GAIA - Green Awareness In Action

D1.1 GAIA Design

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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
EDS	En-Decoder System

Executive summary

As GAIA reaches its first milestone after 6 months of activity, this deliverable summarizes the work conducted thus far in task T1.1 of the project, by describing the trial sites, the buildings, their building services and existing metering technologies. A detailed discussion on the design of interfaces between these metering technologies is included in this document, along with an expansive set of KPIs, facilitating the evaluation of the progress and the performance of the project as it moves forward, as well as grasp the potential contributions of the project into various fields.

Regarding the important aspects of GAIA's design philosophy, we provide a lengthy discussion on the principles that will help shape the outcomes of the project:

- Uniformity of design, replicability and reusability
- Anonymity and Privacy
- Compatibility with school buildings design
- Compatibility with school daily activity and organization
- Open source approach
- Conformance with existing standards
- Non-invasive installation
- Minimal operational costs
- Use of existing resources for GAIA trials
- Monitoring-only infrastructure with no actuation capabilities

This discussion aims to provide a starting point for describing the overall project efforts so far, and explain several decisions behind the design presented in this document. Regarding the actual infrastructure that will be utilized throughout the project, we report on:

- *The school building sites that will participate in GAIA*: an effort has been undertaken by the consortium for the past months, to describe in detail the available buildings and associated existing infrastructure. We present here only a part of it, due to the huge amount of space required.
- *Design of IoT infrastructure*: we describe IoT infrastructure installations that will be completed in the coming months at GAIA school buildings.
- *Actual progress in implementing IoT infrastructures*: The project has already completed a large percentage of the envisioned installation and interconnection to a cloud infrastructure. We report on the actual situation at this moment inside all of the school buildings involved.

Furthermore, this deliverable additionally provides detailed information regarding the metering technologies that will be utilized in GAIA, along with the related interfaces to the GAIA data platform, as they have been defined up to this point. A number of platforms are available to the consortium from SMEs participating in the project (SparkWorks, Synelixis, OVER). We plan to utilize all of them in our deployments, in order to build a truly heterogeneous and versatile system for GAIA. This is complemented by the fact that the buildings involved have a number of differences between them, and there isn't a single platform available that can provide an efficient answer for all cases in a holistic manner. Moreover, the consortium has already worked with third party solution providers, and has integrated their solutions to the GAIA platform under development, to a certain degree. We additionally provide short descriptions of these solutions, along with pointers to further information.

Continuing this line of thought, about the versatility and heterogeneity of the developed GAIA platform, we also make our case in favor of producing open source software and hardware results. A certain part of the project's activity will aim for producing such kind of results, especially since GAIA is dealing with the educational sector. We make a point regarding the open source philosophy of GAIA in various aspects, describing its contributions thus far, which materialize in the form of utilized IoT sensor nodes, which have been modified based on existing designs, and have not been published as open source previously.

We also include additional dimensions into the work envisioned, such as the educational kit described in this document, aiming to enhance the overall end-user experience and potential impact of the project. This is an aspect that was not originally included in the DoW of the project, and which will be further developed in the coming months along with the related educational material. We try to provide information in all of these aspects, along with insights on how the hardware infrastructure will be used further on in the project, together with the educational activities and the gamification aspects.

After providing the general descriptions regarding the project infrastructure design, philosophy and aims, we continue with a discussion on how existing partner platforms will be integrated in order to provide a unified GAIA cloud infrastructure. A set of APIs are discussed, in order to give insights as to how this implementation will take place in the coming months, and what kind of data and applications it will enable and support.

Furthermore, a lengthy discussion on KPIs is provided in this document, aiming to form a more analytic and coherent list of performance indicators, that will help to put forth all the contributions of the project, and not just energy savings. This list will simplify the procedure of quantifying such aspects of the project. Regarding the envisioned GAIA trials, this deliverable describes all necessary additional sensors and metering devices that will be installed to serve the considered use cases. We also include elements of the gamification and application design, as they have been formed at this point in time.

Finally, within the project this document will serve as a guideline for the technical implementation of the trials and also as a controlling mechanism for the validation of the trials. It is worth stressing that while in the DoW, the results of the work of task 1.2 regarding the use scenarios for energy efficiency (heating, electricity, etc.) as well as requirements and characteristics that need to be taken into account are going to be presented in D1.2, as this comes on M24, we have outlined in the current deliverable the envisioned scenarios and the requirements it introduces as these guide both the provision of equipment and the design of the GAIA applications. In this course, the scenarios and requirements will be elaborated and refined in D1.2.

