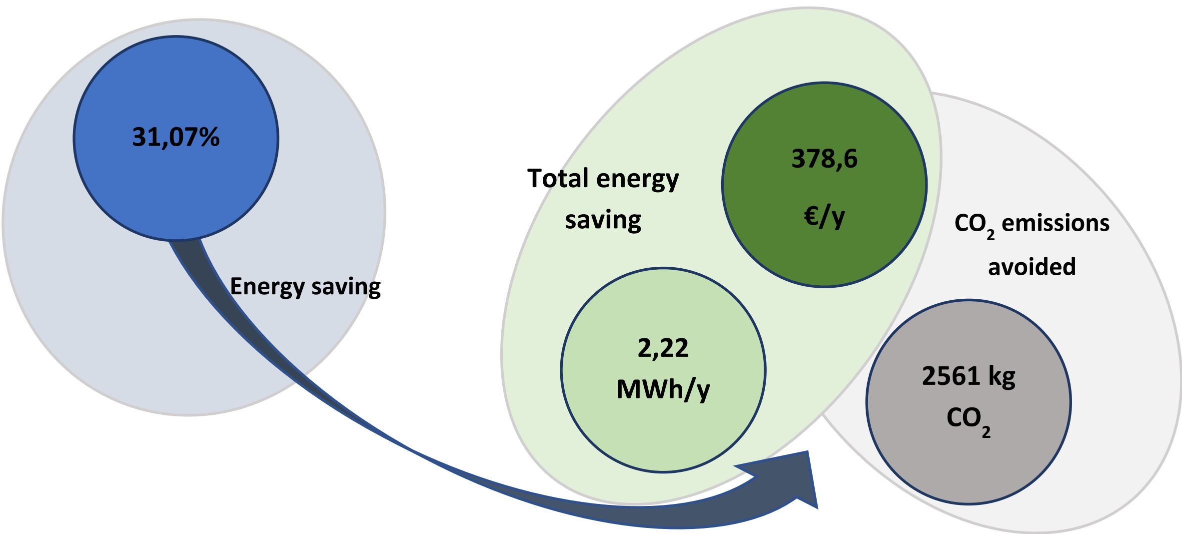
Week	Consumption [kWh/week]	Difference with baseline [kWh/week]
Reference week	340,3	0
Energy saving week	160,32	179,98

In this building, the installation's XBee network consists of eight Arduino based environmental monitoring devices, one Arduino based electrical power meter and one Gateway device with a total cost of 1127 Euros. According to the estimated energy savings of 1591 Euros per year, the cost of the installation in the school will be reimbursed in 0,7 years.

Talos Robotics School, Volos (GR26)

Total people:	170
People directly involved:	30
Square meters:	996
Volume:	N/A
Working schedule	20 hours/week

The school measured the consumption during a formal week with lessons. The best week for this purpose was the week from 15/4/2019 to 21/4/2019. That week, all student groups were in the building. There were no excursions and no teachers were absent, so that the planned teaching activities would normally take place. The average energy consumption for this week was 137.81 kWh. During the week from 6/5/2019 to 12/5/2019 was the period that started energy-saving actions in school. This week, all students and staff were informed about disabling electrical equipment that is not in use. There were also students who were assigned to monitor the building and disable unused equipment. The average value for this week was 0.66 kWh per hour. By deducting the reference consumption, which occurred from the week of 15/4/2019 to 21/4/2019 and the week from 6/5/2019 to 12/5/2019, from the average consumption recorded during the energy-saving week, we ended up reducing our energy consumption by 94.98 kWh per hour, or 14% during the energy-saving week.



Week	Consumption [kWh/week]	Difference with baseline [kWh/week]
Reference week	137,81	0
Energy saving week	94,98	42,83

In this building, the installation's LoRa network consists of six Arduino based environmental monitoring devices, two Arduino based electrical power meters and one Gateway device with a total cost of 742 Euros. According to the estimated energy savings of 378,6 Euros per year, the cost of the installation in the school will be reimbursed in 1,96 years.

1st Junior High School of Nea Filadelfeia, Athens (GR01)

Although the school was very active in several aspects of the project, and especially during school year 2017-18, during the final trials period the school did not conduct structured energy-saving activities that followed the GAIA methodology. For this reason, it is difficult to establish the cause and effect of any energy savings achieved in the school during specific periods. However, when comparing the total electricity consumption in the second floor of the school, where the GAIA-assigned students had classes, we can substantial differences between school years 2017-18 and 2018-19. More specifically, when comparing consumption between start of September and until the end of June for these 2 years, we see that there is 8.24% in energy savings for this specific part of the building.

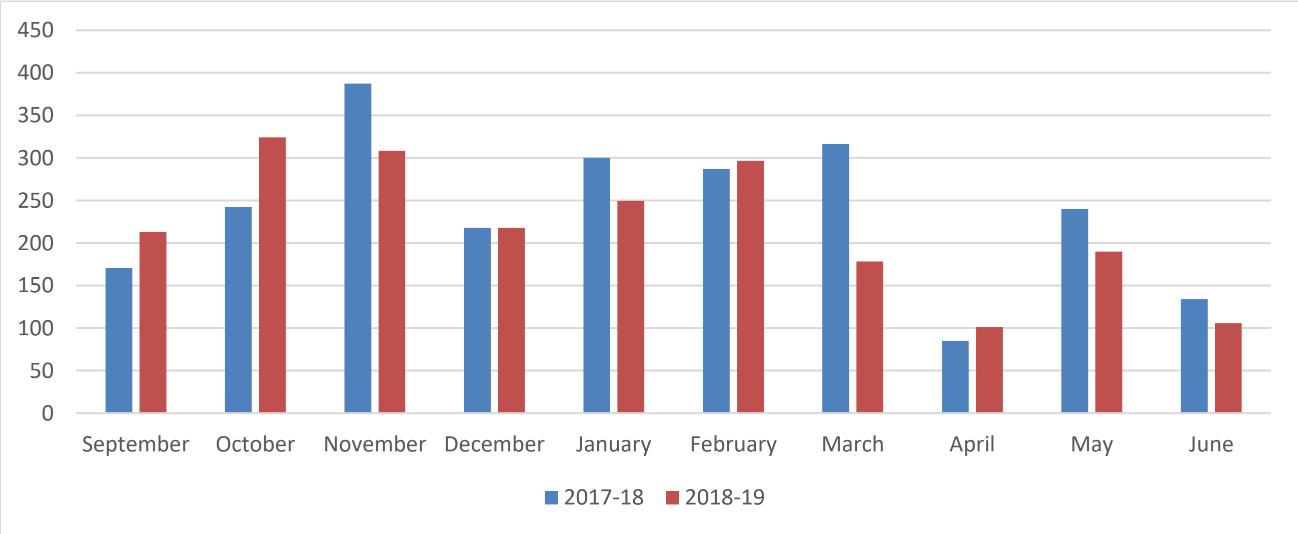
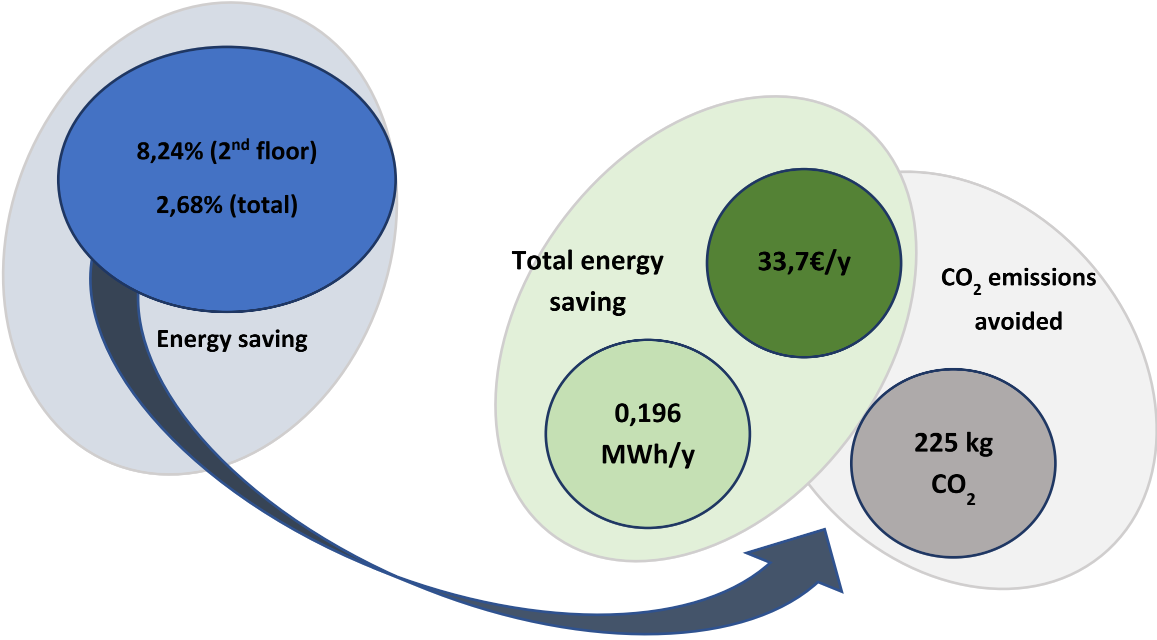


Figure 59 Power consumption (kWh) in the second floor of the 1st Junior High School of N. Filadelfeia

Furthermore, it is very interesting to note that in this specific school, there are two power meters installed monitoring different parts of the building. The second meter monitors the first floor of the building, where other students, i.e., ones that did not participate directly to GAIA activities, had classes. For that part of the building, we saw negligible differences in the total yearly consumption of the school (4 kWh for the whole year). However, the overall consumption in the first floor is more than double the one in the second floor, so it constitutes a larger part of the total consumption of the school. In the following figure, we can see the power consumption in the second floor of the school, and we can see that there are months in 2018-19 that exceed the consumption for the respective period in the previous year. From these data, we could argue that GAIA activities, with some probability, could have affected the behaviour of a part of the students for certain periods and this resulted to the reported energy savings in the second floor of the school.



In terms of the cost of the IoT infrastructure in the school, there are two power meters (1 GAIA-based and 1 commercial), 5 environmental monitoring nodes and 2 gateways. Altogether, these have an estimated cost of €1195. Given that the energy savings that we have measured add up to €33,7 per year, this results to a very large period for the payback of the equipment. However, a large part of the cost was taken by the purchase and installation of the commercial power meter used (€426), which could have been skipped completely, since it was used to monitor a part of the building not central to GAIA's activities. This was one of the first installations conducted by the consortium, before having more mature in-house developed solutions to utilize.

Experimental Junior High School of Laggouras, Patras (GR07)

In similar fashion to the school in Nea Filadelfeia, the Experimental Junior High School of Laggouras was one of the most active schools in GAIA during school year 2017-18. However, the school did not conduct structured energy saving activities with their students during 2018-19, although it was one of the schools with the highest participation in the Lab Kit activities and the students had a very high level of familiarity with DIY electronics and robotics. There were 2 meters installed in the school building. Interestingly, one was a GAIA open source hardware meter and the other a commercially available power meter. The GAIA-based meter had an almost 100% availability during the school years 2017-18 and 2018-19, while the commercial closed-source had several connectivity issues that resulted in loss of data over various periods. For this reason, although we saw reductions in energy consumption in both parts of the building that GAIA monitored, we report here only the ones for the part for which we have more detailed data. In the following figure, we display these data.

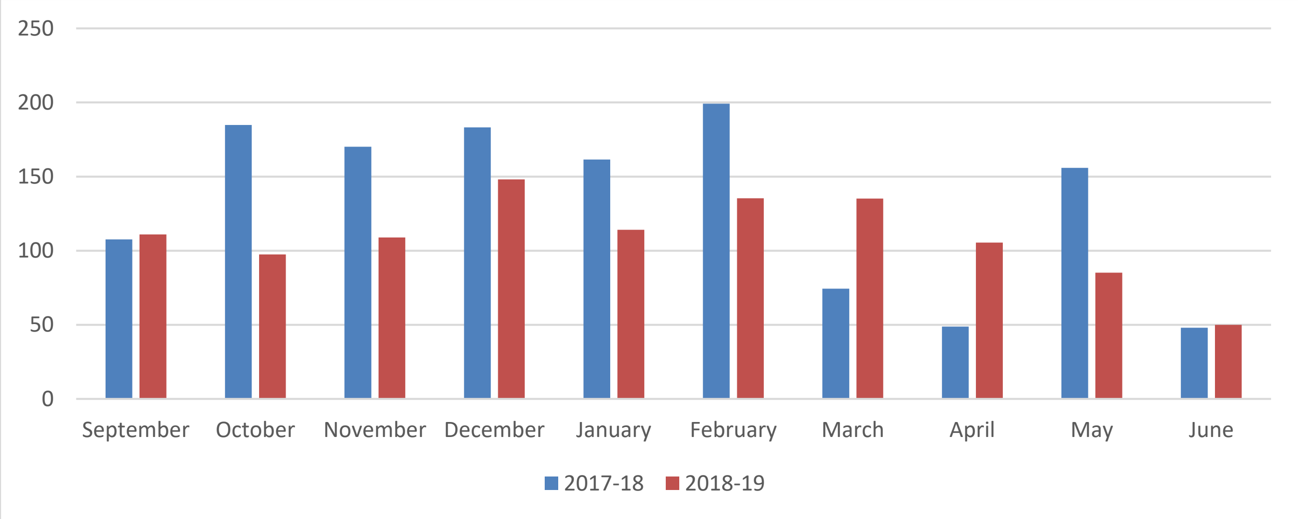
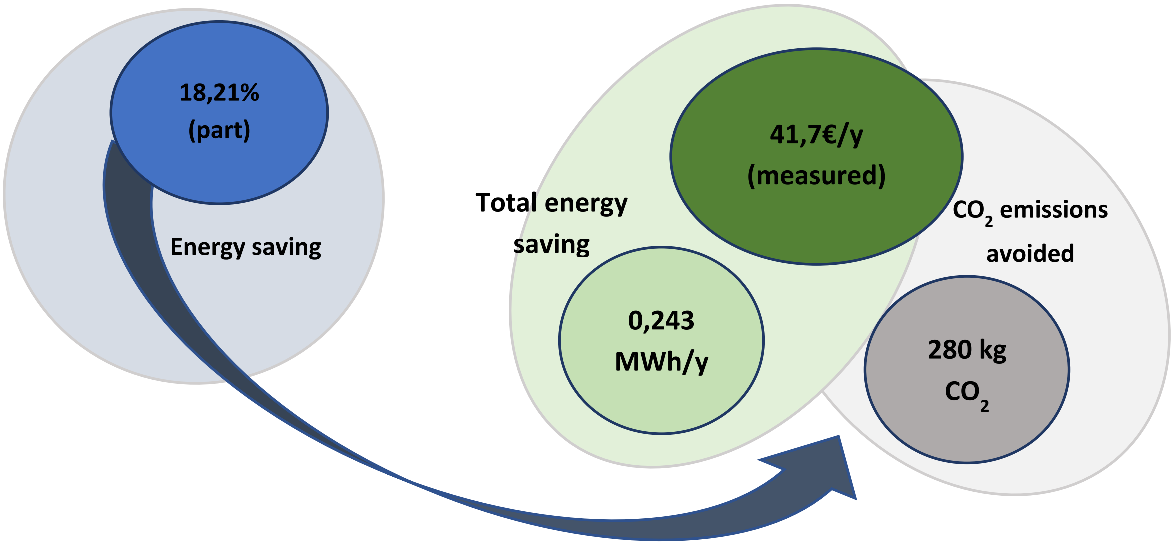


Figure 60 Power consumption (kWh) at part of the Experimental Junior High School of Laggouras

Overall, in the figure above we see that there was a 18,21% of energy savings between the two consecutive years. We also see that for some months (March and April), the consumption is higher than the previous year, but the difference for the rest of the months results to this number of savings. Again, since the school has not produced a detailed log of activities it is difficult to attribute these savings to specific student actions, but there is an evident long-term positive change in the power consumption of that part of the school. For the part of the building for which we have partial data, we also see for some periods similar data. The power consumption on that part is almost 6 times greater; for September 2018, on the first part we have a total power consumption of 111 kWh, while on the second part it is 572 kWh, according to the available data.



With respect to the installation in the school, there are 2 power meters, 6 environmental monitoring nodes and a weather station. Having in mind that the overall cost for an installation in terms of hardware with current GAIA hardware is close to 1300 euros, the installation will be repaid in a very long period. However, a large part of this sum was due to the commercial power meter and gateway used (550 euros). If we had instead utilized a GAIA meter, the cost in that case would be around €860. Similarly, if we included a projection for the whole building, the yearly savings would be several times greater than the 41,7 euros we observed.

Analysis of the effect of other processes on energy consumption in Greek Schools

In this section, we attempt an analysis of the effect of other processes on the energy consumption of a number of schools in Greece, in order to give a picture of the current situation in such schools. In the following table, we summarize energy consumption in 7 schools and compare between working hours, evening and nighttime. It is evident that in all schools the percentage of power consumed outside lecture time is significant, and in certain schools it is evident that it dominates the overall power consumption. This is more highlighted in the example of the 8th Junior High School of Patras.

Table 4 Sample results showcasing power consumption in several schools in Greece during different parts of the day

School	Working Hours	Consumption during working hours	Evening Hours	Consumption during evening hours	Night Hours	Consumption during night hours
Primary School of Megisti	08:00-14:00	58.5%	14:00 – 20:00	27.98%	20:00-08:00	11.92%
Primary School of Lygia	08:00-14:00	31.01%	14:00 – 20:00	15.64%	20:00-08:00	49.42%
1st Primary School of N. Psychiko	08:00-16:00	46.45%	16:00 – 20:00	16.38%	20:00-08:00	30.16%
46th Primary School of Patras	08:00-16:00	51.12%	16:00 – 20:00	10.45%	20:00-08:00	34.33%
8th Junior High School of Korydallos	08:00-15:00	57.23%	15:00 – 20:00	14.26%	20:00-08:00	22.69%
Experimental Junior High School of the University of Patras	08:00-14:00	43.52%	15:00 – 20:00	16.02%	20:00-08:00	35.76%
8th Junior High School of Patras	08:00-14:00	20.35%	14:00 – 20:00	34.53%	20:00-08:00	41.95%

We now proceed with a brief analysis of our data, in order to give insights to how this distribution of power consumption to different categories can be justified, and what kinds of external processes influence the respective data.

8th Junior High School of Patras (GR03)

This school is a characteristic example of issues that could complicate the operation of schools in Greece, and are still present mostly in Greek major cities, due to lack of space and available public buildings to host schools. The school building is shared with another technical school that operates in the late evening hours. Although the second school has much less students and occupies less than half of the rooms occupied in the morning, it still has higher peak consumption, due to technical educational activities taking place, that use electromechanical equipment. In Figure 61, we see the chart of the overall power consumption of the school, with comments on the activity performed inside the building. It is clear that there is high power consumption almost for 20 hours per day, with only during the period between 14:00 and 18:00 being relatively low. During the night, the building has a lot of external lighting turned on, which consumes a lot of power.

	Monday	Tuesday	Wednesday	Thursday	Friday	Weekends
8:15-9:00	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	-
9:00-10:50	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	-
10:00-10:45	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	-
11:00-11:40	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	-
11:50-12:30	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	-
12:35-13:15	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	9-10 classrooms	-
13:20-14:00	9-10 classrooms	-	9-10 classrooms	-	-	-
18:00-19:00	4 classrooms	4 classrooms	4 classrooms	4 classrooms	4 classrooms	-
19:00-20:00	4 classrooms	4 classrooms	4 classrooms	4 classrooms	4 classrooms	-
20:00-21:00	4 classrooms	4 classrooms	4 classrooms	4 classrooms	4 classrooms	-
21:00-22:00	4 classrooms	4 classrooms	4 classrooms	4 classrooms	4 classrooms	-
22:00-22:30	2 classrooms	2 classrooms	2 classrooms	2 classrooms	2 classrooms	-

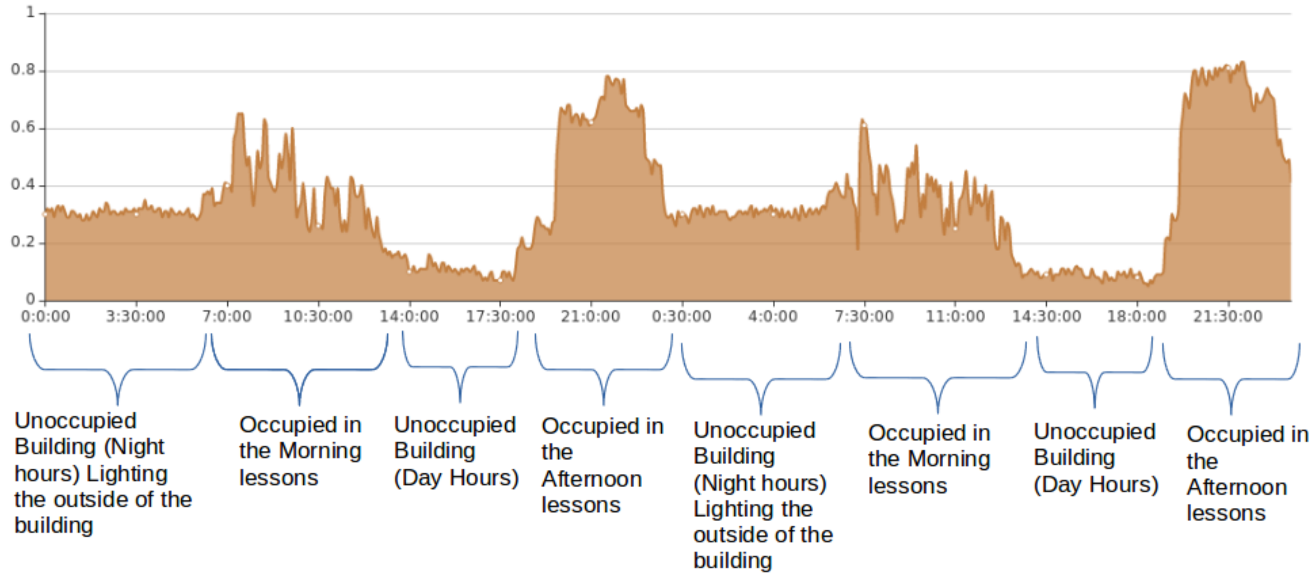


Figure 61 Period from Monday (1/4/2019) to Tuesday (2/4/2019)

Continuing with power consumption during weekends, depicted in Figure 62, it is clear that external lighting dominates power consumption. There is a baseline power consumption present as well, but the lighting is almost double the rest of this type of consumption. The school has been informed of the issues in its power consumption profile.

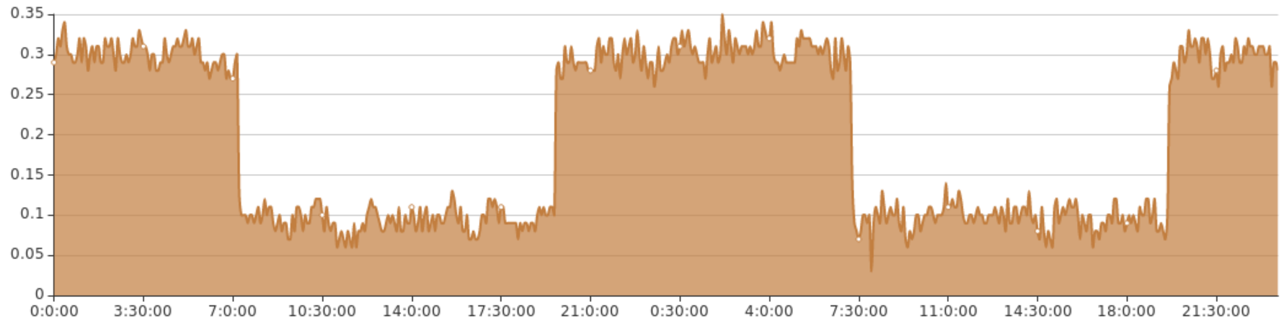


Figure 62 Period from Saturday (6/4/2019) to Sunday (7/4/2019

46th Primary School of Patras (GR10)

We move on to the next school, the general schedule of which is included in the following table:

1st lecture period (1st lecture hour 45'- 2nd lecture hour 40')	08:10-09:40
2nd lecture period	10:00-11:30
5η lecture hour	11.45-12.25
6η lecture hour (End of the main schedule)	12.35-13.15
1st hour of the whole-day school programme, dining and rest	13.20-14.00 (rooms 2,3,4)
2nd hour of the programme, study and preparation for tomorrow's lecture	14.15-15.00 (rooms 2,3,4)
3rd hour	15.15-16.00 (rooms 2,3,4)
** additional hour every Friday	17:00-19:00 (rooms 3,4,5,6) & room 5 until 20:00

During working hours, we see that there is a reasonable power consumption profile, with the data following the hours during which the building is occupied as expected. However, when we move to the period after 13:20, we start to see a pattern in power consumption that fluctuates a lot, and is relatively high. The power consumption that we see in Figure 63 is possibly due to the big fridge that school uses for keeping the children's lunch served, while there is also the power consumption by the ovens used to heat it. The fluctuations in power consumption in the afternoon and evening hours can be attributed to these appliances.