Contents

1. Deliverable Context and Structure

This deliverable presents several of the fundamental GAIA design aspects, which will be realized and tested in the subsequent WPs towards achieving the goals and KPIs already defined in the DoW. Thus, in a number of ways, it sets the ground for the launch, development and progress of the rest of GAIA's WPs. This document mainly summarizes the work already conducted in task T1.1 (as also mentioned in the DoW) and partly the work of task T1.2, with respect to KPIs, use-cases and scenarios, which are necessary for capturing the user and system requirements, for designing the GAIA system/applications and for kickstarting the work in WP2, WP3 and WP4.

We have included several additional aspects not described in the original DoW for GAIA, as work in WP1 has already revealed additional possibilities in terms of hardware and software design. We stress out the open source dimension of the system already in place for the IoT backbone of GAIA. Moreover, placing emphasis on the education and awareness raising through serious games, we have already made good progress in terms of the gamification design aspects of the project, and we thus report on several of such aspects in this document, in order to give a good idea how the fundamental parts of GAIA design will converge to make the envisioned system a reality.

Additionally, we want to emphasize the fact that this is not merely a design document; a large number of the school buildings participating in the project have already had IoT infrastructure installed, which is now operational. This gives us a good head start in terms of actually testing and validating the performance of GAIA's core, and enables us to start building software prototypes as soon as possible. We report on the already available infrastructure and services in detail in this document as well.

GAIA's design philosophy in short

GAIA aims at improving energy efficiency by increasing awareness of specific target groups, all related to the educational process and community. In order to achieve this goal, we will utilize the infrastructure available at schools and enrich it towards gathering information. This information is used by a set of applications to guide energy efficient behavior, which is assessed through the continuous monitoring of building energy consumption. The next chapter in this text includes a more detailed discussion on the design principles and logic that we have followed thus far.

The methodology we follow towards designing the GAIA applications and achieving our goals with the predefined budget and timeline consists of:

- Step 1: Listing of the trial sites, the buildings, their building services and existing metering technologies.
- Step 2: definition of KPIs (breaking down the high level KPIs from the DoW) and of ways to assess them, (e.g. with precise formulas)
- Step 3: Definition of additional sensing devices required to measure the KPIs.
- Step 4: Definition of use case and scenarios to draw user and system requirements.

- Step 5: Specification of the GAIA platform architecture and of the GAIA applications.
- Step 6: Definition of trials set-up and initial specification of the trials control mechanism.

Overall structure of this document

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

Chapter 2: Overview of GAIA's design and its principles.
Chapter 3: Detailed descriptions of the trial sites, the buildings, their building services and existing metering technologies – including the ones owned by the school and infrastructure installed already by GAIA. The information is presented organized by country – Sweden, Italy, Greece. Such information is complemented by details regarding the schools' operation and educational organization.
Chapter 4: Description of the GAIA SME partners metering technologies that will be utilized in the project.
Chapter 5: Description of the GAIA educational lab kit.
Chapter 6: Description of open source efforts in hardware aspects already available from GAIA.
Chapter 7: Definition and analytic description of the KPIs that are going to be utilized in the project to evaluate its progress and performance.
Chapter 8: High-level description of use-cases and scenarios for the envisioned applications and serious games, complemented with elements from the gamification design aspects of the project.
Chapter 9: Trial set-up and validation mechanism (describe all necessary additional sensors and metering devices that might have to be installed). This chapter will serve as a guideline for the technical implementation of the trials in T4.1 and as a controlling mechanism for the validation of the trials in T4.4.
Chapter 10: Description of the GAIA system requirements.
Chapter 11: A summary and conclusions regarding the current status of the project.

A number of annexes that serve to clarify various aspects related to the design presented in this document are also included:
Annex I - List of available data sources for Greek public schools: This section provides an analytic list of existing IoT data sources that will be utilized during the project.
Annex II – **Overview of the Greek Educational System and details about public schools participating in GAIA:** Additional information regarding the Greek educational system and participating schools, complementing the data discussed in Chapter 2 of this document, giving a clearer picture of the schools' profile.
Annex III – Letter from the Province of Prato: an official letter from the Province regarding its policy for school heating.

2. GAIA Design Overview

In this chapter, we aim to give an overview of the current GAIA design regarding school building infrastructure, its principles and goals that has affected its formation, as well as a summary of the current status of the related aspects. We also point out the gamification, educational and participatory sensing concepts adopted in GAIA design as these represent important educational means. An analytic description of each trial site, more detailed descriptions of the currently available infrastructures in schools, and the respective datasources, as well as further information on the GAIA applications are available in following chapters of this document.

GAIA platform architecture and design principles

As explained also in GAIA's DoW, a main objective of environmental sustainability education and energy efficiency awareness initiatives in schools is to make students aware that energy consumption is largely influenced by the sum of individual behaviors (at home, school, etc.) and that behavior changes and simple interventions in the building can have a great impact on achieving energy savings. IoT technologies allow for data production from the real world in order to feed a plethora of people-centric information, education and involvement initiatives conducive to effectively change the ways people live and work inside school buildings and achieve better energy efficiency. This means, by enabling a completely different set of applications, like gamifications apps that bridge the virtual world with the real one, towards the end-goal of such systems people will be better informed and capable of making more educated decisions. Also since public buildings, and in particular educational buildings constitute a large part of the building in Europe, and also students also constitute a sizable part of the overall population [Europe1, Europe2], making these technologies available and tailored specifically for end-user group can potentially have large benefits.

GAIA's design follows the idea that *the availability of actual measurements of environmental parameters, such as energy consumption, indoor and outdoor luminosity, temperature, noise, pollution, etc., enables the conception and realization of diverse applications and scenarios*. Our goal is to provide a platform, which will cater to the requirements of a broad variety of applications that will facilitate the educational sector towards improving the energy efficiency of school buildings. On top of that, the educational sector presents a very interesting and important case for monitoring and management, due to having a very large number of buildings to operate that are oftentimes situated in a very fragmented manner. In national educational systems, we have literally thousands of buildings spread throughout a country, usually with very different characteristics in terms of construction, age, size, etc. We are developing our system keeping these facts in mind, and, subsequently, our design has been greatly influenced by such factors.

Apart from design aspects, *GAIA has already been augmenting and implementing IoT infrastructure in the participating school buildings*. Especially in Greece, the majority of the required IoT infrastructure is already in place, operational and producing data. In Italy, the majority of the required IoT infrastructure in Rome has been procured and on track for installation completion, while in Prato the infrastructure will be in place at the start of the school year 2016-17. The rest of the GAIA sites already have a set of infrastructure already in place that will help to realize the goals of the project for the coming year. The following table provides an overview of the current status of GAIA regarding IoT deployments. Actual numbers will increase in the coming weeks, since additional infrastructure installations are scheduled for specific GAIA sites, but are indicative of the progress achieved thus far in this aspect. Furthermore, a detailed list of currently available GAIA datasources is included in Annex I of this document.

In terms of educational staff and students, Fig. 1 gives an overview of the numbers involved for the academic year 2015-16. We expect the figures for the 2016-17 academic year to be similar. Table 1 includes information regarding *the numbers with respect to actual GAIA deployments so far.*

Table 1 GAIA deployments so far

Country	Parameter	Number	Comment
Greece	Sensing endpoints	872	Each sensor equals 1 sensing endpoint
	Sensing rate	1 minute	Can be modified
	Educators	294	Greek public schools in GAIA
	Students	2267	Greek public schools in GAIA
Italy (Rome)	Sensing endpoints	79	Will soon be augmented
	Sensing rate	1 minute	Can be modified
	Educators	120	University faculty and Post Doc
	Students	1706	University students