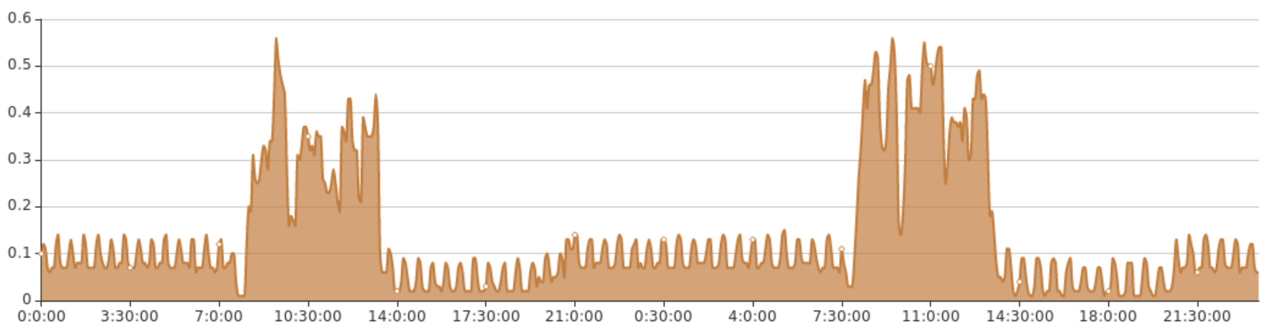


Figure 63 Period from Monday (1/4/2019) to Tuesday (2/4/2019)

When we move to the weekend, we see there is a clear effect of the external lighting in the school during night hours, which more than doubles the power consumption of the building throughout the day.

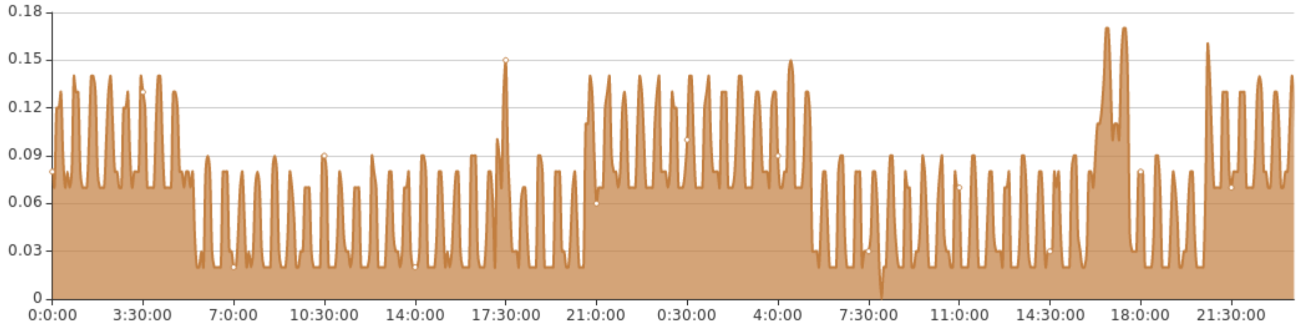


Figure 64 Period from Saturday (6/4/2019) to Sunday (7/4/2019)

In the following figure, it is also evident that the power consumption is tangibly affected by the extra class hours on Friday afternoon and evening.

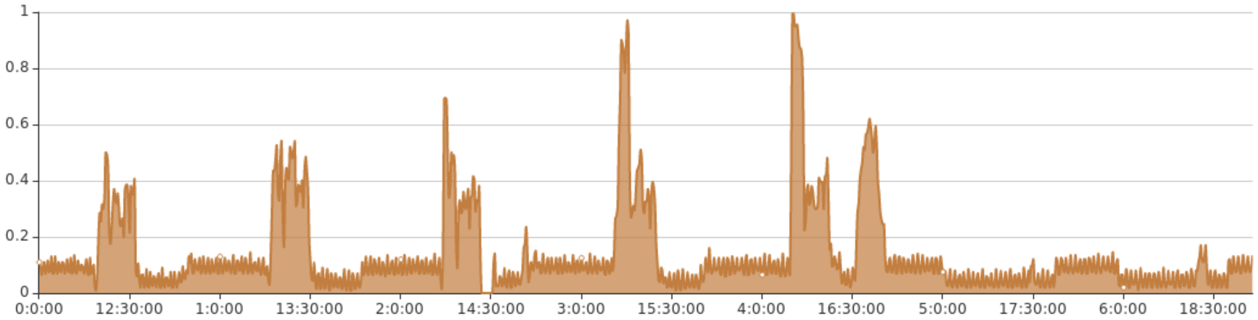


Figure 65 Period from Monday (1/4/2019) to Sunday (7/4/2019)

Experimental Junior High School University Patras (GR23)

The experimental Junior High School of the University of Patras follows a straightforward schedule, with the majority of its rooms occupied every day from 8:00 am to 13:45pm, and some rooms used between 13:45 and 14:45. The building is relatively new in comparison with the majority of school buildings in Greece. Overall, the power consumption data reveal what we expect from a typical school schedule, with no major surprises.

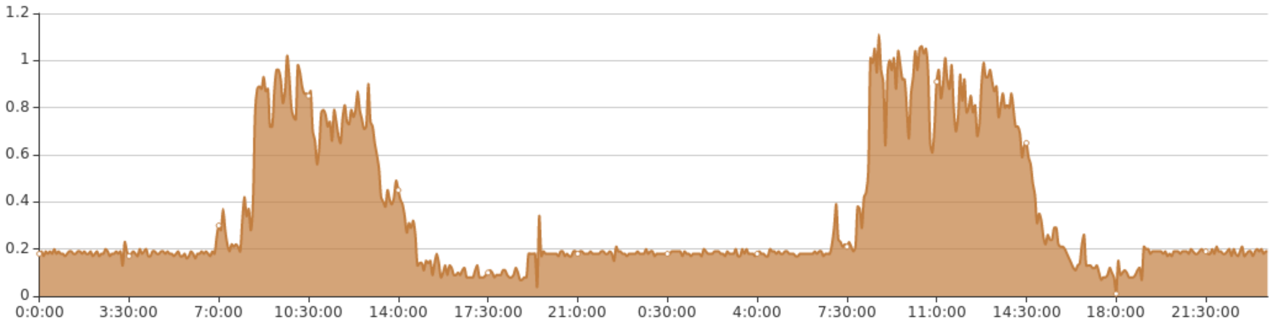


Figure 66 Period from Monday (1/4/2019) to Tuesday (2/4/2019)

In Figure 67, we can clearly the effect of external lighting of the school during nighttime. The figures displayed here are for weekends, so no activity takes place inside the building, and we can see very clearly what the effect is when night lights turn on. The power consumption doubles in comparison to the rest of the day.

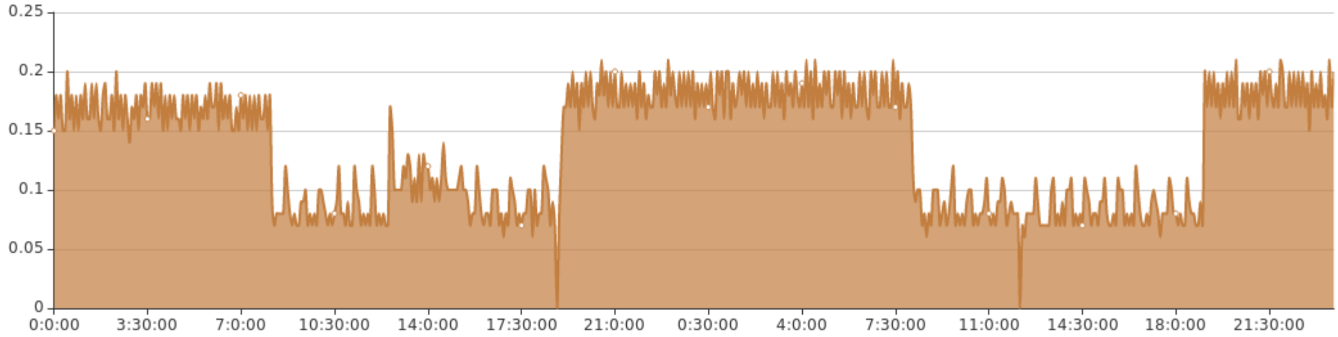


Figure 67 Period from Saturday (6/4/2019) to Sunday (7/4/2019)

Junior High School of Pentavryssos, Kastoria (GR06)

Moving on to the Junior High School of Pentavryssos, we also see a power consumption chart without any major surprises. The school does not use outside lighting during night hours, since there are big light poles from the neighboring areas (a football field and a gym). The power consumption follows the schedule of the lectures, from 8:00 until 14:15 in the afternoon. There is some fluctuation in the power consumption that could be attributed to turning off lights and appliances during break time. There is however a measurable power consumption throughout the day, that is almost 20% of the peak consumption of the school, i.e., it is quite high and can be further improved.

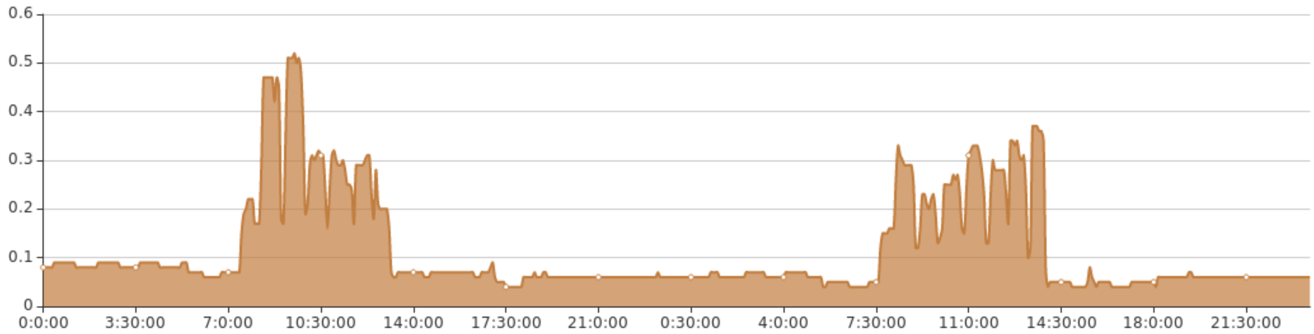


Figure 68 Period from Monday (1/4/2019) to Tuesday (2/4/2019)

Primary School of Lygia, Lefkada (GR04)

The class schedule of the Primary School of Lygia follows the typical time schedule of primary schools in Greece, with working hours between 8:00 and 13:15. There are no external group activities taking place at the building outside of class hours. Overall, during daytime the power consumption graph presents no surprises, generally following the class schedule and having a higher power consumption during early morning hours. This power consumption could be attributed to the canteen of the school, which during those exact hours is using ovens to bake certain items.

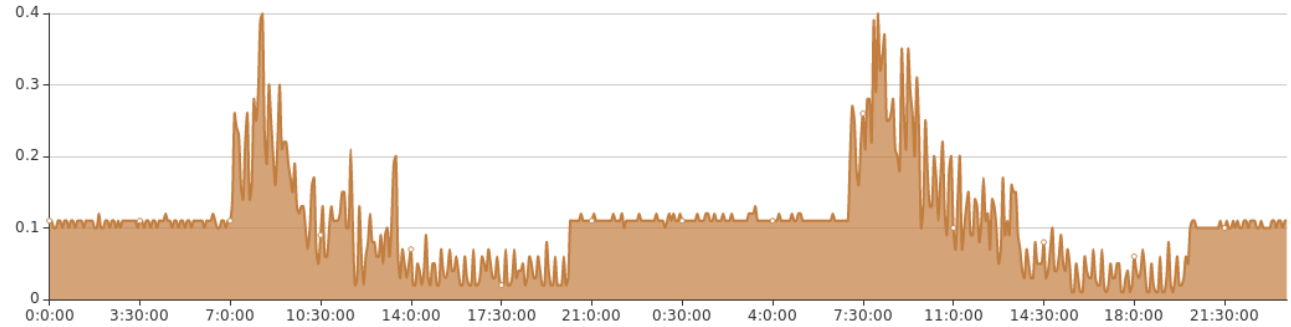


Figure 69 Period: Monday (1/4/2019) to Tuesday (2/4/2019)

On Figure 70, we can clearly see the effect of external lighting during the night hours. This school is another characteristic example of the school buildings in Greece where their lights are used in the nights, because there is not sufficient lighting in the area. This in practice translates to the power consumption during nighttime essentially surpassing the consumption during daytime. Moreover, from our experience in most such cases the lights used are not energy-efficient. The school themselves also have limited access to funding to replace such lights, or the procedure to realize such an initiative may be complicated.

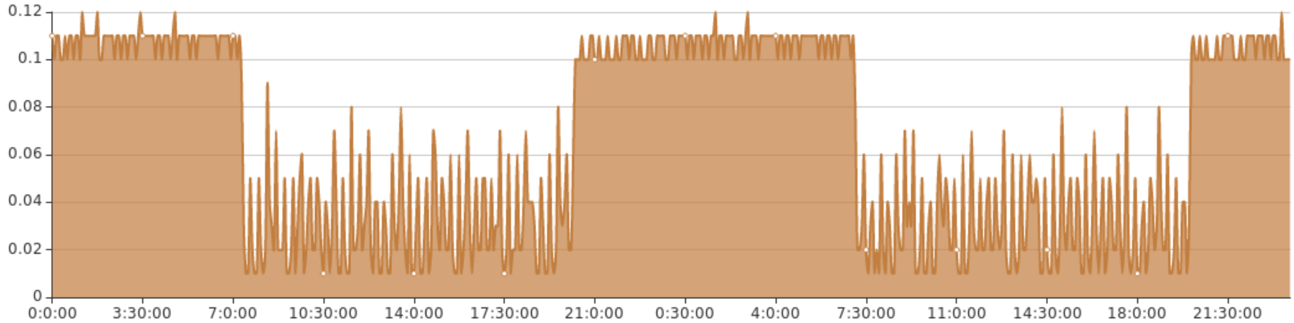


Figure 70 Period from Saturday (6/4/2019) to Sunday (7/4/2019)

Primary School of Megisti, Kastelorizo (GR05)

The primary school of Megisti at Kastelorizo also has a normal educational schedule, with class hours between 8:00 and 13:30. The power consumption follows occupation by the students and the teacher. We also see that it is one of the very few school buildings in GAIA that has very little power consumption when the school is closed, because it does not have external lights during nighttime.

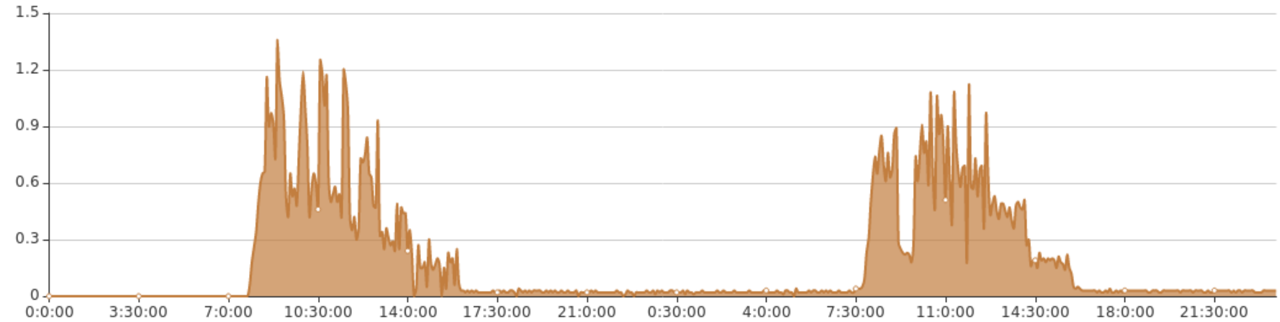


Figure 71 Period from Monday (1/4/2019) to Tuesday (2/4/2019)

11. Analysis of indoor conditions in GAIA schools

In this chapter, we provide a brief analysis of indoor conditions in GAIA schools. It is important to note that although the schools were interested in the thermal comfort aspects of the project, and in generally were quite aware that there could be problems detected by the GAIA infrastructure, were not as eager to act on these issues as they were in energy-related aspects. In some cases, this is also because aspects like heating were not under the direct control of the schools themselves, but were administered by external entities, like the municipalities. Nevertheless, generally, in most cases this was due to the fact that schools in all 3 countries have had limited time resources to dedicate to their participation in GAIA.

Thus, when the schools were presented with the choice on what kind of activity to dedicate time to, they chose to focus on energy savings in the vast majority of cases. A number of schools in Greece attempted to look into thermal comfort-related activities, and one school actually did implement a noise levels-focused activity (the Experimental Primary School of the University of Patras). However, in terms of time dedicated to these activities, and in comparison with the energy-focused activities, there was a large difference.

As a side note, the prospective of conducting experiments with noise levels seemed an interesting prospective for both students and teachers. Probably this was because they understood clearly the concepts of low and high noise levels, and that they could affect immediately by shouting or keeping quiet. Therefore, we think that this is an interesting aspect of GAIA's results, which should be further investigated in the future.

Thermal Comfort analysis

We continue now with an overall presentation of results from the data that we gathered inside GAIA's schools during school year 2018-19. We focused on temperature and relative humidity measurements during two periods, November 2018 – January 2019 (winter) and April – May 2019 (spring) periods of this school year. We include four figures (Figure 72 - Figure 75), that illustrate the percentage of time, during working hours for the schools, in which our readings showed that conditions inside the school were outside of what is considered to be comfortable. In general, we checked against the following constraints:

- Temperature should be between 19 and 28 degrees Celsius (for temperature we allowed some flexibility due to sensors calibration).
- Relative humidity should be between 40 and 60%.

As a general comment, in most of the school a very large percentage of time they do not have indoor conditions that could be considered as comfortable. In fact, at a number of schools, especially during winter, there is almost constantly too much humidity combined with low temperatures.

In contrast to this, there are some schools that almost never stepped into the territory of uncomfortable conditions, like Staffangymnasiet in Söderhamn, which has less than 1% of the time uncomfortable conditions with respect to temperature, or EA, which follows closely. However, it is also evident that Staffangymnasiet does not follow suit in terms of humidity. We have also witnessed some limited cases of temperatures over the comfortable limit during winter, as well as many instances of temperature below comfortable levels in Greece during spring. This could partially be attributed to the fact that Greece had this year an unusually cold and rainy period.

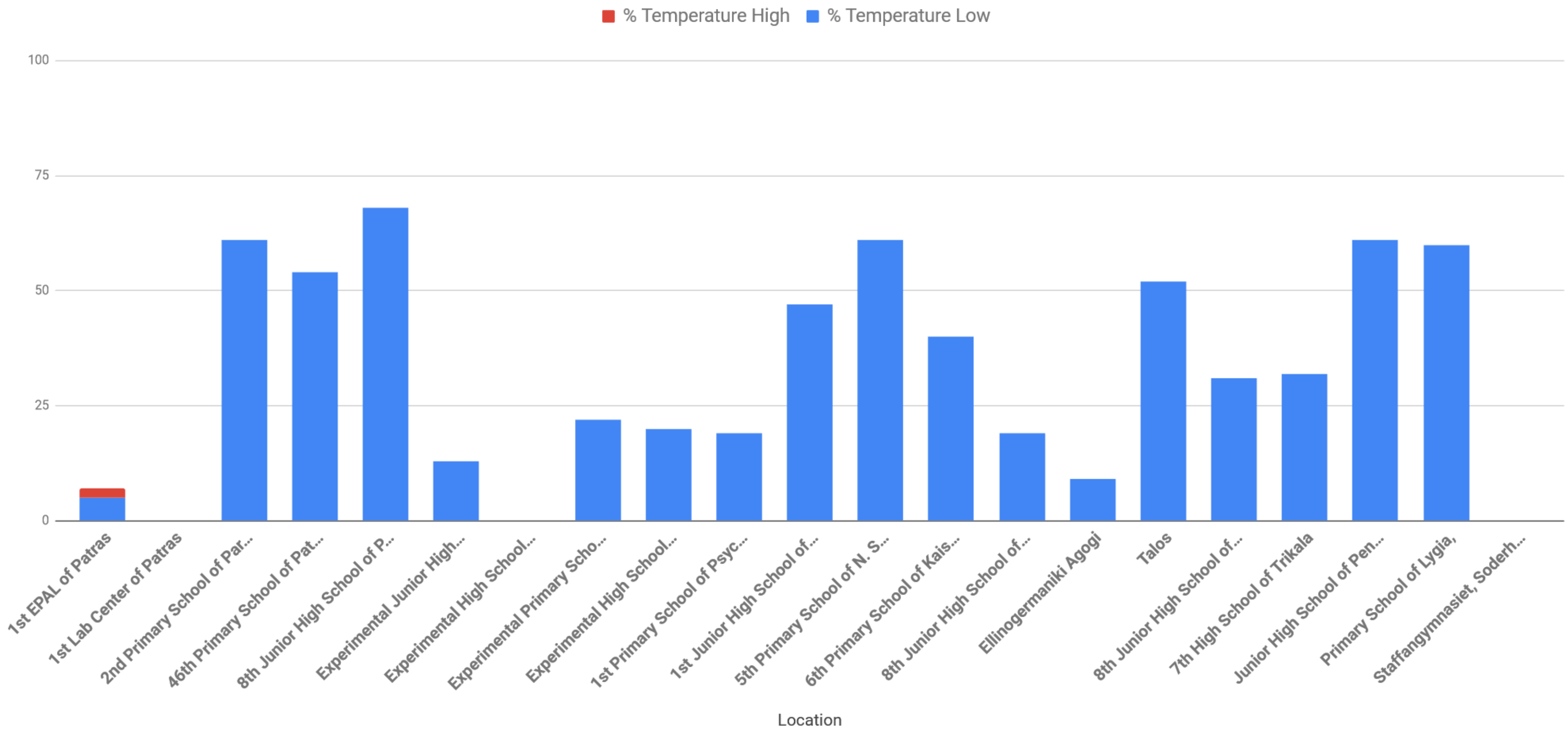


Figure 72 Percentage of time in which temperature was outside of standard levels during winter 2018-19

In the figure above, we see that there are several schools in Greece that have serious issues with temperature during wintertime. This is also observed in schools in both urban and rural areas, thus it is a matter of the building's construction mostly. The "coldest" building is the one in Pentavrysso, which is located at one of the coldest areas in Greece. We also see that the 1st EPAL in Patras, had the exact opposite problem for a small percentage of time, i.e., it was too warm inside the classrooms. On Söderhamn, we note that almost 100% of the time the temperature is within comfortable limits.