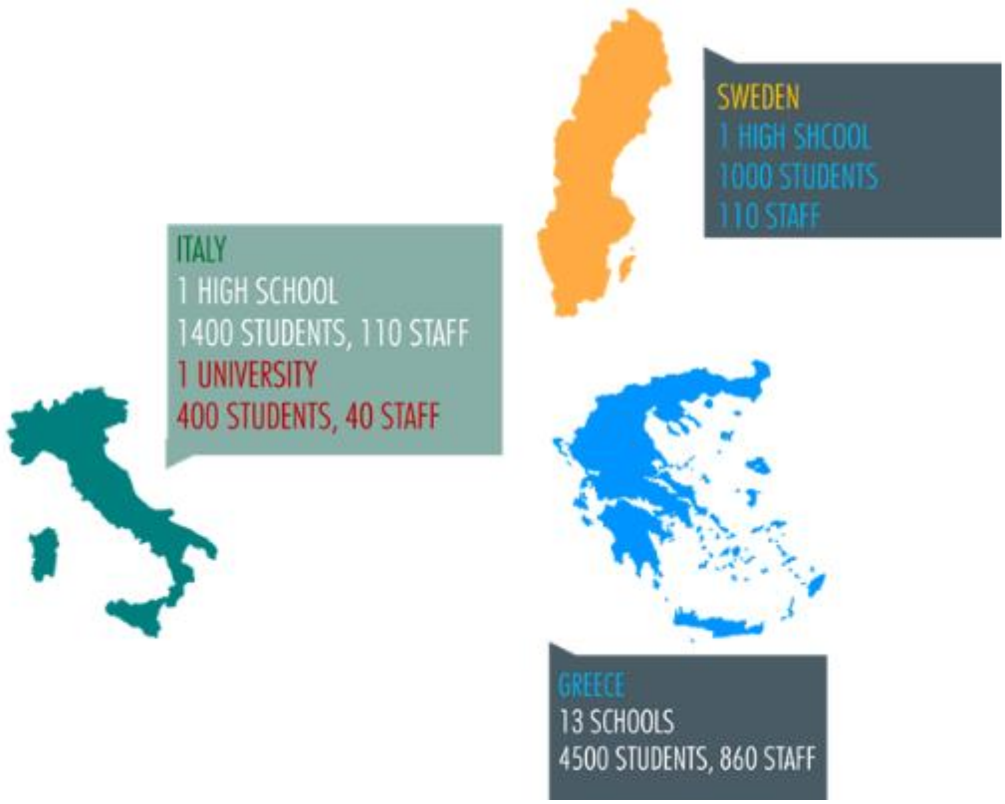


Figure 1 Main figures regarding GAIA sites and end-users

Fig.2 gives an overview of the architecture of GAIA; it is apparent that the IoT level and associated ecosystem runs through all of the architecture levels. Thus, it is important to outline the thinking behind the design presented in this document, and why it fits with the envisioned GAIA architecture and overall planning for the project and school trials. We now continue analyzing the pillars in GAIA's design philosophy, and how they are referenced in this document.

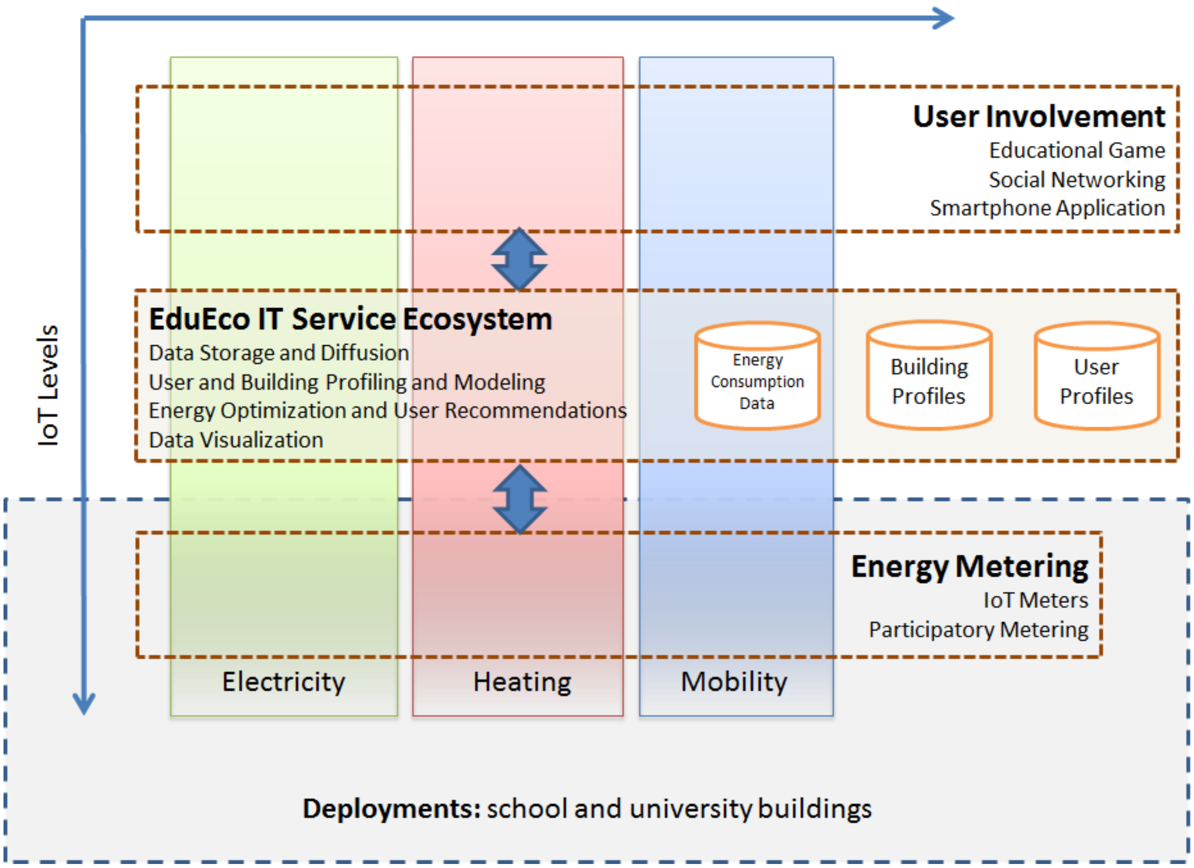


Figure 2 GAIA architecture design overview

Uniformity of design, replicability and reusability: all of the GAIA trial sites follow similar design patterns regarding their infrastructure, even though they are applied in different environments, and based on different device types and vendors, as explained in: a) Chapter 4, where metering technologies used in GAIA are presented, and, b) Chapter 6, where we detail our open source approach on hardware. This allows GAIA to have great flexibility with respect to hardware, thus having an approach that is *replicable and reusable*, *both in terms of hardware and software*, since end-user applications can make the assumption that all GAIA sites feature similar capabilities.

Anonymity and Privacy: since GAIA is dealing with very sensitive end-user groups in terms of privacy, the design needs to respect such aspects. The technologies and installations described in this document attempt to capture the activities of groups of people, rather than specific end-users, where possible. This greatly simplifies the process of anonymization of data that will be generated during the project's run. In any case, GAIA will respect and fully comply with the newly agreed Regulation on personal data privacy EU 679/2016.

Compatibility with school buildings design: GAIA's deployments try to adapt to the design and organization of school buildings; although there are several cultural differences in the way school buildings are designed in Sweden, Italy and Greece, there are many similarities as well. Also, school buildings have features that are in many ways very different than other public buildings, e.g., office buildings. Such characteristics have been taken into account. Chapter 3 gives an overview of the buildings that will be involved in GAIA trials.

Compatibility with school daily activity and organization: GAIA infrastructure and ecosystem aim to become a part of the educational activity taking place at the participating schools. As mentioned above, the data originating from the IoT can potentially stir the interest of students and educators alike, and ideally make for a more personalized educational experience. Chapter 5 details the design of the Educational Lab Kit, with the related envisioned activities also being a part of the schools' curriculum.

Open source approach: we wanted our system to be expandable and easy to interface with other systems or components. Chapter 6 gives some details regarding contributions of the project on the hardware plane. Moreover, the utilization of open standards and components gives GAIA great flexibility and adaptability in order to meet such goals; we plan to intensify our efforts towards such aspects. Ideally, the results of GAIA could be further utilized by third parties, replicating the open design results and extend or modify them in ways not foreseen by the project.

Conformance with existing standards: It is reasonable to expect a diverse set of device providers working under the same interoperability framework. Due to this, we are hardware independent: sensors from different manufacturers interoperate with our system. We envision an IoT ecosystem that is composed of a variety of business players that collaborate towards bringing together a diverse set of devices for real-time monitoring and management of school buildings. To do so, we work by following the concept and scope of the IoT as defined by ITU-T in 2012 [ITU-T]. We also follow common practice on the hardware plane, utilizing ubiquitous technologies, such as ZigBee, IEEE 802.15.4, the Arduino ecosystem, popular cloud technologies, etc.

Non-invasive installation: another critical point is the non-invasiveness of the IoT infrastructure of GAIA; as it is crucial that no significant changes are involved in installing new IoT devices inside classrooms, i.e., no significant costs are incurred. As an additional advantage, equipment can be easily relocated to other building spots for convenience. The current design also avoids complex installations, which are already complicated by the fact that GAIA is dealing with school buildings and all the associated limitations and directives.

Minimal operational costs: apart from the installation costs, there are the operational costs associated with the IoT infrastructure. The use of standard hardware components like low-power microcontrollers limits the energy consumption of such devices to several watts, thus the overall energy consumption of GAIA's infrastructure for a building amounts to less than the consumption of a single light bulb.

Use of existing resources for GAIA trials: our design follows the principle of pervasive computing, in that it should become a part of its environment and not require sophisticated methods to operate. The Educational Lab Kit will also follow this principle, and will be run by school staff and students.