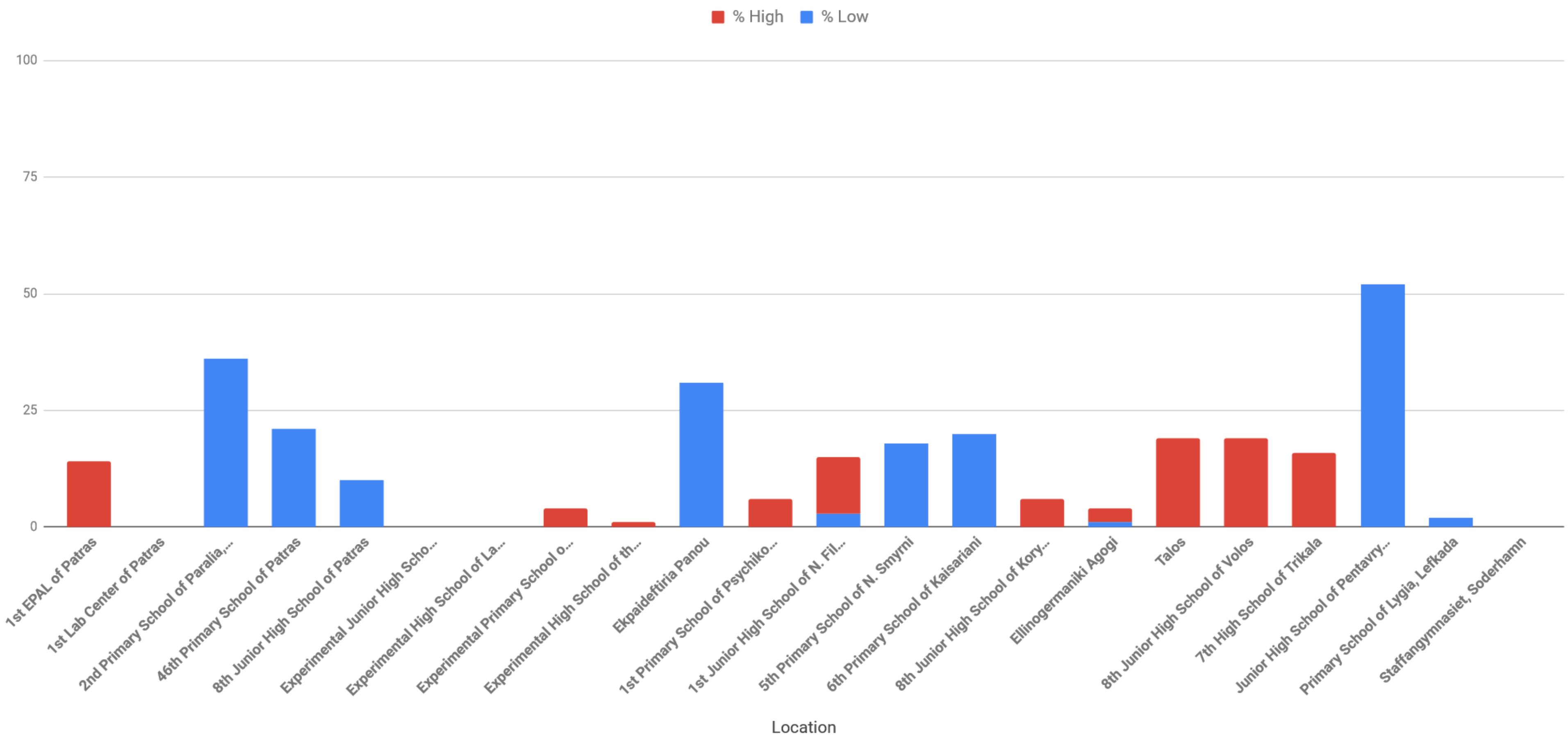


Figure 73 Percentage of time in which temperature was outside of standard levels during spring 2018-19

During spring, the picture is completely reversed; most of the schools have better indoor conditions, with respect to temperature, with again some schools exhibiting low temperatures. Some other schools exhibit high temperatures although such conditions appear at a much lower rate than winter.

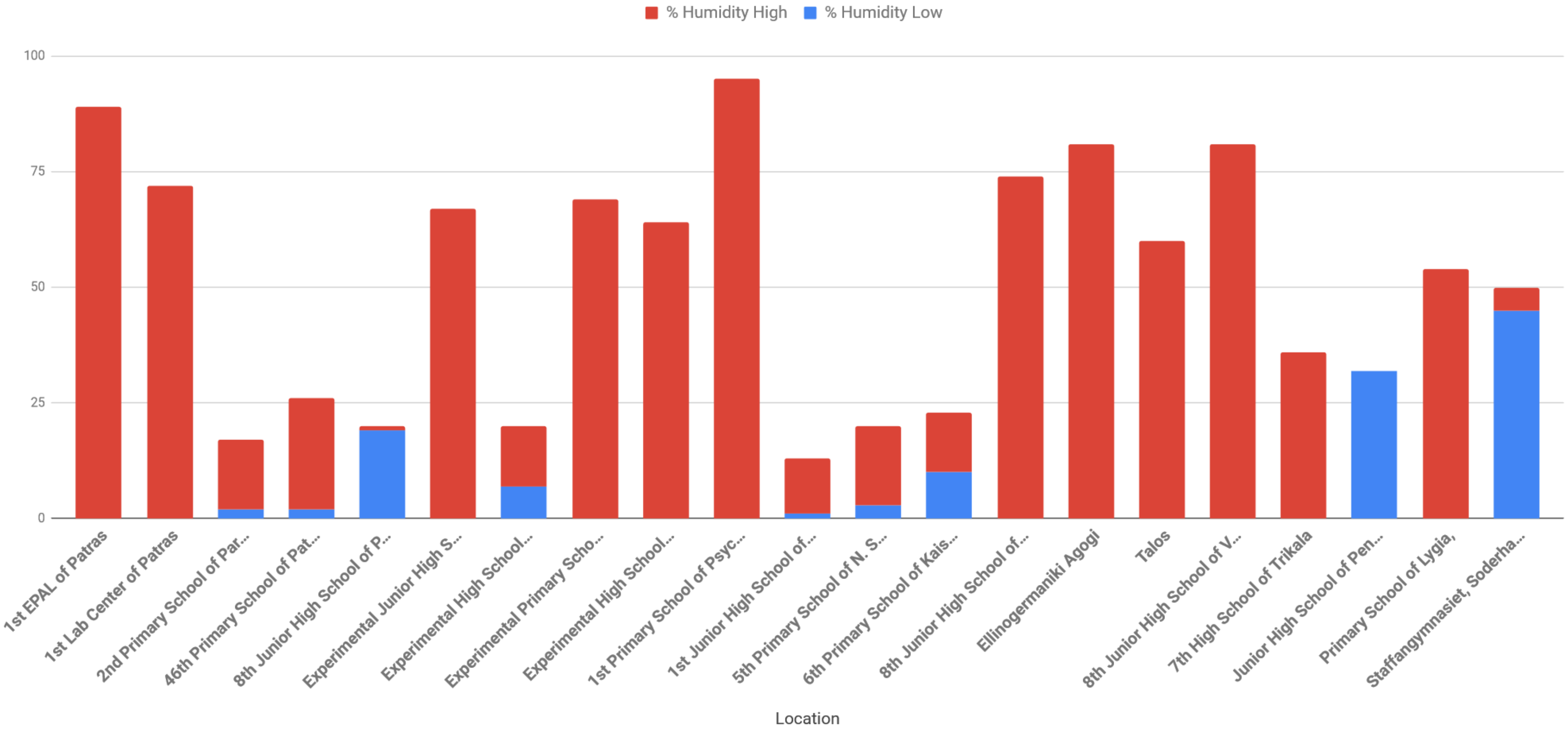


Figure 74 Percentage of time in which humidity was outside of standard levels during winter 2018-19

Moving on to relative humidity during winter, we see that all schools exhibit very high humidity values, regardless of their location. There were some schools, like Staffangymnasiet and Pentavrysso, which exhibit low humidity levels (below 40%). This figure is consistent with the one about temperature during winter and verifies the poor insulation of many of the school buildings, although the issues here are not as pronounced, i.e., the percentage of time outside of comfortable levels is lower.

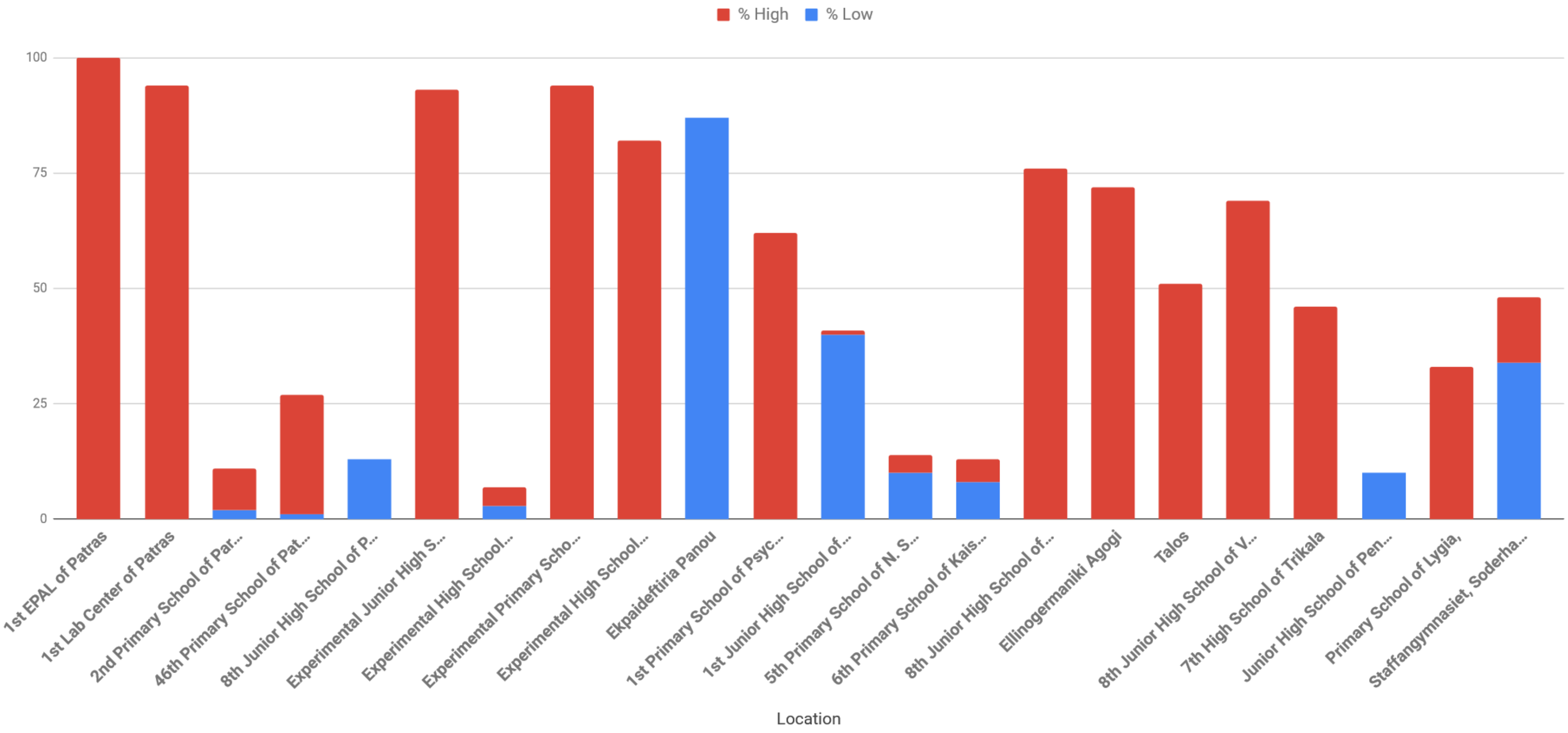


Figure 75 Percentage of time in which humidity was outside of standard levels during spring 2018-19

Finally, relative humidity during spring shows a similar picture. Again, we should mention that this spring was an unusually and humid period for Greece, and especially for Western Greece. There were also schools that had levels of humidity below 40%. In contrast, some schools in the area of Patras exhibit levels of humidity above 60% during almost 100% of this period. E.g., the three experimental schools of the University of Patras, which are located in the same area, exhibit a common picture.

Noise levels analysis

In this section, we present some results with respect to noise levels inside 4 schools in Greece, with 3 of them being primary schools and 1 a Junior High school. In these schools, we installed, along with more typical environmental sensors, nodes with digital noise level meters. These nodes have been calibrated to a certain degree before installation. They essentially calculate the average noise level every 5 minutes, and then report this numbers to GAIA's cloud infrastructure. In the following table, we present our results for multiple rooms in each school that represent the percentage of working hours in these schools in which the noise levels exceed 40, 50, 60, 70, 80 and 85 dBA.

School	Room	% > 40dBA	% > 50dBA	% > 60dBA	% > 70dBA	% > 80dBA	% > 85dBA	Time period
1st Primary School of Psychiko	103	35.55%	27.26%	22.49%	18.62%	3.65%	0.28%	08:00-16:00
	105	42.86%	37.23%	28.7%	8.43%	0.97%	0.02%	08:00-16:00
	E	48.32%	41.29%	32.09%	8.14%	0.16%	0.00%	08:00-16:00
	203	44.15%	33.13%	27.47%	7.41%	0.86%	0.16%	08:00-16:00
46th Primary School of Patras	E1	67.82%	48.53%	38.31%	16.89%	5.77%	2.72%	08:00-16:00
	E2	28.04%	0.0%	0.0%	0.0%	0.0%	0.00%	08:00-16:00
	ST1	13.21%	0.21%	0.0%	0.0%	0.0%	0.00%	08:00-16:00
	ST2	20.2%	0.3%	0.02%	0.0%	0.0%	0.00%	08:00-16:00
8th Junior High School of Patras	2	55.04%	50.2%	42.01%	22.84%	2.19%	0.31%	08:00-14:00
	I1	53.75%	46.91%	38.15%	20.62%	3.63%	0.89%	08:00-14:00
	1	46.49%	35.22%	22.26%	3.29%	0.0%	0.00%	08:00-14:00
	B2	84.63%	46.89%	38.65%	27.01%	5.9%	1.95%	08:00-14:00
	Ground	10.22%	0.02%	0.0%	0.0%	0.0%	0.00%	08:00-14:00
Primary School of Lygia	A	77.76%	62.47%	51.48%	28.72%	2.12%	0.31%	08:00-14:00
	B	76.9%	48.32%	39.89%	17.53%	0.47%	0.03%	08:00-14:00
	C	79.36%	49.56%	41.42%	24.81%	1.65%	0.23%	08:00-14:00
	D	70.19%	50.97%	41.23%	18.56%	1.05%	0.07%	08:00-14:00
	E	54.06%	46.98%	36.94%	9.08%	0.14%	0.00%	08:00-14:00

The World Health Organization and the European Union have made public a set of guidelines with respect to noise. The most well-known of these guidelines is the one suggesting that people should not be exposed to noise above 85dbA for over 8 hours. However, for children this is closer to 70dbA, and there are guidelines for schools that state that noise inside schools should not exceed 40dBA.

From our readings, we can see that in some schools even the threshold of 85dBA is reached, although not for long periods. However, as we lower the threshold, we see that average values rise very quickly. There are rooms in these schools where there is noise above 70dBA for more than 1 hour. This issue requires further investigation and actions to inform students, teachers and the public about the dangers involved in such high levels of noise.

12. Evaluation of the Building Manager Application

In this chapter, we provide an evaluation of the Building Manager Application (BMA). Upon the completion of the GAIA project and the trials undertaken at the participating schools in particular, we were able to offer a final analysis on the usability of the GAIA BMA platform. The platform and the accompanying mobile applications were created to aid the building managers in evaluating their energy consumption and better allocating the corresponding resources in their schools. In most schools, the role of the building manager is performed by the headmaster. As the project progressed, we realized offering access to the teachers and even the students to the BMA will add value to their educational experience.

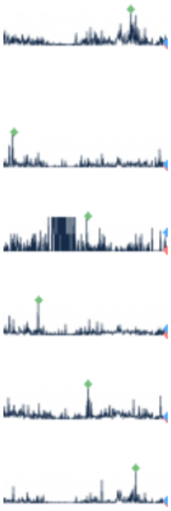
Given the above, we can proceed with presenting the metrics of the evolution of the use of the BMS tool throughout the project lifetime. We focus on two different periods:

- The first one covers the project lifetime.
- The other covers the trials (M24-M40).

The total registered users to the BMA platform to date are 254 individual accounts. Given the number of the participating schools and observing the user profiles, it is obvious that not only the building managers registered but also a significant number of teachers and many students as well. Therefore, our goal in attracting different groups of users has been effectively achieved.

The most important statistics on the visits to the platform are presented in the figures that follow:

Figure 76 Visits overview during the project lifetime



2,121 visits

9 min 40s average visit duration

10% visits have bounced (left the website after one page)

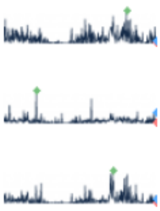
18.1 actions (page views, downloads, outlinks and internal site searches) per visit

0.23s average generation time

34,448 pageviews, **6,046** unique pageviews

Figure 77 Visits overview during the trials period

It is obvious that most visits of the platform occurred during the trial period, while the average duration and actions taken declare that meaningful tasks were being performed during those visits. Most of those were of course visits by users returning to accomplish a task. Most returning visits in both observed periods were executed in consecutive days, showing the true engagement of the users.

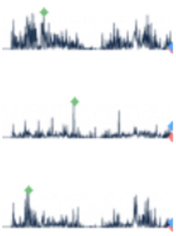


1,519 returning visits

18.4 actions per returning visit

27,959 actions by the returning visits

Figure 78 User engagement during the project lifetime



2,314 returning visits

17.7 actions per returning visit

40,950 actions by the returning visits

Figure 79 User engagement during the trials period

DAYS SINCE LAST VISIT ▲		VISITS
New visits	25.5%	792
0 days	74.3%	2,307
1 day	.2%	5
2 days	0%	-
3 days	0%	-
4 days	0%	-
5 days	0%	-
6 days	0%	-
7 days	0%	-
8-14 days	0%	-
15-30 days	0.1%	2

'0 days' represents 74.3% of 3106 Visits with Days since last visit.

Figure 80 Visits by days since last visit

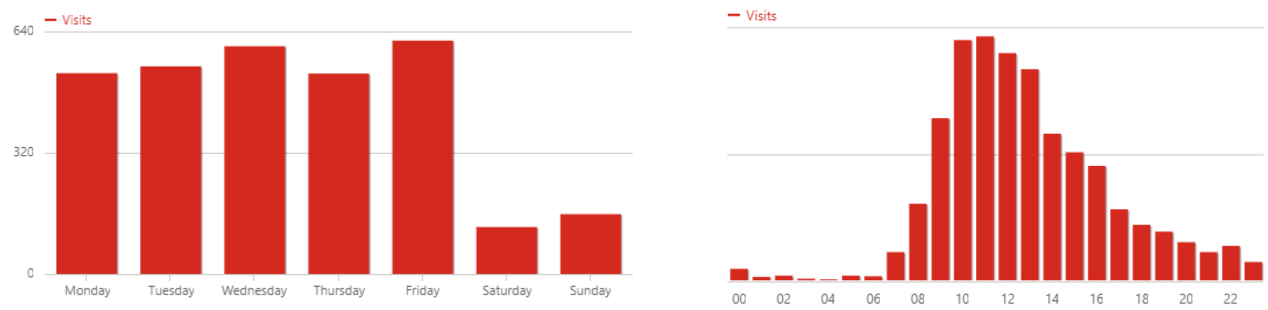


Figure 81 Visitation days and hours (local time) throughout the project lifetime

The platform was especially frequented during school days and hours as was the expected result:

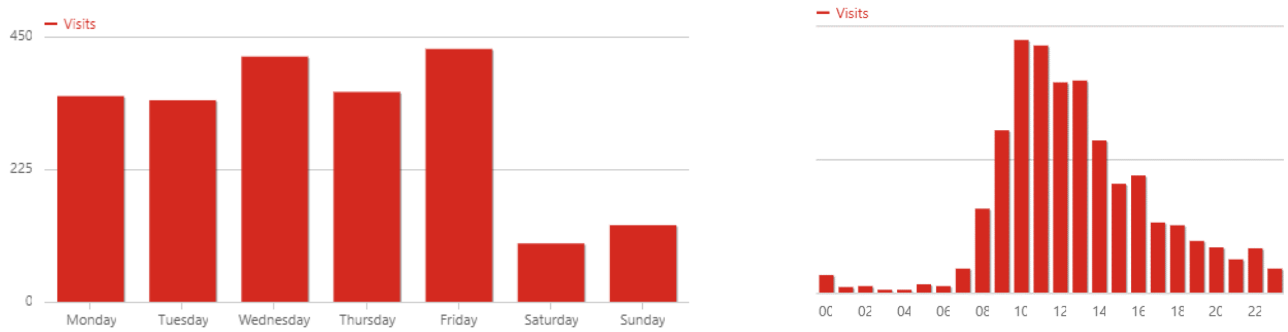


Figure 82 Visitation days and hours (local time) during the trials period

It is interesting to note however, that there is access to the BMA beyond school hours and even during weekends. During the trial period, the most visited and "eventful" pages are depicted below:

PAGE TITLE	PAGEVIEWS
GAIA - Building Manager	9,600
Buildings	12,474
Building View	3,754
Sensors	4,506
Areas	1,548
Authorization	249
Anomalies	654
TopView	287
Notifications	255
Site Comparison	212
Multiple Resources Chart	270
Different Schools Comparison	168
Multiple Sensors Comparison	148

Figure 83 Pages visited during the trial period

EVENT CATEGORY	▼ EVENTS
⊞ Building	2,891
⊞ Compare	426
⊞ VirtualSensor	396
⊞ Sensor	127
⊞ Different Schools comparison	99
⊞ RuleEngine	23
⊞ Area	16

Figure 84 Event categories during the trial period

We can deduct from the above figures that the most used tools of the BMA platform are the user dashboard and sensor overview where the user can see the overall condition of the building and the specific measurements for each area carrying sensors. The next most important tool is the comparison tool, which compares values in the same or different buildings. On the other hand, the rules feature seems not to have attracted so much attention as was initially expected. On another note, during the project lifetime the device most used to access the platform is the desktop computer followed by the smartphone:

TYPE	VISITS
Desktop	2,658
Smartphone	402
Tablet	25
Phablet	21

Figure 85 Device used to access the BMA

In conclusion, the statistics and metrics on the platform use indicate that BMA has successfully achieved the goals it set out to accomplish, offering the necessary tools for building management and educational purposes. However, the final version of the system seems to carry an abundance of features, of which not all are essential in an educational environment. Therefore,

13. Evaluation of the GAIA Challenge

GAIA Challenge is GAIA's online playful introduction to sustainability and energy saving, aimed mostly at the students in the schools that participate in the project. The challenge utilizes gamification mechanics to motivate participants to engage in energy saving topics by collaboratively working on online "quests" and participating in real-life activities. Moreover, students experience their impact on the facilities' energy consumption over the course of the challenge, while also competing and comparing against other classes and schools in other countries. The Challenge was one of the first software components to be released by the project, and its successful implementation has helped the rest of the project considerably.

We include in the following table some representative KPIs for the Challenge to show its progress from the numbers reported in D4.2, up until the end of the trials period (May 2019).

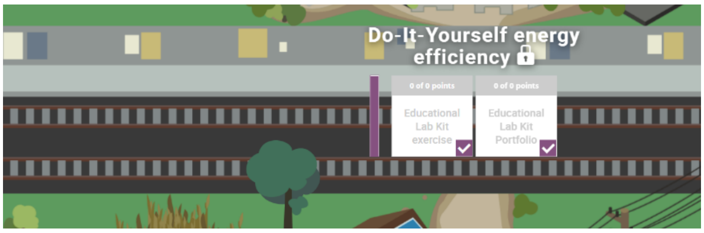
KPI	**Overall GAIA Target**	**Oct-Nov 2017 (GAIA Challenge only)**	**Result at the end of trials (GAIA Challenge only)**
Time spent using the Web portal (GB.1)	7-10h for all WP3 applications combined	52 min is the average total time spent by registered users	44 minutes for all registered users, estimated at 180 minutes for users that started at least one mission
Registered Users on Gaia Challenge (GB.2)	30% of 6.900 for *all* GAIA applications combined	319	3777
Unique visits / Sessions per user (GB.3)	30 sessions per user for all WP3 applications combined	1.015 unique visits 831 visits by users 2.5 sessions per user	12.157 unique visits 9.532 visits by users 2,97 sessions per user 3,08 sessions per user (incl. Administrators)
Average session duration (GB.4)	5-10 min	17 min, 29 sec	14 min, 11 sec for all registered users, estimated higher for users that started at least one mission

After the activities that tool place during the previous school years, 73 teams appear to be active in the Challenge, with 7 teams achieving a score above 11.200 points (the total of regular points each user can earn). This essentially means that they must have played not just the complete learning part of the challenge, but also achieved big portions of the limited time bonus (there are max. 3.780 bonus points). The actual number of active users is lesser than the total number of registered users, because we have applied a mechanism in place for auto-deleting inactive users after a period of six months. In other words, a large number of students that participated in the mini trials and during trials in the school 2017-18 were auto-deleted from the Challenge. This is consistent with our ethics and privacy policy, for keeping as little information about the users as possible, and deleting it after the time period which is no longer required.

Learnings from mini trials and school year 2017-18 – Changes and updates to the GAIA Online Challenge

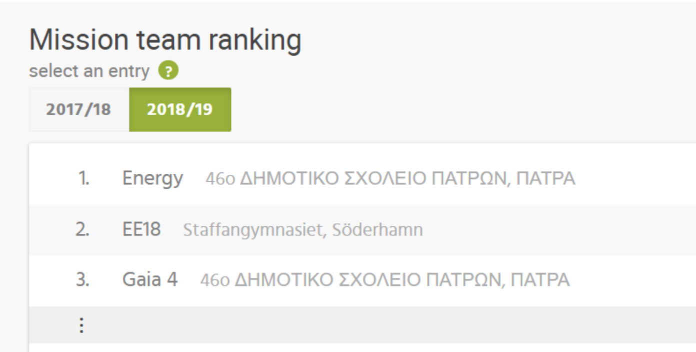
Third action mission

Since the educational lab kit proved to be a very successful concept during the mini trials, we integrated a third action mission, *"DIY energy efficiency"*, in the GAIA Challenge:



Filter School year

We included an additional filter for school year in the Mission team ranking upon request from multiple schools and users. Now, it is much easier to make comparisons between schools in different periods.

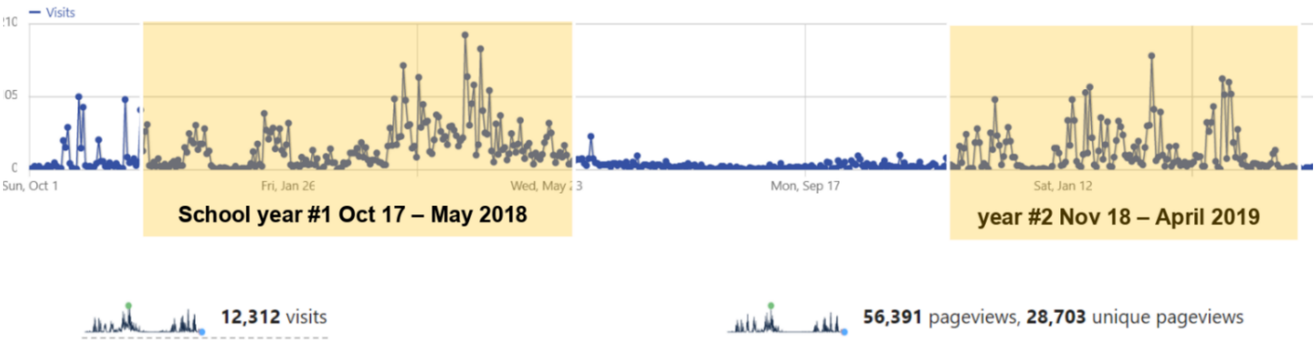


"Certificates" to value high quality portfolios

We had an intense discussion with a school from Prato on how to earn points on the Challenge. A specific teacher (which class put a lot of effort in the Challenge and ranked second) found it not fair that student do not get points for portfolios. After a discussion both with the teacher and at the consortium meeting in Söderhamn we remained firm in our decision not to give points for a portfolio since the portfolios are to be evaluated by the teacher in a qualitative way. However, we introduced a GAIA certificate to help teachers to distinguish and honour good student portfolios.

User statistics for GAIA Challenge

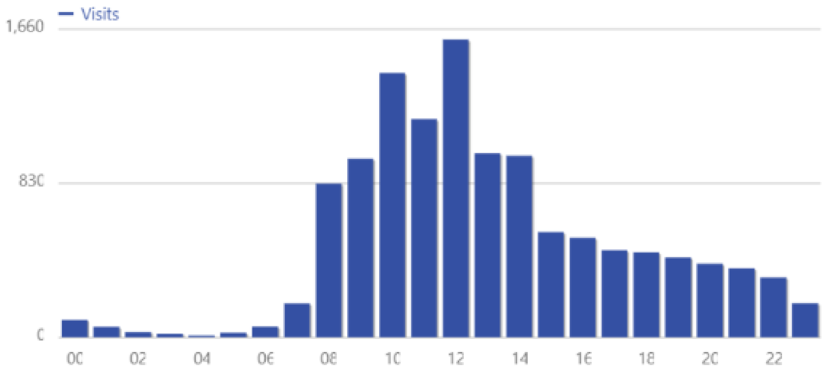
Total visits to GAIA Challenge between October 2017 and April 2019



Total registered users on gaia-challenge.com (as of 31.05.2019)	**3.762**
Active users	**1.747**
Auto-deleted users (users after long periods of inactivity are deleted by default)	**2.015**
Active teachers	**55**
Mission teams	**165**
Portfolios created	**38**
Snapshots created	**788**

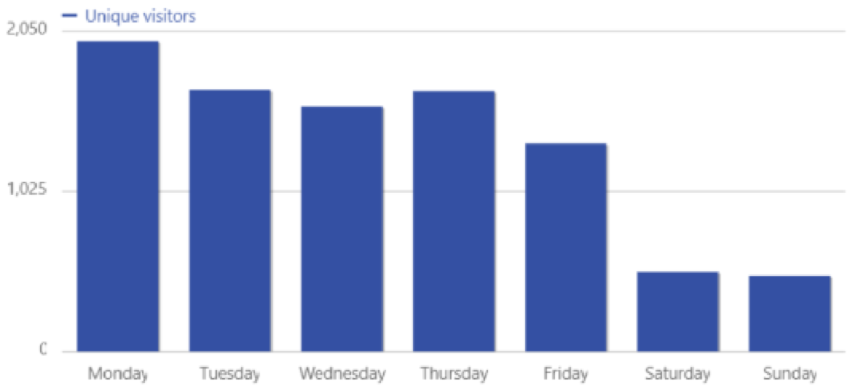
Visits local time

Statistics show that the GAIA Challenge is being played also in the afternoon and even in the evening. This could be because of a flipped classroom setting or, even better, by students continuing to play the Challenge from their homes. In all cases, it seems that the students really liked the Challenge and dedicated serious time in completing its missions.



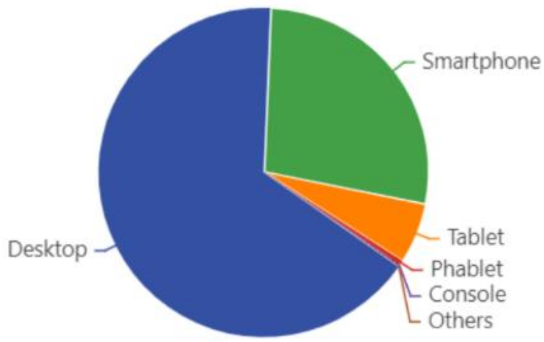
Visits per weekday

Interestingly, 11% of the Challenge visits happen on weekends, which is another indication of the students' overall acceptance of it and their continued engagement.



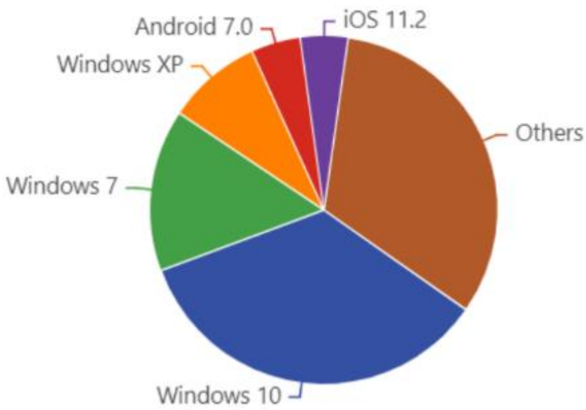
Visits per device

28% of the challenge usage comes from smartphones, although the Challenge was designed mostly for big screens. The vast majority of the visits originates from desktop and laptop computers, which was expected. There is also a sizable part of the visits from tablets.



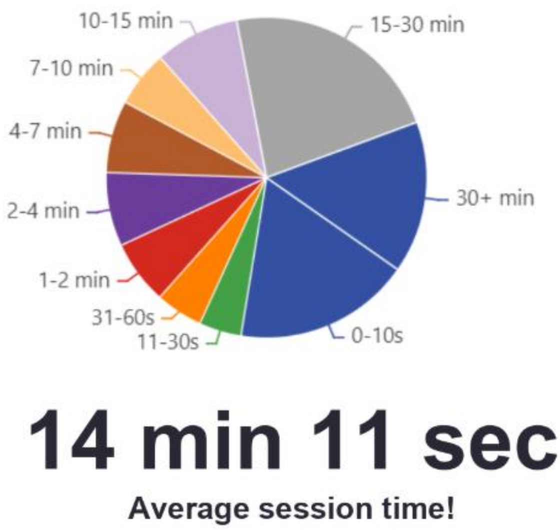
Visits per operating System

No surprises here, apart from the still high spread of Windows XP and Windows 7, which was an observation that we shared from our visits to Greek schools; in many of the schools in Greece the computing infrastructure in laboratories is quite old, although this is an observation that applies to many other countries as well.



Duration per visit

The average session time of all users, including unregistered users, is very high for this sort of application, and in comparison with similar gamified systems.



Visits per location

Most visits come from Greece (5.435) followed by Italy (2.752). In Sweden, we had an issue with monitoring the source location of the visits (presumably with a proxy server). Essentially, visits from Sweden appeared as coming from a number of other countries. Thus, our statistics for visits per city do not include Söderhamn.

City

CITY	VISITS
Unknown	4,849
Athens, Attiki, Greece	2,219
Milan, Lombardia, Italy	558
Thessaloniki, Thessaloniki, Greece	480
Rome, Lazio, Italy	305
Villa D'alme, Lombardia, Italy	194
Karditsa, Kefallinia, Greece	180
Saint Petersburg, Saint Petersburg City, Russia	168
Bilbao, Pais Vasco, Spain	137
Pátra, Akhaia, Greece	134
Bergamo, Lombardia, Italy	115
Florence, Toscana, Italy	114
Nichelino, Piemonte, Italy	111
Vienna, Wien, Austria	111
Capistrano, Calabria, Italy	102
Marousi, Unknown, Greece	90
Bologna, Emilia-Romagna, Italy	84
Vólos, Magnisia, Greece	73

Mission completion rates - October 2017 – April 2019 *(all language versions combined)*

92%

mission completion rate

Mission completion rate of users who have started a mission *at least once* (considering one attempt per user):

- 92,30 % All missions
- 92,67 % Knowledge missions
- 91,68 % Action missions

From this data, it can be concluded that more than 9 out of 10 users who have started a mission also have completed it at least once.

Mission completion rate of *all users* (considering max. 1 attempt per user)

- 20,35% All missions
- 31,77% Knowledge missions
- 1,32 % Action missions

Mission Statistics

From our statistics, we found that in the GAIA Challenge there have been **22.429 started tasks altogether**, thus far. The breakdown into the statistics for each knowledge and action mission is included in the following two tables. As a reminder, each mission has two tasks. A player can open a task multiple times, e.g., in order to improve mission completion statistics.

Knowledge Missions		
Mission name	**Tasks in mission**	**Tasks started count**
So, what's the challenge?	Let's GAIA!	8688
	Let's stay on this planet!	
Turn me off unless you need me! - I	Light in the dark - I	4320
	Light in the dark - II	
Turn me off unless you need me! - II	Sleeping demons - I	3395
	Sleeping demons - II	
What a school atmosphere! - I	Hot or cold? - I	3098
	Hot or cold? - II	
What a school atmosphere! - II	Building smartness - I	2360
	Building smartness - II	
Action Missions		
Mission name	**Tasks in mission**	**Tasks started count**
Let's act for energy efficiency! - I	Observe, experiment, act!	421
	Let's 'wake up' the locals!	
Let's act for energy efficiency! - II	Observe, experiment, act!	87
	Let's 'wake up' the locals!	
Do-It-Yourself energy efficiency	Educational Lab Kit exercise	60
	Educational Lab Kit portfolio	

The tasks in Action Missions can be started only by players, granted the Action Mission has been started beforehand by a Teacher for the Player's Mission Team. Not many users have started/opened the contents of Action Missions in the Challenge. There are multiple reasons for this:

- Not all players are part of a Mission Team.
- Not all teachers have started Action Missions for their Mission Teams.
- Some students might have worked on Action Missions together in groups.

Discussion about our findings

Overall, the GAIA Challenge has proved to be an overly successful component of the GAIA toolset and the project's trials implementation strategy. The fact that we have had 3777 registered users by the end of the project, gives both a clear indication of the Challenge's success, as well as of the overall effort dedicated by the consortium partners required to support such a large end-user group in the other parts of GAIA.

An excellent result is the average session duration being above 14 minutes throughout the trials period. This shows that the challenge worked well from both an engagement level as well as a technical point of view. The actual number is considerably higher, because this has taken into account all users. Furthermore, this highlighted the fact that if there were many bugs or issues with playing the Challenge, more early exits would result in a considerably lower average session time.

Anecdotally, from our face-to-face interaction with teachers and students during the trials, they have:

- Praised its overall design approach and simplicity.
- Noticed that the students did not have any major difficulties in using the Challenge, and also that it was very good that the students could use it outside of class hours, e.g., from their homes, due to lack of time to dedicate to this activity. In other words.
- Praised its capacity as a short introduction to sustainability and energy matters, especially for students in primary schools.
- Stated that having the capability to check what the other schools were doing in terms of their score was a major engagement factor for the students.
- The schools and the teachers in general were very supportive of our decision to keep as little information about the students as possible for the Challenge, upholding the privacy aspects of the project.

14. The GAIA Contests

The GAIA consortium held two contests during the trials period of the project: the first one was held in spring 2018, publicly announced on April 2018, while the second one was held on spring 2019, publicly announced on March 2019. In both cases, the contests were announced to schools several weeks before their public announcement, and discussed during the organizational and educational workshops that preceded these announcements on the project website. We envisioned the contests as a means to engage more actively with the schools during educational and energy-saving activities, giving some additional incentives to students, classes and schools as a whole to compete with each other. For more detailed information about the announcements of the contests and the winners, the reader can visit the project website pages containing the respective information, like the following:

- http://gaia-project.eu/index.php/en/2018/04/17/contest-1-show-us-the-improvement-of-your-gaia-class/
- http://gaia-project.eu/index.php/en/2018/06/08/gaia-contests-results/
- http://gaia-project.eu/index.php/en/2019/03/15/announcement-gaia-contest/
- http://gaia-project.eu/index.php/en/2019/05/06/we-are-pleased-to-announce-the-results-of-the-2019-gaia-contests/

We continue with a more detailed description of the two contests.

GAIA Contest 2018

Organization of a contest with four categories (announced on April 2018): three pan-European quests for all participating schools and one national contest only targeting the educators from the Greek schools participating in the project.

Category	Description	Participation
1st category: Show us the improvement of your GAIA class!	School classes (students and teachers) had to present activities already done for energy reduction in their class.	7 Submissions 5 schools awarded
2nd category: Share your GAIA ideas for your next school year!	School classes (students and teachers) had to present their ideas of how they will use GAIA tools in the next school year	5 Submissions 1 school awarded
3rd category: Build your GAIA Challenge portfolio!	Best portfolio in GAIA Challenge	6 Submissions 4 schools awarded
4th category: Be an ambassador for GAIA at Ellinogermaniki Agogi Summer school 2018!	Submission of the best educational scenario (only for teachers)	2 Submissions 1 school awarded

A number of representative videos with the contest winners are available on the YouTube channel of GAIA.




GAIA Contest 2019

A contest with three categories was announced for spring 2019 with three pan-European quests for all participating schools, in order to take place simultaneously with the main trials of the project and help to increase the overall engagement of the schools and the students. Since we had the experience of the first contest, we decided give more weight to the first contest category, in which schools competed for the best result in terms of energy savings within their school building.

CONTEST 1: Show us the improvement of your GAIA class!

WHAT YOU HAVE TO DO:
School classes (students and teachers) will have to present activities already done for reduction of energy consumption in their class.

HOW TO DO IT:
Write a short report (we would love to also receive Videos in addition to the report) with the improvement activities you have performed to achieve energy reduction. Present how you come up with the need (preferably based on the BMS data observed), what did you do and how you assess the outcome (if possible with BMS data).

CONTEST 2: Share your GAIA ideas!

WHAT YOU HAVE TO DO:
School classes (students and teachers) will present their ideas of how they will use and exploit GAIA tools and experience, in the future.

HOW TO DO IT:
Write a report (preferable with a presentation (in power point) /or video) with your ideas of how GAIA tools (GAIA Challenge, GAIA BMS) and the GAIA lab kit can be effectively further used and exploited in your school in the near future (e.g. next school year)

CONTEST 3: Build your GAIA challenge's portfolio!

WHAT YOU HAVE TO DO:
You have to enrich your portfolio in GAIA Challenge.

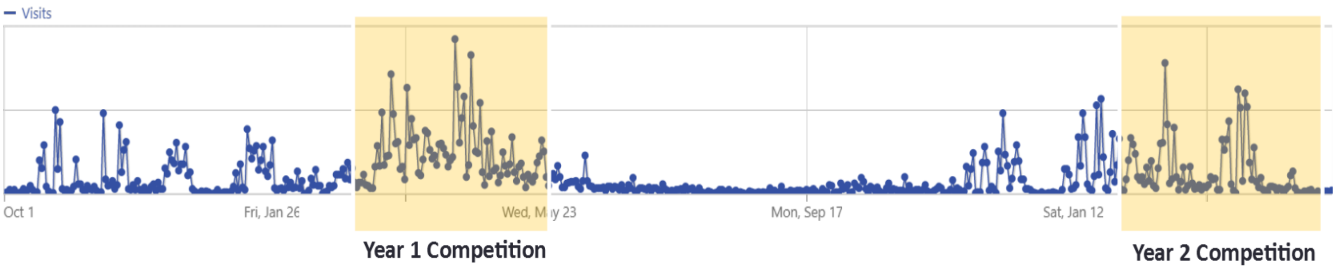
HOW TO DO IT: Go to the GAIA challenge and use all of the available functionalities of the game (upload instances, upload videos, reports and images during the action missions) aiming at enriching your portfolio.

Overall, 10 schools from Greece and Italy participated in the 2019 contest:

- The Experimental Primary School of Patras,
- the 6th Primary School of Kaisariani in Athens,
- the Gramsci Keynes School in Prato,
- the 7th High School of Trikala,
- the 3rd High School of Nea Fladelfia in Athens,
- the 8th Junior High School of Koridallos in Athens,
- the 1st Primary School of Psichiko in Athens,
- the 46th Primary School of Patras,
- the Junior High School of Pentavrisos in Kastoria, and
- the Primary School of Megisti in Kastelorizo.

In terms of submissions to the second contest, the schools had an additional reason to use the GAIA methodology for reporting their results, because it could be submitted, with only a small number of modifications, as their entry for the contest. We have seen in practice that this approach worked quite well, with a number of schools combining their planning for executing their energy-saving strategies in parallel with their activities for the contest.

Discussion of the GAIA contests' effect on the trials



On the figure we above, we are highlighting the effect of running the two GAIA contests with respect to visits to the GAIA Challenge portal during the contests period. This period also coincides with the main trial activities, so it is reasonable to expect that overall would be in any case much higher. However, it is also evident that right after the announcement of the contests, there are sudden spikes in the overall activity. This, to a certain extent, verifies our own experience in terms of interaction with the schools:

- There were many inquiries by the teachers regarding the contests, even before their public announcement, since the schools had already been informed about their forthcoming announcement.
- There were, naturally, additional inquiries from the schools regarding the announcement of the contests' results.
- Empirically, we can say that this was an additional means to make schools in GAIA aware of each other; e.g., we had inquiries from schools in different countries about their respective scores. E.g., one such question was "how is it possible that school X has a higher score than us".
- We can also say that it helped teachers give a very specific goal to their students and engage them to participate in energy saving activities.

Another interesting remark is that students did not necessarily go for the "big" prizes; e.g., in the first contest there were awards for schools like a tablet, or a Raspberry Pi sensor kit, to be handed to the winning class. In practice, we saw that students and teachers were much interested in getting a "recognition", as also noted in the chapter for the GAIA Challenge in this deliverable. After witnessing such behavior, we decided to change the type of awards for the second contest and organize the awards procedure in a more "publicized" manner, in order for the schools and the students to be able to show to their peers their achievements. Overall, we can safely say that the use of the contests as a tool to increase the engagement of the students and the teachers paid off in a very substantial manner for GAIA.

15. The Educational Lab Kit Activities during Trials

Overview of the Lab Kit Activities and educational material

As mentioned in Chapter 2 of this document, there have been two "rounds" of Lab Kit activities in GAIA schools during school years 2017-18 and 2018-19. In order to implement our strategy for the Lab Kit, GAIA consortium partners visited frequently a number of schools for implementing and monitoring the progress of the respective activities. Through the dedication of consortium members and the implementation of the plan for these activities, **a total number of 916 students participated to Lab Kit activities**. For this to happen, CTI had to:

- Design and implement the Lab Kit briefcase (Figure 87), a portable kit with the required hardware to conduct the Lab activities. For each school, we had multiple copies of this briefcase, which was handed to each of the students conducting each time the activities.
- Plan a schedule for the duration of the school year, in order to plan ahead the visits of the consortium members to the schools, as well as the sharing of the lab briefcases among schools (we had 7 copies of the equipment).
- Continuously monitor the implementation of the activities and update the respective material, in order for it to be suitable for use in educational environments.

In short, we followed a recursive approach to developing the material for the activities, which lead to the production of lab material that has been tested inside very different schools, as well as by very different ages – from primary to high school students. This aspect of the lab kit development cycle can be seen later in this chapter, via our evaluation results: overall, it has received an overwhelmingly positive response by students and educators. In terms of monitoring, we have an approach where we kept a detailed log of our observations, as well as used questionnaires to get feedback directly from our end users.

Although the bulk of the related activities were conducted in Greek schools, the Gramsci Keynes School in Prato also implemented some Lab Kit activities based on material produced by CNIT, in collaboration with the school. In some of the schools in Greece that were located far from Patras and Athens, the lab kit material (in the form of multiple GAIA briefcases) was sent by post.

As a reminder, the kit aims to teach students using a "hands-on" approach, in which they use IoT components and electronics. Based on guides provided by the project, they examine data from their school building and go through the peculiarities of consuming energy, how the building behaves in the various classrooms in terms of environmental parameters, and more. The kit includes already assembled devices and commercial IoT sensors and actuators to allow students complete classes and lab tutorials regarding energy and sustainability, as well as provides guidelines for implementing crowdsensing quests. It also serves as a means of interacting with the project and further increasing the end-user engagement, along with the other tools of GAIA, such as the Challenge and the BMA.

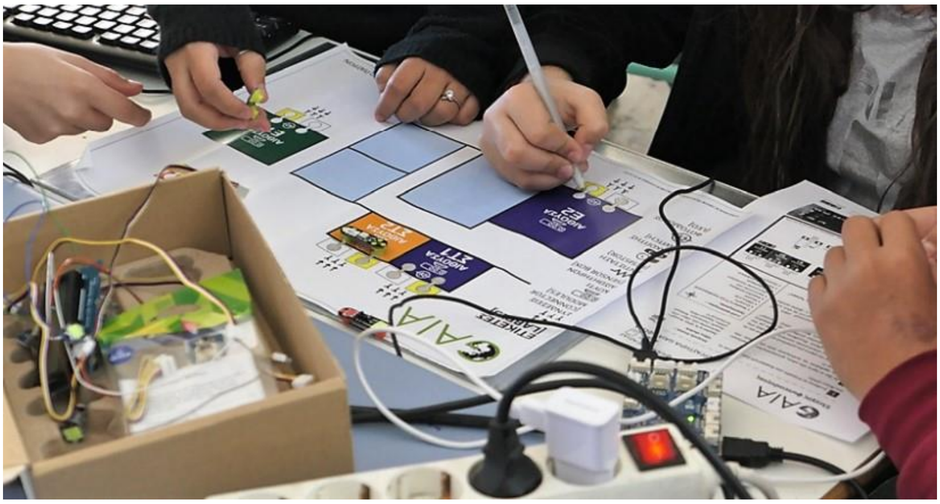


Figure 86 Example of an in-class activity with the Lab Kit. Primary school students use conductive ink to draw circuits on top of a printed floor map of their school.

Figure 87 The GAIA Educational Lab Kit briefcase – this provides a highly portable way to implement the activities in different schools.

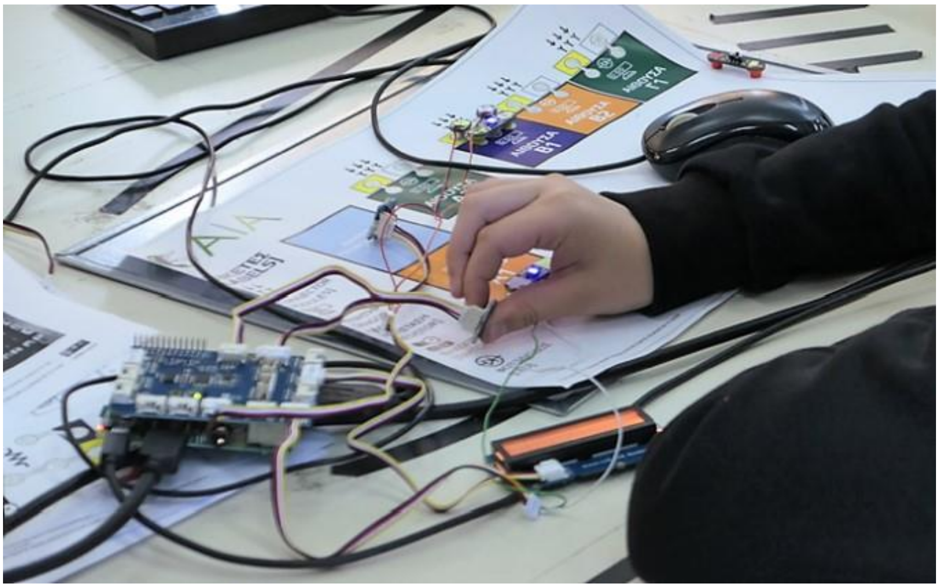


Figure 88 Example of an in-class activity with the Lab kit. A student uses a button to visualize different modes of readings inside his school on LEDs and an LCD screen.

Organization of the Lab Kit activities

Regarding the overall organization of the activities and the provided material, the consortium has prepared a series of lab activities, covering aspects of energy consumption and efficiency inside school buildings. The thematic list covered is the following: a) Energy consumption in our school, b) Lighting inside school buildings, c) Heating inside school buildings, d) Temperature, Humidity and Thermal Comfort, e) Devices and Energy efficiency, and f) Energy Inspectors - The energy footprint of our building. An additional activity can be implemented in case schools would like to implement an interactive installation in the form of a class project by students, in order to depict some kind of energy efficiency metric in its own school building. Regarding the provided material, there are available guides for each activity. In the description of each activity, we include the title of the subject, the necessary cognitive background for the teams (theoretical and practical) and a short description of the tasks to be completed (goal). One set of material concerns the educators, identifying the educational target for each activity, the methods used, as well as a schedule for the proposed lab activity. Another set of material addresses the students' part, giving specific instructions on how to perform the envisioned activities, explaining how to interconnect sensors and electronic components, etc. Difficulty levels are also indicated in the material, with more complex challenges such as coding questions and exercises are available for e.g., high school, or more advanced students).

Evaluation of the Lab Kit activities

In this section, we report on some results we have from the use of the lab kit in schools in Greece. It is important to note that several of the schools participating in the project have educational staff that utilizes, or is comfortable with the use of e.g., Arduino-based activities. However, a large part of the educators and students in GAIA did not have experience with such technologies, as discussed in our survey results. Moreover, in some cases there are educators participating in the project, which do not have a technological background at all. Thus, it is important to stress that the discussion here applies to a diverse set of end-users.

Preliminary evaluation of the lab kit during school year 2017-18

For a preliminary evaluation of the lab kit during the school year 2017-18, we conducted two workshops with two groups of Greek students aged 11-15 years old (primary and secondary school students), including 48 and 58 students in each workshop. The questions asked were the following:

- *Did you have prior experience with electronic circuits before the lab (Y/N)?*
- *Did you face serious difficulty completing the activities during the lab (Y/N)?*
- *Do you think such an activity will help you learn something about your school building and energy consumption (grade 1-5)?*
- *If possible, would you consider repeating similar activities at your home (grade 1-5)?*
- *Did you enjoy the lab activity overall (grade 1-5)?*

With respect to the answers given by the students, there was a very positive response overall. In the first lab, 71% answered that they liked the activity very much (5/5), 23% gave out 4/5, and the rest 3/5. In this case, 58% had some sort of previous contact with electronics, while 87.5% stated that they did not face difficulties during the lab. 98% said that they thought such an activity could help them to learn something about energy in buildings, while 94% said that they would consider doing such an activity at home, if possible. In the second lab, there was some change in terms of positive response, with 58% rating it 5/5, 26% 4/5, and 12 3/5, possibly also reflecting the change of topic for the lab. An 80% stated that they did not face difficulties during the lab, while 96% thought that they learned useful about their building.

Another group, consisting of 7 primary and secondary school teachers in Greece, participated in a daily workshop displaying some sample lab kit activities. After completing the workshop, an evaluation questionnaire was given to them. The questions asked in this group were:

- *Did you find the activity and instructions clear (Y/N)?*
- *Do you believe you could conduct the activities at your school without help from GAIA (Y/N)?*
- *Did you face difficulties in the activities (Y/N)?*
- *Do you believe that students will gain/learn something out of this activity (Y/N)?*

Regarding their answers, five teachers answered that they found the activity and instructions "quite clear", 1 "absolutely clear" and 1 "clear enough". Regarding difficulties faced, only one teacher commented that enough time should be given to complete the activities, depending on the conditions in each school. All teachers answered that they thought that students "could learn something by engaging in such activities".

In addition to the evaluation discussed above, we wanted to investigate overall learning performance outcomes regarding students as well. Given that both teachers and students found the lab activities engaging and useful, the question here is whether these activities contributed to some change in the performance of the students during class in general. With regard to this question, we produced questionnaires and had interviews with 5 teachers from 5 different schools, whose classes participated in the lab activities, over a period of 4 months belonging to the abovementioned student group.

The most substantial question asked was "have you noticed any substantial change with respect to students performance after GAIA activities began?", to which 1 teacher noticed a "mild change" (4), while the 4 others answered with "very significant change" (5), in a scale from 1 to 5. In order to make their answers more specific, we included a free text field for them to fill in. In their free text answers, the teachers who noticed a very significant change noted "positive changes in daily class activity and greater interest towards programming" and that "students who previously were indifferent, now have significant participation during lab activities". In another interesting remark, one teacher noted that "low-performing students had a chance to exhibit their capabilities and receive positive comments from the rest of their class", i.e., this type of students found the activities engaging and easy enough to complete, in comparison with other in-class activities. This kind of detailed remarks help us to identify the strengths and weaknesses of our approach.

In terms of a broader educational setting and contribution to the community, our work can be seen as a verification of the fact that educational activities using IoT hardware and software and that are flexible enough to be combined with the curriculum of each school can produce good results. Moreover, in practice we have seen from our early steps in designing the lab kit that educators can often be indifferent towards educational activities that do not take into account their background, or require them to spend considerable amounts of time to adapt the content to their school's schedule. Having this in mind, we produced content that could be tied together with various classes, is accompanied by educational material and gamification aspects, and also has some tangible goals that can be achieved by students in their own environment, i.e., energy savings. Our initial results verify that this combined approach was received positively by both educators and students.

An interesting observation regarding schools in Greece was that there exist large differences in the kind of experience in maker activities, equipment and educators' backgrounds between schools. Thus, the way that the lab kit is interpreted/received in each school is different. However, even in schools without a "maker" mentality, educators and students welcomed such interventions. In fact, one of the remarks made by the educators was that students that did not exhibit much interest in science classes, during lab kit activities were probably encouraged to participate more actively by the fact that they were able to complete the activities. We also noticed that these students were eager to share this achievement with the rest of their class.

From our experience, the most important issue in this case is to communicate that such activities present an opportunity for educators and schools to integrate new aspects in existing curricula. Another finding that we observed during the lab kit activities was that girls, especially in primary and junior high schools, tended to be more focused than boys in the same class during the kit activities, resulting in them completing the assignments easier and in less time. However, we did not plan to monitor aspects such as this, so this finding is based purely on our own empirical observations during the activities conducted.

In-class evaluation of the Lab Kit during the school year 2018-19

We first describe some more "empirical" monitoring activities related to the lab kit, conducted only in school in Patras, Greece. We monitored the activities in 5 of the GAIA schools in Patras during a series of lab activities in which 84 female and 90 male students participated. We wanted to focus more on questions like what interested the students, or whether female or male students performed better during the lab activities. Students in each school were divided into 5 or 6 groups, depending on their number. The students first chose themselves their team partners. The following time, it was suggested to them who will be their team partners and within which team they will participate. They were divided into same-sex groups as well as mixed teams, usually two boys and two girls in each group. The following general plan was used:

- Visit schools with a 3-member project team (CTI)
- Presentation of the lab activity
- Explanation of teaching goals and tools
- Distribution of educational material
- Explanation of the material
- Processing of the laboratory

During the above process, a member of the training team monitored the interaction of the students' groups with the tools and the educational material. The "observer" intervened where it was needed to facilitate the process. All students, either boys or girls, were provided with the same educational material and the same tools. All observations were recorded in a special form. The educational process was divided into four modules: a) Introduction, b) Luminosity, c) Humidity-Temperature, and d) Energy Consumption. After continuous observation of the teams in each workshop, we found that the majority of the students showed interest and focus in the process. They were listening carefully to the presentation of the material, they were presenting us with interesting questions, which drove to further constructive discussions. During the first workshop and the first contact of the students with the laboratory materials, we noticed a degree of difficulty. The students needed some help and explanation as an introduction to the laboratory material. On the second visit of the group, students had already been acquainted with the laboratory material, and did not seem to have particular difficulty in either the assembly of the material, or the execution of the experiments. The GAIA team was present in the room to answer any question or technical problem they encountered.

During activities, emphasis was placed on observing boys and girls as to their interest in the technological tools and results they obtained. From our experience, they were equally interested and committed to the goal. When teams were segregated in the same gender, we also noticed that there was an "informal" competition between girls and boys about which team would complete the activities first. We also noticed good dynamics within mixed teams, usually divided into two girls and two boys, in which collaboration was noticeable.

It is also worth noting that there have been several cases of students (girls and boys) who have had advanced technical skills for their age, either by means of additional extra-curricular work, or by having a relative in the computer science or programming field. Moreover, some groups observed students who were skeptical about working with the rest of the team, either because they did not understand what they had to do, or because a member of the group had assumed a leading role and prevented their expression. In these cases, we considered it necessary to interfere, as our aim for the workshop was to involve all students without exception. Even in the case of students who did not have earlier technological knowledge (mainly in elementary classes), some basic knowledge necessary for their participation in the workshop was taught on the spot.

Questionnaire-based evaluation of the kit – School year 2018-19

We have conducted a questionnaire-based evaluation of the kit as well. During the school year 2018-19, the consortium partners in Greece have visited a large number of times several schools to implement the Lab Kit activities, together with the educators at those specific schools. There were also two schools that performed such activities on their own, without GAIA members present in the actual lab activities. After each of the lab kit activities, or at a time indicated by the school teachers, the students filled in a questionnaire to evaluate the activities they had just taken part in.

Overall, **we received 778 responses** through this process, with students being able to submit a response after each lab activity, i.e., they could submit a first after completing the first lab activity and a new response after the third one, if they felt inclined to do so. In terms of age groups that submitted responses to this questionnaire, as seen in Figure 89, the vast majority belonged to primary (fifth and sixth graders) and junior high school students (all 3 grades). In general, high schools in Greece have quite tight time schedules, so there was little time available to dedicate to lab activities for GAIA.

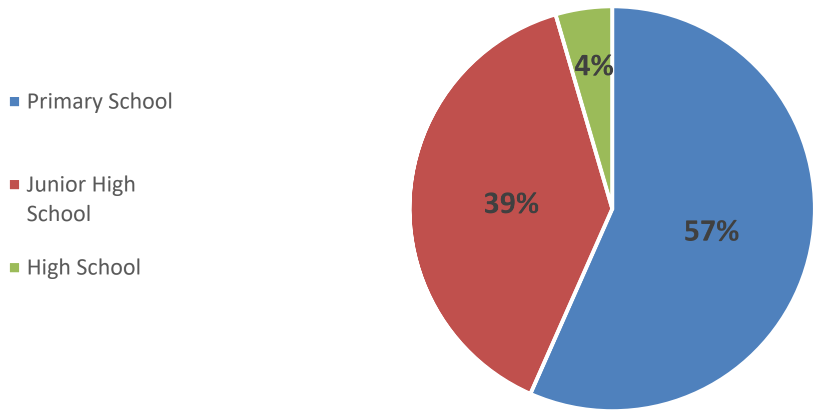


Figure 89 The composition of the age groups of the students that answered the survey

Moving on to the most important question regarding the overall appeal of the Lab Kit, to the question "Did you enjoy the lab kit activities?", we **received an overwhelmingly positive response**, with 76% of the students replying “Much” and “Very much”. An 18% was lukewarm, while 5% said they liked the activities a little and only 1% answered they did not like the lab kit activities at all.

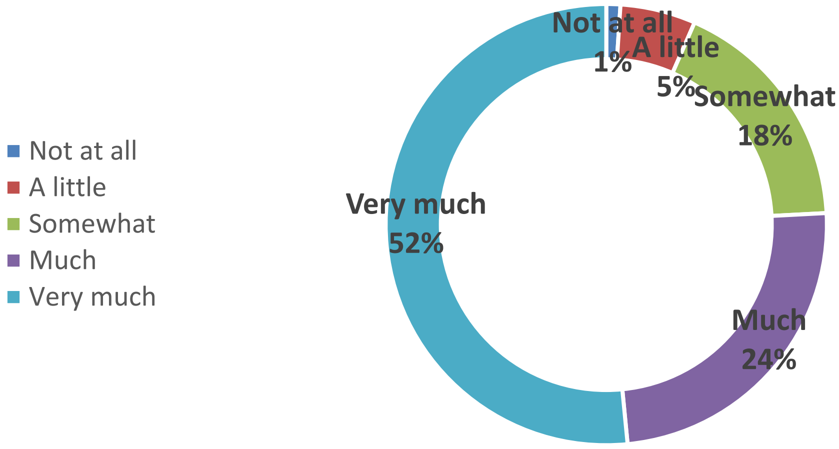
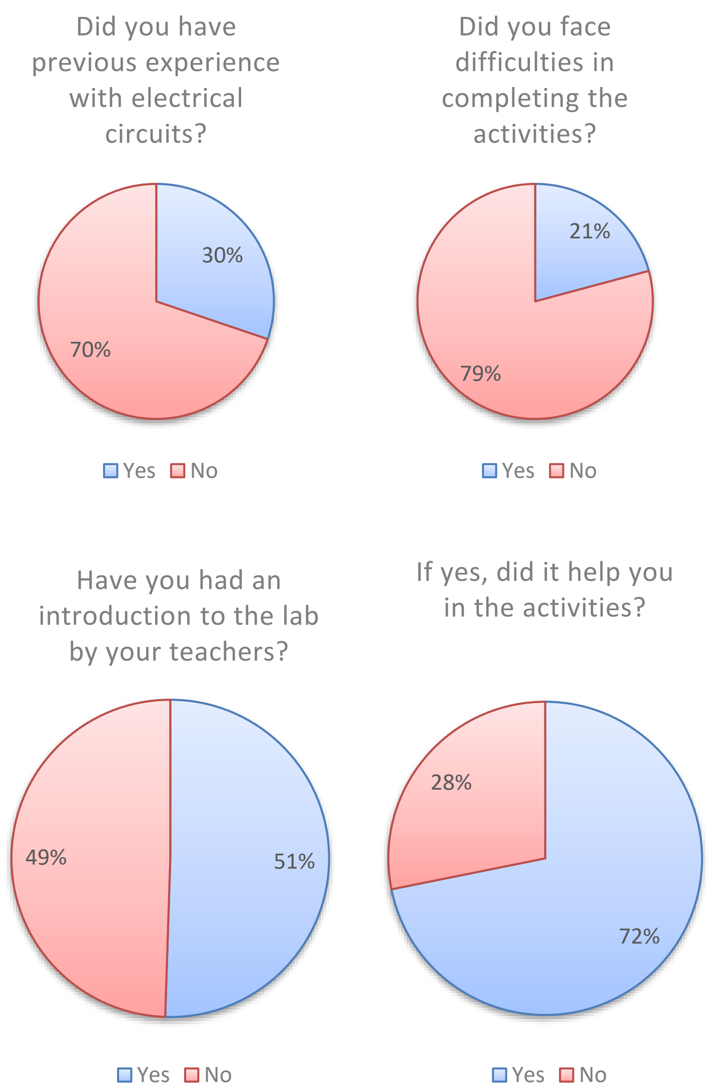


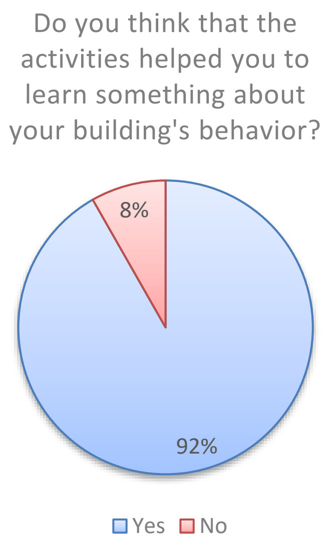
Figure 90 Response of the students to the question "Did you enjoy the lab kit activities?"

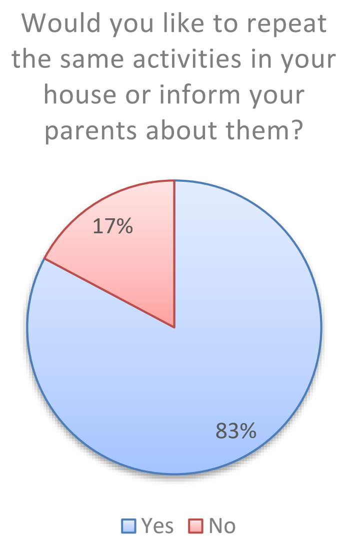
A series of more specific questions followed in the survey, in order to be easier for us to identify certain characteristics about our end-user group. A 30% of the students did have some previous experience with electronics, which although it may sound quite high, it is justified by the nature of the GAIA schools (e.g., the experimental schools in Patras). However, although 70% did not have previous experience with electronics, 79% of our responses indicate that they did not face difficulties in completing the activities, which bodes very well for the level of maturity of the produced GAIA material.

Moreover, we asked the students whether their teachers had done an introduction to the lab activities in previous days, in order to further clarify the level of preparedness of the students for the labs. The responses provided indicate that the situation was divided almost exaclty in half, with 51% having had some introduction and 49% not. Of those students that had an introduction to the lab kit activities, 72% responded that it did help them to complete them, while 28% replied that it did not. This is probably due to the fact that the teachers participating in GAIA had a diverse background as a group, and did not always have a technological background.



The last two important questions asked whether the students throught that the activities helped them to learn something useful regarding their school building's behavior, and whether they would repeat the activities home or tell their parents about them. In both cases, again, we have an **overwhelmingly positive response, with 92% and 83% replying "yes" respectively**.





In terms of shortcomings to this survey activity, we should note that we tried to minimize the time and interaction required by students and educators participating in the activities in order to fill out the questionnaires handed out to them. Therefore, the respective set of questions was rather small, in order to balance out the time spent on the activities and filling out e.g., informed consent documents. Another shortcoming was that a number of educators involved did not have a maker or even a technological background overall.

Discussion of the Lab Kit results

Regarding the overall question whether GAIA's approach can motivate students towards energy-saving activities, we believe that the answer is "yes". In practice, we have seen that the lab kit activities are an efficient engagement mechanism, since the activities span across multiple weeks and gradually introduce students to certain energy-related concepts. Through this procedure and through the GAIA Challenge, we saw good engagement results from both teachers and students. However, we also noticed in some cases a tendency of the educators to perceive these activities as the main part of the energy-saving actions. In other words, it should be made clear to educators that the lab activities are complemented by school-driven actions.

With respect to the question whether the open-source approach followed by GAIA works in practice, the answer is a resounding "yes". The educational community in Europe has embraced the use of open-source platforms like Arduino and they are comfortable with what we use in GAIA's activities. In some cases, schools purchased directly the equipment for the activities themselves, and were able to kickstart the activities with little help from the GAIA team.

Moreover, with respect to the question whether such activities can be successfully integrated within the school curriculum, the answer is again a "yes", but the degree of success in this case depends on the educators' familiarity with the related technologies and the school's overall approach to updating its daily schedule. Although the activities were well-received and educators thought in general that the instructions and lesson plans provided were clear enough to carry them out, scarcity of additional lecture hours and familiarity with existing lesson plans meant that in some cases certain schools decided to dedicate significantly less hours to GAIA-related activities than others.

The Lab Kit Booklet

We have compiled the finalized version of the material related to the educational lab kit in the form of the GAIA 'Lab Kit Booklet'. Regarding the provided material in the booklet, there are available guides for a number of Lab Kit activities. In the description of each activity, we include the title of the subject, the necessary cognitive background for the students' teams (theoretical and practical) and a short description of the tasks to be completed (goals). One set of material concerns the educators, identifying the educational target for each activity, the methods used, as well as a schedule for the proposed lab activity. Another set of material addresses the students' part, giving specific instructions on how to perform the envisioned activities, explaining how to interconnect sensors and electronic components, etc. Difficulty levels are also indicated in the material, with more complex challenges such as coding questions and exercises are available for e.g., high school, or more advanced students).

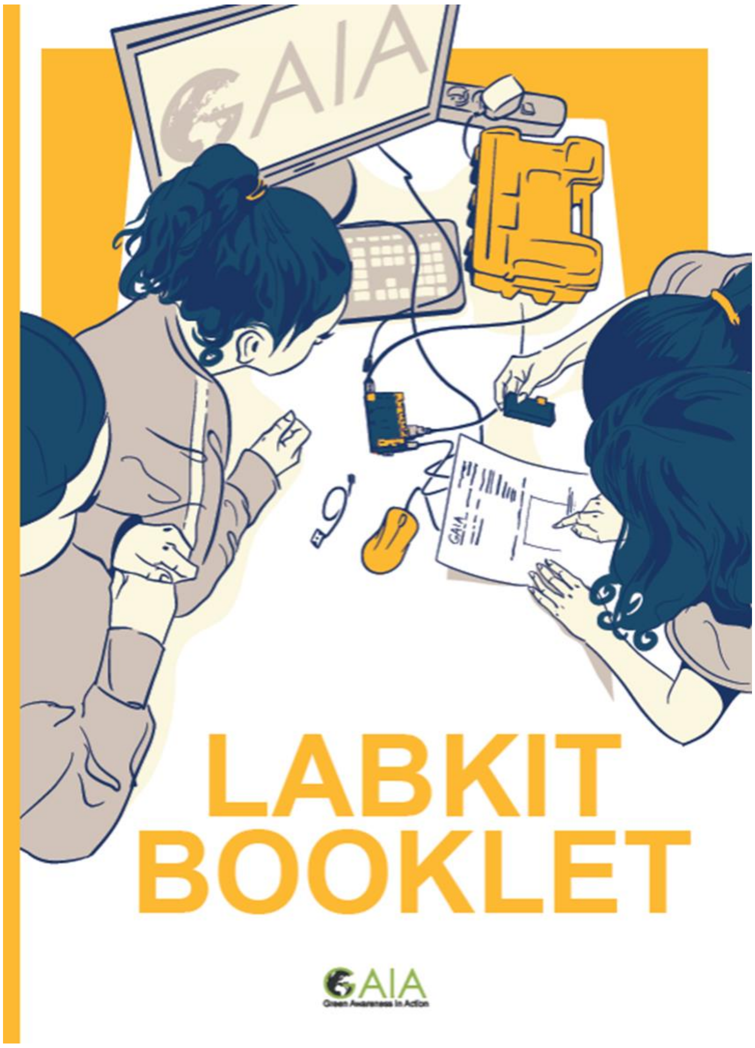


Figure 91 Front Cover of the Lab Kit Booklet

16. Evaluation of the Sustainability Awareness results of GAIA

The pre-activities survey

Before or shortly after the start of the GAIA activities at schools in the academic year 2018-2019, an online questionnaire was administered to participating students (cf. the “Before GAIA activities” questionnaire in Annex I). The aim of this pre-activities survey was to establish a baseline understanding of students’ awareness of energy issues and of their attitudes and behaviors relating to action for better energy efficiency.

Overall, 363 students participated in the questionnaire survey, which corresponds to 21.3% of the total 1702 students who participated directly in the GAIA activities this school year, a sample which can be considered representative of that population. The participation in the survey was almost balanced in terms of gender (46.3% female respondents), and comprehensively covered different participating schools and regions. The responses came from both primary (52.5%; up to 11-12 year-old-students) and secondary (47.5%; 12-18+ year-olds) education students.

Energy awareness

To establish students’ awareness and understanding of energy consumption at a first general level, the pre-activity survey questionnaire asked them to state how much energy they consume at home. The response revealed that 29.1% of the students considered that they consume ‘much’ energy, and 6.2% ‘very much’ energy. The middle point in the response scale (‘some’) gathered more than half of the responses (51.3%).

The above general question was combined with a more focused investigation of students’ perception of the devices found in their homes and of their energy consumption intensity. Participants were presented with a list of 22 different devices and appliances, all of which were identified by large parts of the participating student population as existing in their homes. However, when asked to identify 4 devices out of the 22 listed which, in their opinion, are responsible for the biggest energy consumption, the response was less clear and not always consistent with the expected average-citizen knowledge about energy-hungry devices (cf. that usually the following are listed as the top energy users at home: by far heating and cooling systems, followed at a distance by water heaters, lighting, washing machines, refrigerators/freezers, etc). Students more frequently tended to identify the refrigerator (48.1%), the water heater (47.8%), the oven (47.5%), the washing machine (37.3%) and the TV (35%) as those devices which consume the most energy in a household. The vast majority of students failed to recognize the heavy consumption of energy for heating or cooling the rooms of the house.

Nevertheless, many students declared awareness of the problem of energy waste. When asked how sensitized they were to energy waste, 41.6% answered ‘very much’ or ‘much’ (10.9% ‘very much’ and 30.7% ‘much). Further, approximately one third (32.4%) of the respondents stated that they were ‘somewhat’ sensitized to energy waste, while only 19% answered ‘a little’ and 7% ‘not at all’.

In addition, respondents’ existing knowledge of ways to save energy appears to be significant in the pre-activity stage. 40.9% of the students answered that they ‘know many ways to save energy’, and an additional 21.2% that they ‘know 3-4 ways to save energy’. Further, more than one third (35.1%) of all students selected the answer ‘I know some basic ways to save energy’, while those who stated that they knew no ways to save energy were just 2.9%.

Attitudes and behaviours

Further to awareness, the pre-activity survey sought to establish students' existing attitudes and behaviours relating to energy use. Again, respondents' self-portrayal in relation to their motivation to save energy and energy-saving practice tended to be positive.

About 43%-45% of all respondents claimed that they 'are motivated to save energy' and that they 'save energy and think that they can make a difference'. In addition, large groups of respondents (32.1%-42.9%) also cluster on the middle points ('somewhat') of the relevant scales. The relevant results are summarized in Table 5.

Table 5 Energy-saving motivation and practice before the GAIA activities

	Not at all	*A little*	*Somewhat*	*Much*	*Very much*
Are you motivated to save energy?	6.3%	16%	32.1%	33.5%	12%
I save energy and I think I can make a difference.	1.7%	11.5%	42.9%	31.1%	12.9%

Further, more than two thirds (69.3%) of the students stated that they had already had the opportunity to decrease energy consumption at their homes, and almost three out of four students (73.3%) reported that they use saving energy techniques at home. When asked to identify these techniques, by far the most frequently selected (80.9%) was turning off the lights and devices when not needed. The second most frequent choice was using energy-saving lamps (59.7%). These results are presented in Table 6.

Table 6 Energy-saving practice details before the GAIA activities

	No	*Yes*
Have you ever had the opportunity to decrease energy consumption at your home?	30.7%	69.3%
Do you use energy saving techniques at home?	26.7%	73.3%
If so, which? [multiple choices possible]:		
I turn off the lights and check that devices are turned off before I leave the house		80.9%
I use energy-saving lamps		59.7%
I try to change my daily habits to save energy		38.3%
I use low-energy-consumption devices		34%

The pre-activity survey sought to probe further into students' practices in relation to energy efficiency, by asking them to state how often they perform certain energy-wasting behaviours. The relevant results are summarized in the Table 7, revealing differences in students' perception of their energy-waste habits. Especially if we focus on the 'non-advisable' end of the relevant statements, we will find out that 'always' or 'most of the times' 26.3% of the students leave a device charging even if its battery has already been fully charged. In comparison, approximately 17% of the respondents leave devices in stand-by mode or the computer turned on when not in use, and only 11.6% leave the lights turned on when there is no one in the room.

Table 7 Energy-waste habits before the GAIA activities

	Never	*Rarely*	*Sometimes*	*Most of the times*	*Always*
I leave your computer turned on while it is not in use	51.3%	19.1%	12.8%	10.8%	6%
I leave the lights turned on when there is no one in the room	36%	28.9%	23.5%	8.2%	3.4%
I leave devices in stand-by mode	28.8%	25.6%	28.2%	10.4%	6.9%
I leave a device charging even if its battery has already been fully charged	28.8%	16.9%	28%	17.5%	8.8%

Turning the focus to the location of students' efforts to save energy, the pre-activity survey showed that 47.5% try to save energy every day, at home as well as at school; 35.4% save energy only at home; and 11.2% save energy only at school. In the same questionnaire item, only 5.9% of the respondents state that they are not interested in saving energy.

As one further element of the attitude to energy efficiency issues in the pre-activity stage, the students were asked to indicate the extent to which they actively follow energy consumption issues and look for opportunities to be informed. 'Not at all' and 'a little' was selected by 25.8% of the respondents (6.2% 'not at all' and 19.6% 'a little'), while 41.4% responded 'much' or 'very much' (30.5% 'much' and 10.9% 'very much').

Finally, students showed a very positive attitude towards controlling energy consumption. To the question 'If you controlled energy consumption at home, do you believe this would help you to become more sensitized to the importance of saving energy?', 82.1% of the participants of the pre-activity survey answered 'yes'.

A concluding note on the pre-activity survey

Overall, it should be highlighted that the pre-activity survey revealed a quite positive picture drawn by students about their own awareness of, and engagement with energy issues. This, on the one hand, can be linked to the well-known social desirability bias that is an inherent problem of self-report measurements, as many respondents typically tend to present themselves in a socially acceptable manner and portray themselves in a good light. Given the scope and relatively resources of the project, this bias could not be counterbalanced through additional techniques, such as in-depth individual interviews or observations. Nevertheless, the results of the pre-activity survey were valuable On the one hand, they revealed a high threshold that the GAIA intervention had to attempt to pass through careful organization, adjustment and implementation. On the other hand, these results established the baseline and background the results of the post-activity survey should be projected on.

The post-activities survey

Close to or shortly after the end of the GAIA activities (depending on the specific schedule of each school) in the academic year 2018-2019, an online questionnaire was administered to the participating students (cf. the "After GAIA activities" questionnaire in Annex I). The aim of this post-activity survey was to establish the impact of GAIA activities and of the GAIA experience overall in the course of the school year, on students' awareness of, attitudes to, and action for energy efficiency.

Overall, **723 students** participated in the questionnaire survey, which corresponds to 42.5% of the total 1702 students participating in GAIA activities in this school year, thus constituting a strong representative sample of that population. The participation in the survey was balanced in terms of gender (49.6% female respondents), and comprehensively covered the different participating schools and regions. The responses came from both primary (45%; up to 11-12 year-old-students) and secondary (55%; 12-18+ year-olds) education students.

Increased awareness

Students were asked to think about what they had learned and done at their school about energy consumption and energy saving in different aspects of every-day life ("for lighting, heating, traveling, working, reading, having fun...") and consider how well they now know and understand the consequences of wasting energy for the environment. Three quarters of the students responded that they know and understand these consequences 'very well' (32.1%) or 'well' (42.4%). Despite this very positive message, it is worth noting that still, after activities such as those of GAIA, 9% of the students respond that they know and understand the consequences of energy waste for the environment only 'a little' or 'not at all'.

Importantly, the GAIA activities seem to have increased the number of students with high energy waste awareness by almost one third. More specifically, the comparison to the pre-activity survey results for the corresponding question ('*How sensitized are you to energy waste?*') clearly demonstrates this increase. Those at the highest level of awareness (responding 'very much'/'very well') have increased by 21.2%, and those who responded 'much'/ 'well' increased by 11.7%. Counted together, respondents on the positive end of the scale ('very much'/'very well' and 'much'/ 'well') increased by 32.9%. The relevant results from the pre-activity and post-activity survey summarized in the following table and in Figure 93.

Energy waste awareness	*Not at all*	*A little*	*Somewhat / So and so*	*Much / Well*	*Very much / Very well*
Before the activities	7%	19%	32.4%	30.7%	10.9%
After the activities	5.7%	3.3%	16.5%	42.4%	32.1%
Change after in comparison to before	*-1.3%*	*-15.7%*	*-15.9%*	*11.7%*	*21.2%*

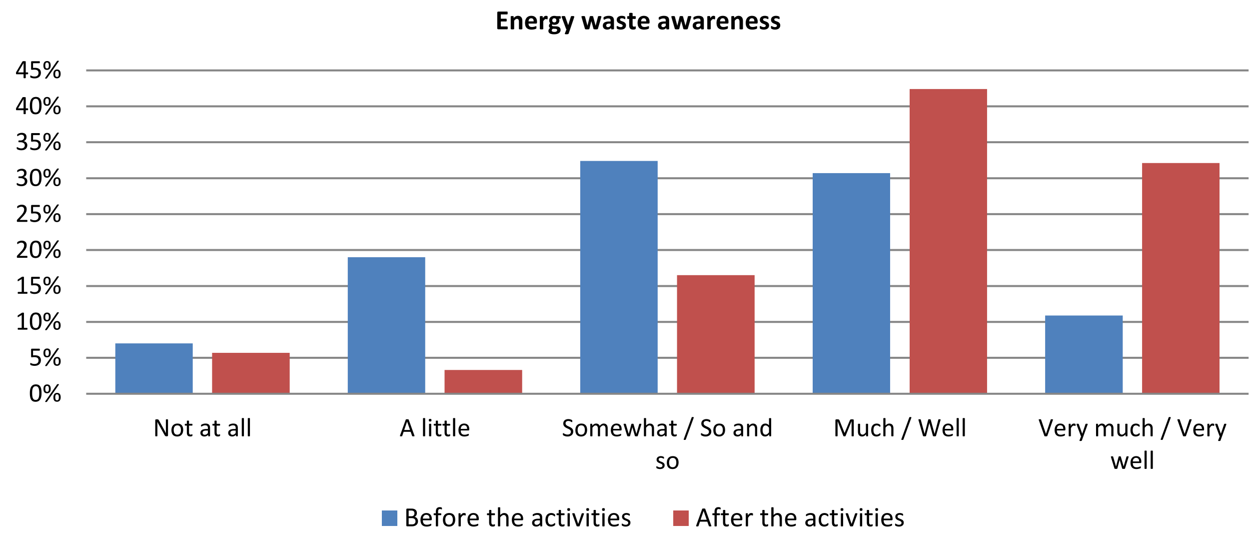


Figure 92 Energy waste awareness before and after the GAIA activities

Subsequently, students were asked to indicate the extent to which they know and understand in what ways energy is consumed at school and in everyday life. About two thirds of the students responded that they know and understand this 'very well' (24.1%) or 'well' (41.2%). This is an encouraging result which to a considerable extent can be credited to the focus of GAIA activities on the use of energy within the school environment.

Nevertheless, when comparing the responses to the two statements above, it becomes evident that a more general awareness of the negative consequences of wasting energy for the environment is stronger than a more concrete awareness of the ways in which people consume energy at school and in everyday life (Figure 93). In other words, while students tend to know well that energy waste is bad for the environment, they seem to be somewhat less well informed about the particular ways in which energy is used and possibly wasted at school and in everyday life. This may indicate the need for further awareness-raising educational work in this direction.

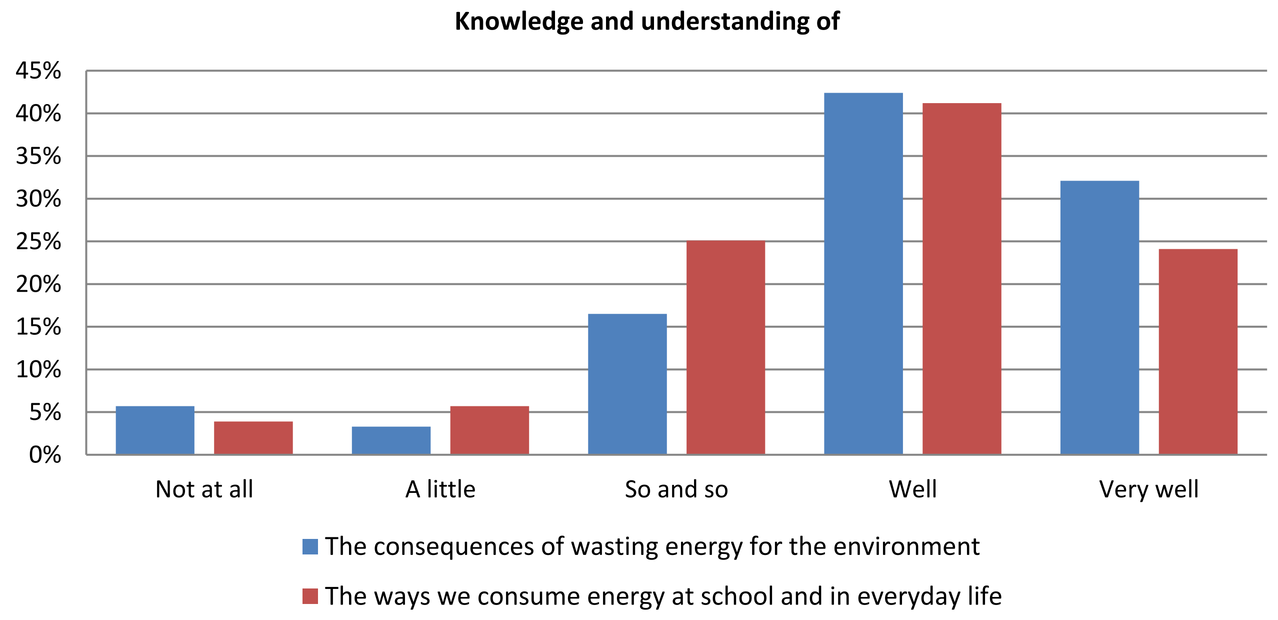


Figure 93 Answers regarding familiarity with energy consumption and saving

Concluding the examination of the domain of energy-saving awareness, the questionnaire also instructed students to think fast and consider how many ways of saving energy come to their mind immediately. Three quarters of the students responded that they can immediately think of 'many' (32.2%) or 'some, e.g. 3-4' (43.2%) ways to save energy. A further 15.8% of the students declared that they could immediately think of 'a few, e.g. 1-2' ways in which energy can be saved. In addition, the comparison to the relevant results from the pre-activity survey reveals a clear improvement in students' awareness of ways to save energy. Those who responded they know 'many' or 'some, e.g. 3-4' ways increased from 62.1% to 75.4% (a difference of +13.3%).

Taking action

The questionnaire survey subsequently sought to establish to what extent students are prepared to change their behavior and/or take action in order to achieve better energy efficiency in their everyday life, after what they had done at school about energy saving.

More than three out of four students (77.1%) declared that they had tried to change some of their everyday habits to save energy, at least to some extent. Among them, 43.9% said that they had done so 'very much' (14.8%) and 'much' (29.1%). On the other end of the spectrum, however, an important part of the respondents (22.9%) stated that they had tried to change some of their everyday habits only 'a little' (13.1%) or even 'not at all' (9.8%). In other words, the survey yielded a clear tendency of more students declaring to have changed everyday habits in order to save energy than those declaring to have done so to a limited extent or not at all. Evidently, also, one third of the respondents (33.1%) thought that their efforts to change some of their everyday habits to save energy were mediocre ('so and so') Figure 94).

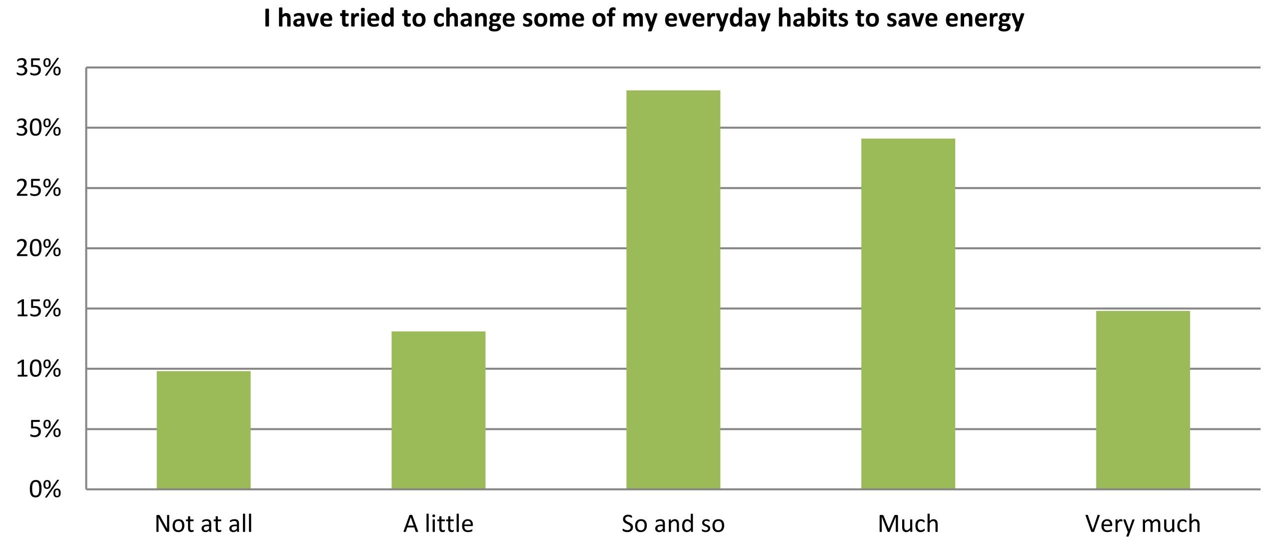


Figure 94 Answers regarding whether 'I have tried to change some of my everyday habits to save energy'

The comparison of these results to relevant background questions from the pre-activity survey shows a slight yet existent improvement especially on the positive end of the scale. Before the GAIA activities, approximately 12.5% of the respondents selected the highest point in the scale, i.e. 'very much', in two relevant questions (12% are 'very much motivated to save energy', and 12.9% 'save energy and think they can make a difference very much'). The response attached to this positive end of the scale in the above mentioned post-activity survey question has increased to 14.8%, representing a positive change by approximately 2.4%. In addition, in the pre-activity survey 69.3% of the respondents declared that they had had the opportunity to decrease energy consumption, and 73.3% that they used energy saving techniques (the average of those two percentages is 71.3). On the other hand, as mentioned above, 77.1% of the post-activity respondents declared that they had tried to change some of their everyday habits to save energy at least to some extent. This reflects an increase by approximately 5.8% in the number of students who state that they are practically involved in energy saving.

To investigate students' willingness to take action and even confront others for the sake of energy efficiency efforts, the survey further asked students whether they would advise or even tell someone off, if they saw them wasting energy. Almost three out of four respondents (73.4%) agreed that they would do so. While the majority among them (44.4% of all respondents) would do so only if the waste of energy seemed to be big, those most determined, stating 'Yes, of course, this is very important!', reached 29%.

Action to stay informed about energy and environmental problems is another aspect of students' engagement with questions of energy efficiency which was investigated. Almost two thirds of all students (65.6%) indicated that they try to stay informed about such issues frequently (from 'quite often' to 'very often'). Approximately half of them (34.4% of all respondents) do so because they find energy and environmental issues interesting or important, while the other half (31.2% of all respondents) are motivated to stay informed because of school requirements. On the other hand, about one third of all students stated that they find staying informed about energy and environmental problems "boring". Thus, next to the positive message about a quite well-established environmental consciousness-raising among young people, these findings underline the need for more efforts to motivate all young people for environmental awareness and energy efficiency in engaging ways which will increase their intrinsic motivation to stay informed and take action.

In comparison to students' responses before the GAIA activities, we can observe some improvement in their reported willingness and motivation to stay informed on issues relating to the impact of energy use on the environment. In the pre-activity stage 41.1% stated that they actively follow these issues and look for opportunities to be informed about them 'much' or 'very much'. Respectively, in the post-activity survey the relatively equivalent response (from 'quite often' to 'very often') has increased to 65.6%, corresponding to a change of +24.5%.

To delve deeper into students' energy-related behavior and action-taking, the survey further asked them to think fast and consider what they had done the previous day and on the day they completed the questionnaire in order to save energy. Beyond 22.7% of the respondents who admitted to having done 'almost nothing', the rest of the students are almost equally divided between those who only 'thought about that' (39.1%) and those who, to a lesser or greater extent, tried to save energy (38.2%) (Figure 95).

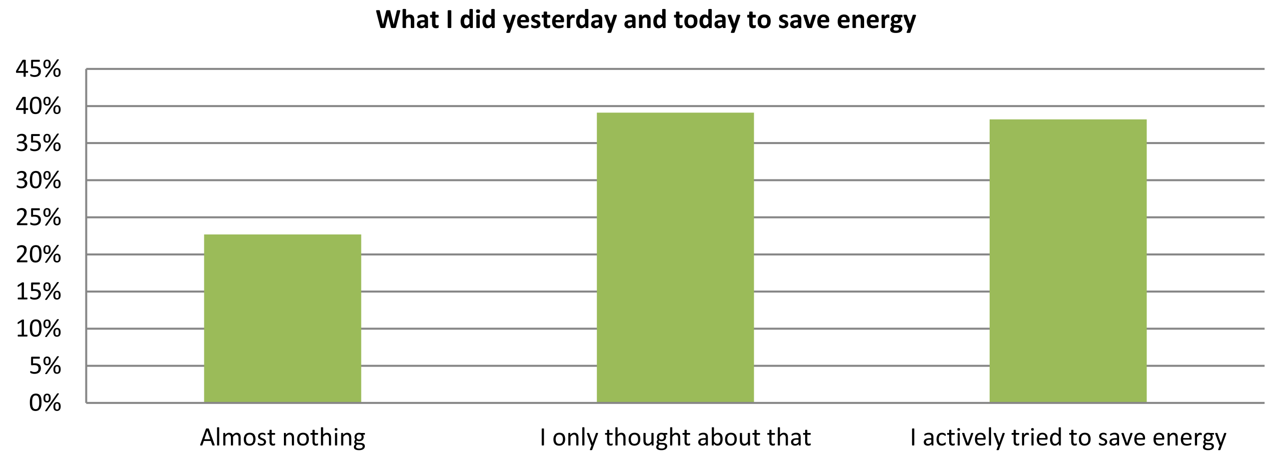


Figure 95 Answers to 'what did I do yesterday and today to save energy'

In more detail, it is interesting to note that in each of the two ‘positive’ clusters, ‘thought about that’ and ‘actively tried’, greater engagement is less frequent. Thus, 21.4% “thought about that a couple of times”, as compared to 17.7% who “thought about that many times”. Similarly, 25.8% “tried to save energy through their choices and practice”, while only 12.4% stated that they “did really a lot to save energy and paid attention to this matter all the time”.

A final attempt to establish the level of students’ true engagement with action for energy efficiency through a multiple-choice question was made through the questionnaire item which asked them if, with what they had done recently at their school, they had managed to save energy in the school. More than half of the respondents (52.9%) thought that their school had probably saved energy, although they admitted not knowing exactly how much energy was saved. In addition to them, more than one in four participants (26.8%) without reservations stated that their school had saved energy and that they knew some details about that. These two cohorts combined produce a vast majority of students (79.7%) who recognized that through the GAIA-based activities their schools had managed to save energy. The remaining respondents were almost equally divided between those who that they had tried to save energy but it had been difficult (9.1%) and those who stated that they were not aware of any relevant effort in their school (11.1% choosing ‘No, I don't think we tried’) (Figure 96). Therefore, it seems that GAIA managed to achieve its goal to convince students in practice about the possibility to increase energy efficiency in the school building, with space remaining for further improvement in future interventions in relation to better communicating and explaining the details of the relevant energy saving results to the school community.

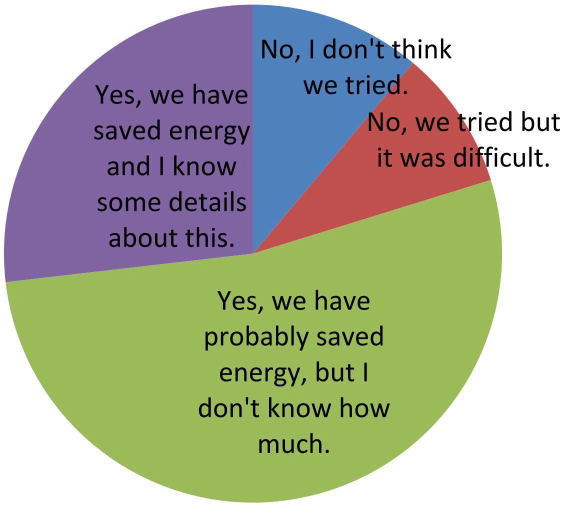


Figure 96 Answers by the students regarding whether ‘With what we have done recently, we managed to save energy at my school’

Next to the above multiple-choice items, the questionnaire also included two open-ended questions which sought to establish students’ engagement with action for energy efficiency. Thus, on the one hand, respondents were asked to think of and mention a case when they managed to do something important against wasting energy at their school or at home. Approximately 80% of the respondents provided answers to this question in the form of short statements, as instructed. By far, the most frequently mentioned energy-conscious behavior was switching off the lights when they are not needed, which was the response of the majority of those who answered the question. In addition, a second open-ended question asked students to consider and state what makes it difficult for them to pay more attention to energy consumption in everyday life. Again, about 80% of all respondents provided short statements as answers to this question. The most frequent reasons for not attending more to energy efficiency mentioned by those who responded were the power of habit and the pressure of everyday routine on time available to stop and think about energy. It is noted that the qualitative analysis of these open-ended responses is being continued and correlated with a refined statistical analysis of responses to other questionnaire items, the results of which will be reported in scientific publications by the consortium in the coming period.

The impact of the different aspects of GAIA activities

Through the post-activity online questionnaire, the consortium also sought to gain insight into the impact the different aspects of the GAIA intervention had on students.

On the one hand, the survey asked students to state to what extent they **liked**: a) the "GAIA Challenge" digital game, b) to observe and use the data and measurements, and c) the lab activity with the circuits etc. The table below summarizes the distribution of the relevant responses.

From the things we did at school about saving energy, I liked:	***Not at all***	***A little***	***So and so***	***Much***	***Very much***	***I don't think I did this***
The game ("GAIA Challenge")	11.6%	7.1%	21.4%	22.4%	32.1%	5.4%
To observe and use data and measurements	10.4%	10.1%	26.2%	24.8%	22.1%	6.3%
The lab activity with the circuits	9.4%	8.6%	21.7%	25.4%	25.0%	10.0%

Overall, approximately half of the students stated that that they liked these GAIA activities 'much' or 'very much' (54.5% the digital game, 50.4%the lab activity, and 46.9% the data and measurements). The overall somewhat positive to positive response, i.e. excluding the responses 'not at all' and 'a little', approaches or reaches the level of three quarters of the respondents (75.9% the digital game, 73.1% the data and measurements, and 72.1% the lab activity). As becomes evident in the graphical representation of this data (Figure 97), the GAIA Challenge game tended to be liked the most, followed by the lab activities.

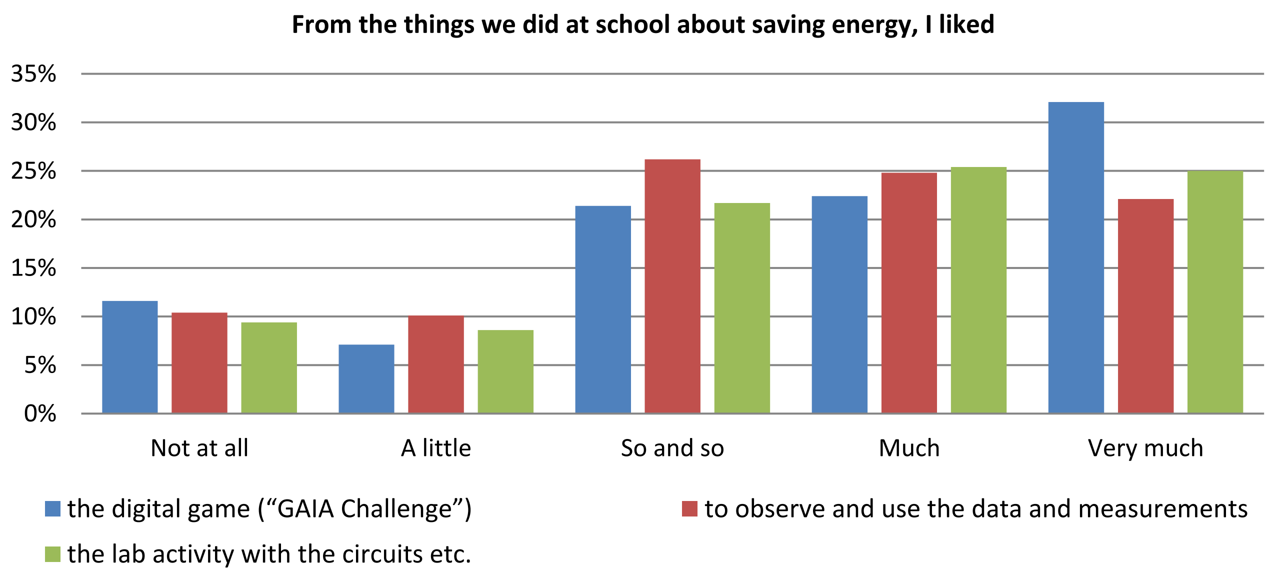


Figure 97 Answers provided by the students to 'From the things we did at school about saving energy, I liked'

In addition, students were asked to state to what extent they **had learned about energy:** a) by playing the "GAIA Challenge" digital game, b) by observing and using the data and measurements, and c) in the lab activity with the circuits etc. The response is summarized in the following table.

I learned a lot of interesting things about energy:	***Not at all***	***A little***	***So and so***	***Much***	***Very much***	***I don't think I did this***
By playing the game ("GAIA Challenge")	8,8%	10,3%	18,7%	30,1%	27,0%	5,1%
By observing and using the data and measurements	8,3%	10,0%	24,5%	30,7%	19,4%	7,1%
By the lab activity with the circuits	6,7%	8,4%	25,2%	26,0%	23,1%	10,6%

In this case too, at least half of the respondents stated that that they had learned about energy 'much' or 'very much' through the GAIA activities, with the tendency to evaluate the digital game even more positively as a learning resource in comparison to the other two types of activities (57.1% by playing the digital game, 50.1% by observing and using the data and measurements, and 49.1% in the lab activity). Similarly, also, the overall somewhat positive to positive response, i.e. excluding the responses 'not at all' and 'a little', reaches the level of three quarters of the respondents (75.8% by playing the digital game, 74.6% by observing and using the data and measurements, 74.3% in the lab activity). The graph in Figure 98 reflects this overall positive stance towards the GAIA activities as opportunities and resources for learning about energy, as well as respondents' relatively higher tendency to recognize the GAIA Challenge digital game as such a resource.

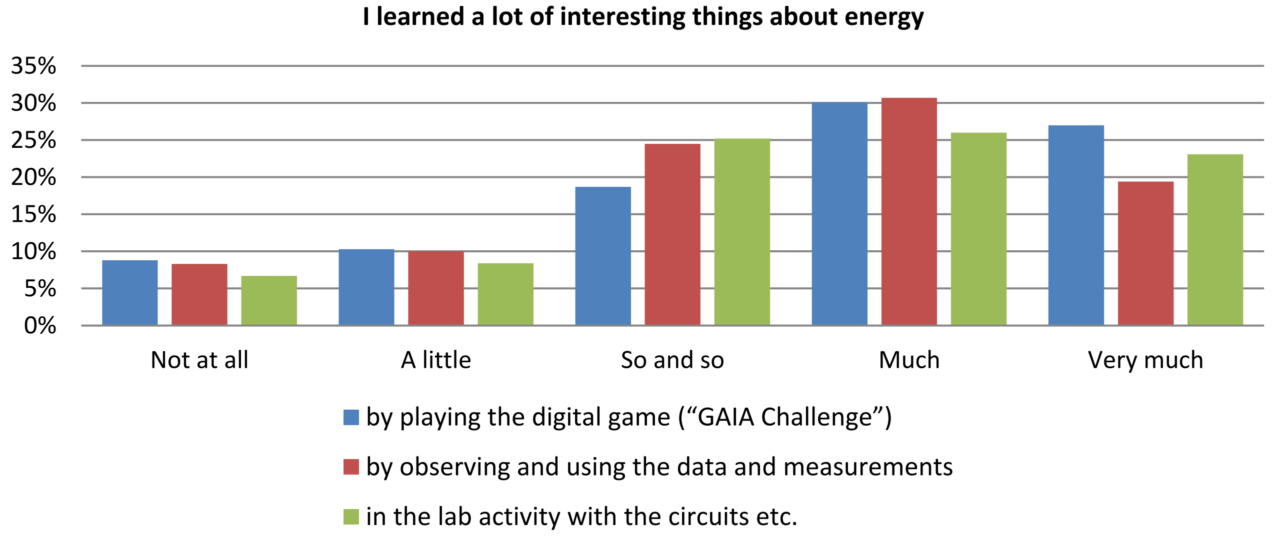


Figure 98 Answers provided by the students to 'I learned a lot of interesting things about energy'

Finally, the positive stance of the majority of respondents towards the value of the GAIA activities as resource for learning about energy is confirmed through numerous responses provided by students to an open-ended question of the online questionnaire. That question had respondents consider and mention what they would like to do at school next year to learn more about saving energy. Approximately 75% of the respondents provided answers to this question in the form of short statements, many of which referred to repeating activities such as those introduced by GAIA. The qualitative analysis of these open-ended responses is being continued and correlated with a refined statistical analysis of responses to other questionnaire items. More details will be reported in scientific publications by the consortium in the coming period.

The post-activities survey in a nutshell: highlights from the results

The post-activities survey in a nutshell: About 75% of students were positively affected by GAIA

After the GAIA activities, the survey found:

Increased awareness

- Three out of four students know and understand the consequences of wasting energy for the environment 'very well' or 'well'.
- Two out of three students know and understand in what ways energy is consumed at school and in everyday life 'very well' or 'well'.
- Three out of four students can immediately think of 'many' or 'some (e.g. 3-4)' ways to save energy.

More preparedness for action

- More than three out of four students tried to change some of their everyday habits to save energy at least to some extent.
- Almost three out of four respondents would advise or even tell someone off, if they saw them wasting energy
- Almost two thirds of all students actively try to stay informed about energy and environmental problems frequently.
- More than three out of four students had thought about or had taken action for energy efficiency on the day they responded and on the previous day. Out of them, 38.2% had, to a lesser or greater extent, actively tried to save energy.
- Almost 80% of students recognized that through the GAIA activities their schools had managed to save energy.
- When asked to think of a case in which they managed to do something important against wasting energy at their school or at home, most frequently students mentioned switching off the lights when they are not needed.
- When asked to think about what makes it difficult for them to pay more attention to energy consumption in everyday life, most frequently students mentioned the power of habit and the pressure of everyday routine on time available to stop and think about energy.

A positive impact of all aspects of GAIA activities

- About three quarters of the students liked the GAIA activities, and approximately one in two students liked those 'much' or 'very much'. The GAIA Challenge game tended to be liked the most, followed by the lab activities.
- Three quarters of the students thought they had learned about energy through the GAIA activities, and at least one in two students thought that they did so those 'much' or 'very much'. Within an overall positive stance towards all GAIA activities as resource for learning about energy, the GAIA Challenge game tended to be evaluated even more positively.
- Many students spontaneously mentioned that they would like to do more activities like those of GAIA at school next year in order to learn more about saving energy.

However:

Despite the above very positive messages, there is still a small proportion of students (approx. 10-20%), on whom the activities did not have the wished positive impact.

The focus study at EA, Greece

The pre- and post-activity survey presented in the previous sections allowed the consortium to draw interesting general conclusions about the impact of the educational interventions of the GAIA project on students' awareness, behaviour and attitudes related to energy efficiency.

To complement this general, necessarily shorter survey with a deeper investigation into the impact of the GAIA experience on students, EA conducted an additional focus study with the participation of the almost 150 year-six students at its school, all of whom systematically participated in GAIA activities in school year 2018-2019.

The aim of this focus study was to make use of existing academic knowledge and expertise in the field of environmental education in order to gain deeper insights into students' energy efficiency-related knowledge, behaviour and attitudes before and after the GAIA intervention. To this end, EA negotiated and secured the academic collaboration of the University of Bayreuth (Germany), thanks to which GAIA was able to use a specifically adapted version of calibrated and established research instruments measuring ecological behaviour, environmental knowledge, and attitude towards nature, which the Bayreuth researchers have co-developed in the framework of their work on a competence model for environmental education (cf. e.g. Nina Roczen, Florian G. Kaiser, Franz X. Bogner and Mark Wilson (2014). 'A Competence Model for Environmental Education'. Environment and Behavior, 46: 972). The collaboration of GAIA with the University of Bayreuth became possible through a synergy that EA agreed and developed for GAIA with the Open Schools for Open Societies (OSOS) European project (www.openschools.eu).

A rigorous statistical analysis of the rich data collected has taken place in the context of doctoral research at the University of Bayreuth, and has already produced interesting findings. It should be noted that the relevant doctoral study and the analysis of data is currently in progress, and that more results and their discussion are expected to be provided in the form of academic publications in the following months. Already at this stage, the focus study has confirmed the findings of the general survey of the project, highlighting in particular the difficulty of improving student's behaviours and attitudes in relation to energy efficiency and the environment. The results from the focus study, as well as more generally the relevant academic literature, imply that these attitudes and behaviours may start changing after a longer period of students' exposure to interventions such as those of GAIA.

However, the focus study found an interesting effect of the GAIA activities on the 'low achievers' among the participating students. As presented in Figure 8, the analysis revealed a significant knowledge growth for the 'low achievers' in the participating classes, which can be considered as an important success of the GAIA project in terms of an inclusive approach to energy-efficiency education, without leaving disadvantaged students behind.

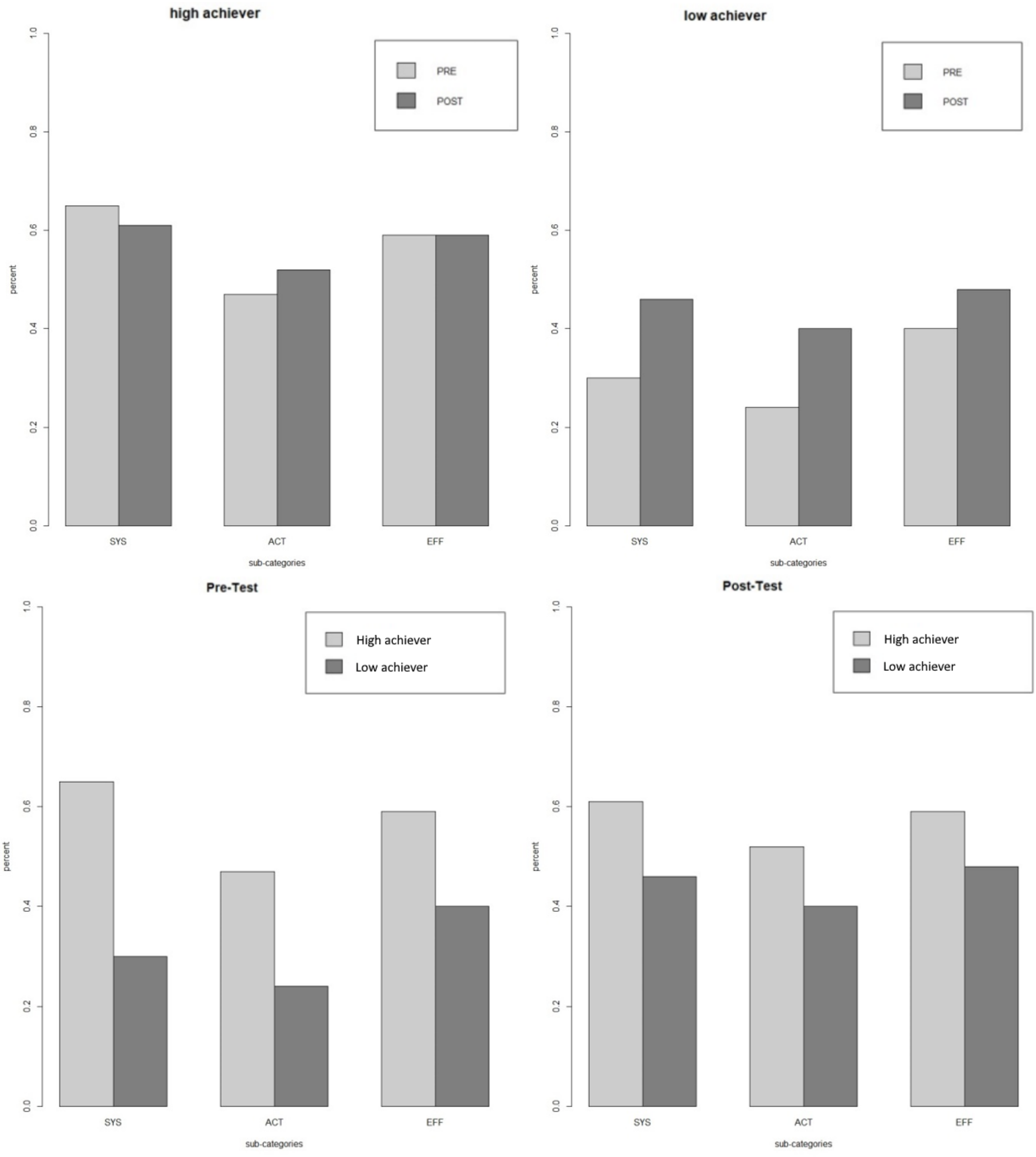


Figure 99 Significant knowledge growth for the ‘low achievers’ through the GAIA activities

17. Discussion on infrastructure installation, costs and practical considerations

In this section, we provide a discussion on some more practical aspects with respect to the ways that schools and building managers could have in mind when considering to install an IoT infrastructure in their school building, which could be similar, in terms of hardware, with what GAIA currently utilizes. There are a number of aspects that should be taken into consideration in such a process:

- The cost of the installation and the respective potential payback period.
- The scale and location of the installation.
- The sensing hardware used in the installation, the respective sensing modalities and potential educational uses for in-class activities.

After having presented in the previous chapters our results from the energy-saving and educational activities during the main phase of the trials in GAIA, we can now start discussing the abovementioned aspects in a more concrete manner. First, we will recap some of the financial aspects mentioned in the previous chapters in the following table. We focus on some examples from the GAIA schools in Greece, which are small to medium size school buildings in terms of size and number of students and staff. The table below contains 9 characteristic examples of schools that have achieved energy savings in various levels, and whose payback time and annual return on investment (ROI) rate varies considerably. We also include the number of sensing endpoints in each school, i.e., the number of unique sensors that produce data. E.g., an IoT node with temperature, humidity and luminosity sensors corresponds to 3 endpoints, giving an idea of the size of the infrastructure in each school.

Table 8 Examples of school buildings in Greece with respect to payback time and annual ROI

School	Installation Cost (€)	Sensing Endpoints	Yearly savings projection (€)	Payback time projection (years)	Annual ROI
6th Primary School of Kaisariani	713	26	250	2.85	35%
7th High School of Trikala	658	43	815	0.8	123,8%
Exp. Primary School of the Univ. of Patras	571	32	728	0.78	127,5%
8th Junior High School of Volos	826	48	480,7	1,71	58,2%
Primary School of Lygia	769	42	331	2,32	43%
Junior High School of Pentavrysso	1127	58	1591	0.7	141,2%
Talos Robotics School	742	40	378,6	1,96	51%
1st Junior High School of N. Filadelfia	1195	53	33,7	35,4	2,8%
Exp. Junior High School of Laggouras	1300	40	41,7	31,17	3,2%

At this point, we should stress again that the numbers above regarding savings in energy costs are based on yearly *projections*, following the assumption that the energy savings achieved during trial periods can scale across a full academic year.

As is evident, there are various levels of success in terms of energy saving results among these schools, which are reflected in the considerably variable payback time and annual ROI projections. We should also point out that the cost for the installations varies greatly between some of these schools, reflecting largely the progress within GAIA in terms of hardware and software design and implementation. The three priciest installations (Pentavrysso, N. Filadelfia, and Laggouras) were all performed in the initial stages of the project. Later installations that were based on newer revisions of the hardware designed within the project, and which did not utilize closed-source commercial platforms are considerably cheaper at around half or two thirds of the price. Especially in the case of the installations in N. Filadelfia and Laggouras, the closed-source solutions comprised almost one third of the cost for the schools, also because the companies providing such solutions typically charge for the actual installation by their staff and use of their software platforms, e.g., cloud storage.

Aside from these cost-specific aspects, and more importantly, one should keep in mind that there are also different ways that the various GAIA installations contribute to the curriculum. In practice, we have seen that school present very big differences in terms of the background, experience and expertise of their educational staff that wishes to be involved in activities like the ones offered by GAIA. Depending on these factors, there will be different approaches in practice taken by the schools to utilize the affordances provided by GAIA, as well as different benefits to the educational process as a result. E.g., a teacher with a computer-science background will likely choose to focus on different aspects than a teacher with a physics background, or a Literature background. In Greece, we have seen in practice that such big differences do surface in the various schools that participated in the project, so there does not quite exist a one-size-fits-all educational approach to how to integrate tools like GAIA's in the curriculum of the school. This dimension has shaped largely the educational design of GAIA, as well as the strategy for conducting the trials in pilot schools.

Another dimension that is interesting and one that we did not fully anticipate, is the ways in which students of different age/background react to the various types of sensors utilized by GAIA. E.g., in some cases we noticed that primary school students showed great interest to noise levels-related activities, because they understood that they could create noise as input for the GAIA system immediately, as well as in teams. In other instances, students of older age expressed interest towards the way some more other sensors work, e.g., power meters. We also saw that students that participated in "maker" activities in their schools or other environments (e.g., robotics clubs organized by third parties) also expressed in some cases more "technical" questions, e.g., how do the sensors send the data to a system in the GAIA "cloud" infrastructure, or "how can I/we build a similar thing for our school/home".

In light of the above, the schools' administration has to consider these factors when making a decision on the approach they will follow for making an installation to support energy-saving and sustainability-focused activities similar to GAIA's approach. E.g., the teachers should consider whether they want to focus on energy consumption, on sustainability in general, on understanding building processes, indoor air quality, etc., or a combination of all of these aspects. The outcome of these decisions could affect e.g., the composition of the IoT infrastructure required to carry out the educational activities envisioned by each school. A school that wishes to focus exclusively on energy consumption could consider a smaller-scale infrastructure installation that would have a number of power meters, but less environmental monitoring sensors compared to a typical GAIA school installation. Of course, such a decision has on the one side the advantage of lower cost or better granularity in power consumption data, but on the other hand, it limits the potential overall uses of the installation in the educational process.

Moreover, there is of course the question of the total cost of such an installation to support activities similar to GAIA. The most recent installations included in the table above have a cost between 550 and 750 euros. Depending on the budget of each school, this may or may not be a cost that has to be considered seriously before deciding to proceed with such an installation. From our numbers, it is clear that there can be quite tangible results in terms of cost savings, but there can certain cases where the level of potential cost savings can influence the decision about the installation, or its size. Furthermore, in terms of power consumed, the devices in such installations usually have a maximum consumption in the order of 1-2 Watts, and typically much less. Thus, they do not contribute in any significant way to additional power costs for the schools.

Following this line of thought, and having the experience of the pilots in the project, one additional approach that appears to be interesting would be to have a more “portable” IoT infrastructure, or at least one that can easily be relocated. Such an installation could potentially be set up to function inside certain school buildings for specific periods and then move it to another set of school buildings, or within the same school but different parts of the school’s building. This is probably more relevant in the case of the environmental monitoring sensors. Thus, it would be interesting in the future to investigate such an approach with a more “portable” version of the GAIA IoT infrastructure utilized inside a range of different school buildings. Such a strategy could probably expand the educational benefits to a larger student audience and at the same time justify the installation cost a bit better.

An additional practical consideration for schools is the actual location of the installed power meters and sensors inside the building in general, and inside classrooms specifically. In general, from our experience there are two aspects involved: realities where such devices *should* be placed to measure something with adequate accuracy, and where it *can* be placed in practice inside classrooms. In almost all schools and especially in the case of primary schools, we had to ensure that IoT devices installed inside school premises would be hard to reach (environmental conditions monitoring devices inside classrooms), or practically inaccessible (power meters) to students. Therefore, these requirements create additional restrictions as to where GAIA-like infrastructure can be installed within a school building, and school administrations and building managers should have this dimension in mind when deciding the parameters for a GAIA-like installation at their school.

Other practical considerations concern the design and build of the devices. E.g., we noticed after installing a certain revision of our hardware inside classrooms that using LEDs as device health indicators could pose some issues. More specifically, we noticed that LEDs blinking was, in certain locations, too distracting during class time and we decided to disable these LED indicators to avoid related issues. We also decided to use removable wall-mount bases to install our IoT sensors inside classrooms to minimize our interventions inside classrooms on the one hand, and enable a wider range of movement in the nodes orientation on the other hand. E.g., in some cases we noticed that the initial placement of the IoT nodes did not assist in getting reliable sensing data, and had to adjust their positioning. Using a more flexible installation base helped to simplify such procedures greatly, and allowed e.g., teachers to be able to experiment with such parameters if they wished so. Moreover, and in contrast with the often-used approach to utilize batteries to power the IoT devices, it was clear after a certain point in time that using USB plugs to power the nodes inside classrooms was a good strategy to have a reliable infrastructure that produces data with high sampling rates. It also minimized the need to inspect the hardware periodically to change batteries.

We should also make clear another aspect of the project that is implied in the comments above: the consortium for a large part of the duration of GAIA was also on a path towards designing and implementing stable, trustworthy and overall better-performing hardware. There was a learning curve for the consortium with respect to realizing what can actually be installed and used effectively inside a school environment. This goes for the cost of the installation as well. In this respect, as mentioned previously, GAIA's initial installations began with a cost above 1000 euros, while currently this cost was reduced significantly in a gradual manner.

Finally, as we briefly touched upon elsewhere in this document, we believe it is important to reiterate some points with respect to the issue of using open versus closed-source hardware and software in GAIA, or similar installations inside school buildings. At the beginning of the project, apart from the first revisions of the GAIA hardware and existing solutions of the consortium partners (OVER), the consortium used inside a number of schools in Greece and Italy readily available commercial solutions to speed up the installation of IoT hardware. We also wanted to install both our own solutions alongside these types of hardware, in order to be able to compare their performance against the in-house developed solutions. Of course, this required a certain amount of time, in order to be able to make long-term measurements.

In this respect, for the aspects where we made an apples-to-apples comparison, i.e., when comparing the measurement of the same metric, we saw very small differences between GAIA's hardware and such commercial solutions. However, in certain cases such hardware offers additional capabilities and data, which go beyond our solutions' capabilities. In such cases, there arises a question regarding whether schools really need all that detail in their data, or all of these additional energy-related aspects. In the case of large organizations that have building managers that can utilize such data to devise and implement efficient energy-saving strategies, they are justified. However, in many of the schools that participated in the project, such expertise is not available and it is probably difficult to integrate such data into the educational context of lectures in a meaningful manner.

Finally, there is the additional aspect of reliability and serviceability. In the case of commercial power meters and sensors used in some of the schools in Greece, we had the issue of their batteries being depleted after a certain period. This resulted to these devices going offline, which in turn meant extra costs for servicing and replacing their batteries and periods without data in the meantime. The utilization of the Greek school network for our communication also meant that certain customizations had to be made, in order to get data from these sensors. In the event of new changes in the underlying communication network, this process had to be repeated, adding complexity and costs to the project. In contrast, the in-house developed solution in GAIA was under the consortium's control and could be modified easily to adapt to such changes. In addition, when taking into account that GAIA-like infrastructure is expected to operate for a number of years, such costs add up significantly over time. Essentially, at least in the context that we are discussing for GAIA, it is not the case here that more capabilities and higher cost equals better results and reliability. Therefore, this is an additional dimension that building managers and school administrators should have in mind.

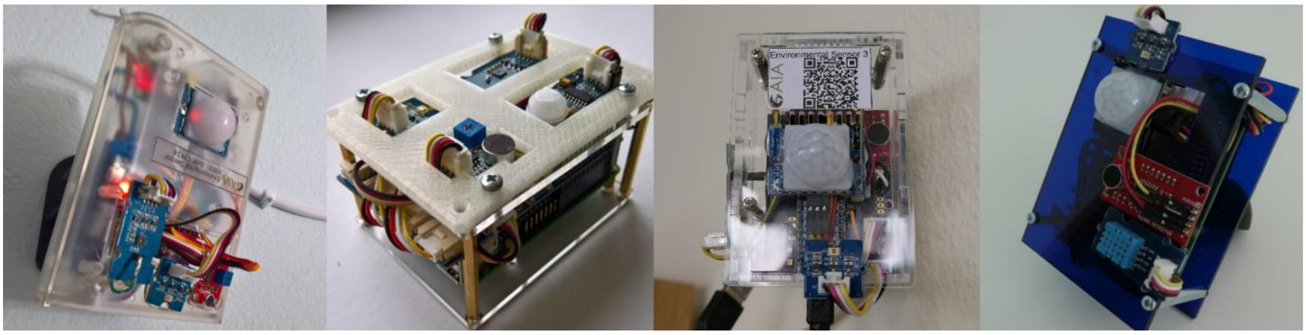


Figure 100 Different revisions of the GAIA environmental IoT nodes

18. Overall GAIA trials evaluation results and KPIs

GAIA defined in deliverables D1.1 and D4.2 a list of Key Performance Indicators to allow the assessment of its results and of the achievement of its primary set of KPIs defined in the DoA. As explained in Deliverable D4.2, the monitoring of trials had a two-fold purpose:

a. to monitor students' and teachers' involvement in school activities regarding the GAIA project, and,
b. to monitor how the KPIs change during the period of trials.

Overall, the schools' activities were monitored through GAIA applications, as well as by using reports and questionnaires during the activities or shortly after they took place inside the schools. With respect to the numbers of students in the schools in GAIA that participated in the core educational activities, we have utilized the numbers given directly by the schools reporting the number of students in classes that were assigned to participate in the project. For the total number of students in each school, we have utilized the numbers given by the schools and in the case of public schools in Greece the numbers provided by the system supporting the operation of the Ministry of the Educational Affairs, which is operated by CTI. This enabled us also to have the number of discrete students participating in the project for two consecutive years, since there was an overlap between these 2 years. With respect to activities that were conducted by or in cooperation with the consortium, like the Lab Kit activities, we utilized our own logging reports to count the number of students that participated in each school.

With respect to the use of the software components of GAIA, e.g., the GAIA Challenge, the project website and the Building Manager Application, as mentioned in previous chapters we have used open-source analytics platforms like Matomo (formerly Piwik, as referred to in previous deliverables). This enabled us to have very detailed statistics for many aspects of the end users' engagement with the project, e.g., tracking the average session time for the Challenge.

We continue with the results of the project with respect to the most general KPIs defined in GAIA's DoA.

Table 9 The KPIs identified in GAIA DoA and results at the end of the project

#	GAIA KPI identified in DoW	Results at the end of the Project
1	6900 students and educators reached directly during the project	The school communities in the project included in total more than 9,000 students and teachers for the 2 school years 2017-18 and 2018-19. In practice, of those students, 3084 participated directly during the project for long periods, in the context of GAIA-focused educational in-class activities. As detailed in Section 2 and Table 1 of this document, we provide specific numbers for each school and academic year and make an additional categorization between students that were reached directly through the overall activities of the project and ones that participated to the core, long-term educational activities in the trials period.
2	An order of magnitude more after the end of the project through established dissemination networks	The consortium has participated in many exhibitions and science festivals with thousands/tenths of thousands of visitors. We have also disseminated our results through established networks, such as IEEE (e.g., IEEE IoT Newsletters) and the Greek School Network Portal. The consortium will actively support the existing network of schools and

		expand it until at least the end of 2020. Thus, the consortium has established a foundation to deliver on this aim as well.
3	24 educational sector buildings in 3 countries covering North, Central and South Europe	School and university buildings in 25 locations in Greece, Italy and Sweden with GAIA IoT infrastructure, as detailed in D4.2 and this document. There are plans within the consortium to continue the expansion of the GAIA infrastructure to additional schools in Greece.
4	2 courses, sets of educational material and handbooks will be produced, available in Italian, Greek and English	2 GAIA booklets produced, to be made available in Italian, Greek and English, shortly after the end of the project. Other sets of material for in-class activities and questionnaires were also produced. Educational material such as the one for the Lab Kit has been tested in-class for 2 consecutive school years with 916 students.
5	Reductions of over 15% on the energy that can be influenced by the end-users	Energy savings results in schools are detailed in several sections and tables of this deliverable. The vast majority of the schools in GAIA that engaged in educational energy-saving activities have produced tangible energy savings during the trials periods. Moreover, the consortium has been successful of superseding this 15% goal in several schools, although not in all of them.
6	Develop educational games, mobile apps, and social networking tools for fostering energy efficient behavior	The consortium has developed the GAIA Challenge, the Building Manager Application, the Scavenger Hunt, the GAIA Companion Android app, the Participatory Sensing Android app, and the GAIA Lab Kit toolset among others. They have been tested extensively by our end-user group, e.g., the GAIA Challenge has had 3777 registered users by August 2019. As mentioned in this document, the consortium will support these tools until at least the end of 2020, keeping them available to students and teachers.

Energy-related KPIs

Table 10 Energy-related KPIs for GAIA at the end of the project

Code	Name	Brief description	Validation Methodology	Results at the end of the project
E.1	Primary Energy Consumption per m^2	Building energy consumption related to the floor space	Measured in kWh	The respective results are presented in detail in Chapters 6-10 for the schools that participated in the project.
E.2	Primary Energy Consumption per m^3	Building energy consumption related to the building volume	Measured in kWh	
E.3	Energy Consumption for lighting	Building energy consumption related to lighting activities	Measured in kWh	
E.4	Energy Consumption for heating (where applicable)	Building energy consumption related to heating activities	Measured in kWh	As stated in D4.2, the measurement of this KPI strongly depends on the specific school building and we relied on crowdsourcing for such input. Schools in general opted to focus much less on heating than overall electricity consumption.
E.5	Energy Consumption per other school processes	Building energy consumption related to other activities, such as school cafeteria, security, 3rd party groups activities, etc., which will be identified for each school separately	Measured in kWh	The respective results are presented in detail in Chapter 10, for multiple schools in Greece. Schools in most cases can now identify the energy used in such processes.
E.6	Energy Consumption Peak load		Measured in kWh	The respective results are presented in detail in Chapters 6-10.

Environment-related KPIs

Table 11 Environment-related KPIs for GAIA at the end of the project

Code	Name	Brief description	Validation Methodology	Results at the end of the project
ENV.1	CO_2 emissions per m^2	Building energy emissions related to the floor space	Measured in kg of CO_2 per m^2	The respective results are presented in detail in Chapters 6-10, for multiple schools.
ENV.2	CO_2 emissions per process (lighting, heating, other)	Building energy emissions related to the building volume	Measured in kg of CO_2	

KPIs ENV.3 (CO_2 emissions for trips to/from school) and ENV.4 (Other pollutants related to heating from diesel) included in D4.2 were originally designed to be calculated based on crowdsourcing activities, alongside other community-focused activities (e.g., ridesharing, collective cooking) that were assigned as project tasks to the consortium partner EDOC. Since EDOC left the consortium, these aspects could not be handled sufficiently by other members of the consortium, and have been removed from our list of evaluation KPIs.

Cost-related KPIs

Table 12 Cost-related KPIs for GAIA at the end of the project

Code	Name	Brief description	Validation Methodology	Results at the end of the project
F.1	Cost savings	Absolute cost savings due to reductions brought by GAIA in energy (all types) consumption	Evaluation of costs relative to energy consumption and comparison with previous years	The respective results are presented in detail in Chapters 6-10, for multiple schools.
F.2	Simple Payback Period	The time required for the return of the investment in GAIA infrastructure and services	Based upon the savings and the typical cost of providing GAIA services	The respective results are presented in detail in Chapters 6-10, for multiple schools, and in Chapter 17.
F.3	Average annual rate of return on investment (ROI)	Considering a 5-years pay-off time, we will calculate the annual rate of ROI	Calculate infrastructure costs and energy cost savings	The respective results are presented in detail in Chapters 6-10, for multiple schools, and in Chapter 17.

Human comfort-related KPIs

Table 13 Human comfort-related KPIs for GAIA at the end of the project

Code	Name	Brief description	Validation Methodology	Results at the end of the project
HC.1	Thermal Comfort - Minimum indoor temperature	Minimum indoor temperature during winter time, should not be under a specific temperature more than 1% of actual building utilization hours	Predictive Mean Vote, Percentage People Dissatisfied	A detailed discussion is provided in Chapter 11 of this document.
HC.2	Thermal Comfort - Maximum indoor temperature	Maximum indoor temperature during summer time, should not be over a specific temperature more than 1% of actual building utilization hours	Predictive Mean Vote, Percentage People Dissatisfied	
HC.3	Visual Comfort	Amount of light available inside school classrooms	Daylight factor, average level of minimum illuminance	
HC.4	Indoor Humidity	Amount of humidity present inside school classrooms		
HC.5.OPT	Aural Comfort (OPTIONAL)	Average level of noise inside classrooms and other school areas. According to the WHO guidelines for noise levels, daily exposure to noise levels over 85dB is considered dangerous	Use of noise level sensors, monitor school classrooms where possible	Some representative results from schools in Greece are presented in Chapter 11 of this document.
HC.6.OPT	Air quality Comfort - Minimum Airflow rate (OPTIONAL)	Quality of air depending on the concentration of particles, indoor pollutants, room use, end-user activity	Use of suitable IoT sensors in select schools and classrooms	

Behavioral-change related KPIs

Table 14 Behavioral-change related KPIs at the end of the project

Code	Name	Brief description	Validation Methodology	GAIA target	Results at the end of the project
GB.1	Time spent using Web portal	The time spent by end-users on the Gaia-Applications (all 3 WP3 applications combined + GAIA Website)	Use server-side system logging components, monitoring all related activity, while also having in mind privacy issues	7-10h	The average time for BMA visits is 10 minutes and 52 seconds during the project lifetime, while for GAIA Challenge it is 14 minutes and 11 seconds for every visit, both excellent results. However, the session time for the Challenge is affected by users who registered but did not start a mission. Considering users that started and completed a mission, the projected value of total time spent on the Challenge is 180 minutes, instead of the 45 minutes calculated on average otherwise. This combined with the 140 minutes spent on the BMA on average, and the time spent on the website, gives a result of over 6 hours.
GB.2	Persons using web portal	An estimate of the number of different end-users utilizing Gaia-Applications (all 3 WP3 applications combined + GAIA Website) GAIA web portal	server-side system logging (see GB.1)	30-40% of target group (mixed: classroom activities 100%; voluntary usage 20%)	Project website: 21082 all-time views BMA: 256 unique users GAIA Challenge: 3777 users
GB.3	Sessions per user	Average number of separated sessions a user engages with all Gaia-Applications	server-side system logging (see GB.1)	30	The external analytics tool measures the number of the sessions that the user has done for a given time period. The average session numbers

					per user during the project lifetime are: GAIA Challenge: 3.21 GAIA BMS: 12.5
GB.4	Session duration	Average session duration of all users and sessions	server-side system logging (see GB.1)	5-10 min	The average time for BMA visits is 10 minutes and 52 seconds during the project lifetime, while for GAIA Challenge it is 14 minutes and 11 seconds for every visit, both excellent results.
GB.5	Cohort analysis	A measure how long a user stays engaged over the course of multiple days (without interruption; meaning: at least one session per day)		3-5 days	GAIA Challenge: The GAIA Challenge has 0.5% visits that have been executed on consecutive days and 66.4% of recurring visits on the same day. GAIA BMS: 74.3% of the total visits were executed in consecutive days. We observed consecutive days of visits extending for over more than 2 weeks, with most visits taking place on school days.
GB.6	#Action Missions completed (originally named #sensing quests completed)	A measure of how many classrooms started the Action missions (originally called in D1.1 “sensing quests”) Explore, experiment, act.	server-side system logging (see GB.1)	50-70%	Mission completion rate of users who have started a mission at least once (considering 1 attempt per user): • 92,30% all missions • 92,67% knowledge missions • 91,68% action missions It can be concluded that more than 9 out of 10 users *who have started a mission* also have completed it at least once.
GB.7	#educators contributing educational scenarios and educational material	A measure of the engagement of educators with the GAIA platform, based on their	server-side system logging (see GB.1)	8	10 (detailed analysis is provided in Chapter 4). As a side note, the consortium has also submitted publications to conferences and journals with GAIA educators.

		contributions and customizations			
GB.8	#knowledge quest Finishing rate	A measure of how many quests, which have been started are actually finished to a valid result.	server-side system logging (see GB.1)	60-80%	92.67%
GB.9	Participants' awareness	A measure of how much change students', teachers' and parents' awareness regarding the energy consumption after the trials	Pre and post trials survey	Increase	As analyzed in this document, **the result at the end of the project is approximately 75%**, as suggested by our pre- and post- activities survey

Education-related KPIs

The following table includes the respective KPIs, descriptions and goals set for GAIA. GAIA *has reached and superseded all of its education-related KPIs.* Our results are in several aspects an order of a magnitude better in this respect, compared to other related research projects.

Table 15 Education-related KPIs for GAIA at the end of the project

Code	Name	Brief description	Validation Methodology	GAIA target	Result at the end of the project
ED.1	#students directly involved	Number of individual students directly involved with the project, through educational, gamification and other project activities	Student lists from schools	5500	**3084** students participated for long periods **>9000 students** affected overall as detailed in Chapter 2
ED.2	#students indirectly involved	Number of individual students indirectly involved with the project, participating through educational, gamification and other project activities	Participation lists in workshops and other project activities	500	As detailed in D5.4, GAIA has participated in dissemination events with thousands of visitors. We have also organized a large number of workshops, so **this number far exceeds 500.**

ED.3	#teaching staff involved	Number of individual educators directly involved with the project, through educational, gamification and other project activities	Participation lists in workshops and other project activities	900	As described in Chapter 2, **the number of teaching staff involved exceeds 900.**
ED.4	#educational workshops organized	Number of educational workshops organized by GAIA directly involving and aiming at the educational community	Organization of workshops	3	8 (2 summer schools, 4 workshops with teachers in Greece and 2 in Italy)
ED.5	#educational scenarios and toolkits	Number of educational scenarios and toolkits produced by the project	Availability on the project website	20	30 in total, calculated as follows: • the general GAIA pedagogical framework • the 18 reports of activities gathered from schools (i.e. the school-specific realizations of the general framework) • the 6 GAIA lab kit activities • the 2 booklets • the lab kit, as a structured entity • 2 educators' scenarios for the GAIA contest
ED.6	#European languages translated	Number of European languages in which the educational material will be translated and be made available at the end of the project	Availability on the project website	3	3, target reached
ED.7	#parents, relatives or friends indirectly involved	Number of parents, relatives or friends of students that have been informed about the project and related products (e.g., website, game, social presence, etc.)	Participation lists in workshops or press events, or social networking platforms	250	As detailed in D5.4, **our social networking followers' total number exceeds 1150**. Since this audience consists at a large percentage of adults, **GAIA superseded this goal as well.**

19. Conclusions

At this point, we have to thank all of the schools that participated in the trials of GAIA with a sense of professionalism, as well as for all the time and other resources they dedicated to making the implementation of the GAIA trials possible.

In this deliverable, we have presented a detailed log of the trials that took place in GAIA's schools during school years 2017-18 and 2018-19, highlight the most important activities and results produced with respect to the project's educational and energy-saving aspects. During this period:

- GAIA's fleet of school buildings grew considerably with the addition of 7 new schools in Greece.
- The consortium continued to work on its software lineup in order to produce products that are even more complete and support the trials in the best way possible.
- The consortium produced a lot of educational material to be used during educational and energy-saving activities.
- Worked together with the schools to produce realistic plans for using the tools and the educational material to increase sustainability awareness and produce energy savings inside school buildings.

Overall, the implementation of the project's strategy has clearly paid off:

- 3084 students and 213 educators participated directly in educational and energy saving activities.
- Over 9000 students in the participating schools were affected to a certain degree by the project.
- 3777 users registered in the GAIA Challenge platform.
- 916 students participated in the Educational Lab Kit activities.
- 18 GAIA schools with IoT infrastructure actively worked on producing energy savings.
- Tangible energy savings were achieved on most of these schools.
- A representative survey among 775 students at the end of the project revealed a positive change in the 75% of them, with respect to gaining better understanding of the concepts related to GAIA and increased sustainability awareness.

Annex I – Sustainability Awareness Questionnaires

The "Before GAIA activities" questionnaire

Survey of students' awareness of energy-related issues (pre-test)

School:

Age:

- Primary school (6-12 year-old)
- Lower secondary school (12-15 year-old)
- Upper secondary school (15-18 year-old)

Gender:

- Boy
- Girl

What is your attitude towards saving energy?

I save energy and I think I can make a difference.

- Not at all
- A little
- Somewhat
- Much
- Very much

How aware are you of the impact of energy use on the environment?

I actively follow the issue and look for opportunities to be informed about it.

- Not at all
- A little
- Somewhat
- Much
- Very much

How much energy do you consume at home?

- Not at all
- A little
- Some
- Much
- Very much

Where do you apply your knowledge in practice?

- I try to save energy every day, at home as well as at school
- I save energy only at home

- I save energy only at school
- I am not interested in saving energy

How sensitized are you to energy waste?

- Not at all
- A little
- Somewhat
- Much
- Very much

Are you motivated to save energy?

- Not at all
- A little
- Somewhat
- Much
- Very much

Which of the following devices are found in your home?

- Computer
- Laptop
- DVD Player
- Vacuum cleaner
- TV
- Stereo
- Mobile phone
- Wireless phone
- Washing machine
- Dish washer
- Water heater
- Iron
- Hair drier
- Hair straightener
- Air heater
- Microwave oven
- Oven
- Refrigerator and freezer
- Mixer
- Refrigerator
- Air condition

From the above list, which four devices are, in your opinion, responsible for the biggest energy consumption in your home?

………

How often do you leave the lights turned on when there is no one in the room?

- Never
- Rarely

- Sometimes
- Most of the times
- Always

How often do you leave a device charging even if its battery has already been fully charged?

- Never
- Rarely
- Sometimes
- Most of the times
- Always

How often do you leave your computer turned on while it is not in use?

- Never
- Rarely
- Sometimes
- Most of the times
- Always

How often do you leave your devices (e.g. DVD player, computer screen, speakers) in stand-by?

- Never
- Rarely
- Sometimes
- Most of the times
- Always

Have you had the opportunity to decrease energy consumption at your home?

- Yes
- No

If you controlled energy consumption at home, do you believe this would help you to become more sensitized to the importance of saving energy?

- Yes
- No

Do you know ways to save energy?

- I know many ways to save energy
- I know 3-4 ways to save energy
- I know some basic ways to save energy
- I don't know any way to save energy

Do you use energy saving techniques at home?

- Yes
- No

If so, choose which of the following you use:

- I use energy-saving lamps
- I turn off the lights and check that the devices are turned off before I leave the house
- I use low-energy-consumption devices
- I try to change my daily habits to save energy
- Other: ……….

The "After GAIA activities" questionnaire

Please answer the following questions carefully. Your answers are anonymous and will not affect anyone's opinion about you. It is very important to help us understand how young people like you think.

Tell us about you:

I am...

- a girl
- a boy
- I don't want to say.

My age is...

- up to 11-12 years
- From 12-13 to 14-15 years
- From 15-16 to 17-18+ years

The name of my school:

……………

Let's start!

Think of energy consumption every day: for lighting, heating, traveling, working, reading, having fun...

And think about what you learned and did at your school about energy consumption and energy saving.

I know about and I understand...

...the consequences of wasting energy for the environment:

- Not at all
- A little
- So and so
- Well
- Very well

...in what ways we consume energy at school and in everyday life:

- Not at all
- A little
- So and so
- Well
- Very well

Think fast: How many ways of saving energy come to your mind immediately?
• None • One • A few (e.g. 1-2) • Some (e.g. 3-4) • Many
After what we have done at school about saving energy... ... I've tried to change some of my everyday habits to save energy:
• Not at all • A little • So and so • Much • Very much
...I will advise or even tell someone off, if I see that they waste energy:
• Never, I don't think I should. • Maybe, but generally I avoid this. • Yes, but only if the waste of energy seems to be big. • Yes, of course, this is very important!
…I try to stay informed about energy and environmental problems:
• Never, this topic is boring. • Generally, I try, but it's a bit boring. • Quite often, especially if I need that for school. • Often, I am interested in this topic. • Very often, that's extremely important!
Think fast: What did you do yesterday and today to save energy?
• Almost nothing. • I thought about that a couple of times. • I thought about that many times. • I tried to save energy through my choices and practice. • I did really a lot to save energy; I paid attention to this matter all the time.
With what we have done recently at my school... ...we have managed to save energy in the school:
• No, I don't think we tried. • No, we tried but it was difficult. • Yes, we have probably saved energy, but I don't know how much. • Yes, we have saved energy and I know some details about this.

From the things we did at school about saving energy:

…I liked the game (“GAIA Challenge”):

- Not at all
- A little
- So and so
- Much
- Very much
- I don't think I played the game.

...I liked to observe and use the data and measurements:

- Not at all
- A little
- So and so
- Much
- Very much
- I don't think I worked with data and measurements.

...I liked the lab activity with the circuits etc.:

- Not at all
- A little
- So and so
- Much
- Very much
- I don't think I took part in such an activity.

I learned a lot of interesting things about energy...

... by playing the digital game (“GAIA Challenge”):

- Not at all
- A little
- So and so
- Much
- Very much
- I don't think I played the game.

...I learned a lot by observing and using the data and measurements:

- Not at all
- A little
- So and so
- Much
- Very much
- I don't think I worked with data and measurements.

...I learned a lot in the lab activity with the circuits etc.:

- Not at all
- A little

- So and so
- Much
- Very much
- I don't think I took part in such an activity.

And a last thing, please: please think and tell us...

...about a case when you managed to do something important against wasting energy at your school or at home (in a few words):

..what makes it difficult for you to pay more attention to energy consumption in everyday life (in a few words):

...what you would like to do at school next year to learn more about saving energy (in a few words):

Have you answered all questions? Then, "SUBMIT"!

Remember: Your careful attention and the truth in your answers will be a real help in the efforts to use energy smartly and save our planet from the dangers of climate change!

Thank you very much for your help!

Lab Kit Evaluation Questionnaire

Did you enjoy the lab kit activities?

- Not at all
- A little
- So and so
- Much
- Very much

Which one did you like the most and why?

(Free text response)

Which one did you enjoy less and why?

(Free text response)

Did you have previous experience with electrical circuits?

- Not at all
- A little
- So and so
- Much
- Very much

Did you face difficulties in completing the activities?

- Not at all
- A little
- So and so
- Much
- Very much

Have you had an introduction to the lab by your teachers?

- Not at all
- A little
- So and so
- Much
- Very much

If yes, did it help you in the activities?

- Not at all
- A little
- So and so
- Much
- Very much

Do you think that the activities helped you to learn something about your building's behavior?

- Not at all
- A little
- So and so
- Much
- Very much

Would you like to repeat the same activities in your house or inform your parents about them?

- Not at all
- A little
- So and so
- Much
- Very much