Monitoring-only infrastructure with no actuation capabilities: the design reflects the fact that GAIA is dealing with a sensitive sector. It is also a product of the fact that end-users should be included in the feedback-action loop; an ecosystem that acts completely in a transparent manner to the end-users does not help in keeping them engaged in the whole process.

Description of the typical GAIA school building infrastructure

A typical GAIA IoT infrastructure inside of a school building consists of the following components:

- Power meters installed inside electrical distribution panels.
- IoT "smart" plugs, that act as power meters in select building electrical outlets.
- IoT sensor boxes comprising sensing points for temperature, humidity, air quality, presence, and noise levels, which are installed into select classrooms or other school building rooms.
- IoT weather stations, typically installed outdoors on the buildings' roofs or select spots.
- IoT gateway devices, serving as local coordinators of the IoT network and connecting to the GAIA cloud infrastructure and ecosystem.

All of the aforementioned IoT devices communicate wirelessly with each other, eliminating almost all dependency on wired connectivity, apart from the gateway devices. Specific details on networking technologies and protocols used are included in subsequent chapters, but in general GAIA relies on IEEE 802.15.4 and ZigBee in most cases, as well as WiFi. In several cases where wireless connectivity within the building sectors is difficult, due to network topology or building characteristics, we additionally utilize 3G-enabled devices.

For the majority of the GAIA school buildings, a typical actual installation so far consists of the following:

- 1 or 2 power meters, installed inside the school's central electricity distribution panel or one that controls a discrete building sector or floor.
- 5 or 6 IoT sensor boxes, installed inside classrooms dedicated to a specific class, or ones that are share among many different classes. A typical example in Greece is the computer lab classroom, which is shared among all classes of a school.
- 1 weather station installed on the building roof.
- 1 smart plug, which can be moved from room to room by staff or students.

This kind of typical setup enables GAIA to do the following:

- Have a detailed idea of the overall electricity consumption of the building, general patterns in consumption, irregularities, establish energy consumption baselines and extract other useful data.

- In many cases, have a view of how a specific floor or building sector fares in terms of energy consumption against the energy profile of the building.
- Using energy consumption disaggregation techniques, identification of specific devices/procedures can be performed.
- Detailed environmental data from the IoT sensor boxes can give a clear picture of what is actually taking place in classes; if rooms are occupied, how specific parts of the building behave in terms of end-user thermal and visual comfort, etc.
- The IoT weather stations give a precise picture of what is happening outdoors and within the schools areas' microclimates. Such data can be utilized to make detailed studies regarding the buildings' behavior in aspects related to e.g., insulation or even how well procedures such as heating are adjusted to environmental parameters.

Apart from the direct advantages such IoT infrastructure has, with respect to energy consumption, regarding the rest of GAIA's activities and ecosystem:

- Such an infrastructure complies with the privacy policies and restrictions. This is a very important factor to consider for GAIA since we are dealing with students, and by utilizing such infrastructure we already eliminate several risks with respect to identifying individual behaviors and activities since we are dealing with classrooms, building sectors and floors.
- It provides a solid foundation to develop GAIA applications; we are able to retrieve data in almost real-time, with good enough precision, which in turn can be further utilized in other parts of the GAIA ecosystem.
- Regarding gamification, we are dealing with real-world data that can potentially augment end-user engagement, and even provide a certain "scientific" aura to the overall experience.
- Such data can be easily integrated into a school curriculum to provide real-world examples with data produced in real time, enriching the learning process and making it more personal and easier to relate to for students.
- Such data can be used by research communities for algorithm and systems' validation and optimization purposes.

Regarding already existing infrastructure in GAIA's school buildings, in 2 sites, namely Ellinogermaniki Agogi (EA) in Athens and Staffangymnasiet (SK) in Söderhamn, there are existing Building Management Systems (BMS) available, with the respective HVAC monitoring and control infrastructure connected to such systems. GAIA is already working towards integrating these systems, which also represent drastically different cases compared to the Greek public schools, which comprise the majority of the GAIA buildings, in terms of size but also of the complexity of integrating existing equipment and BMSs. To a large degree, the existence of such infrastructure has an impact on additional equipment required by GAIA at those 2 sites.

GAIA is going to take a different approach on each of them:

- GAIA has a strong focus on open source technologies, and will develop hardware and software under such principles. In the case of Staffangymnasiet, this will be further utilized in the school's curriculum. Since it is a technical school with relevant classes, students will be assigned to assemble/manufacture sensor boxes similar to the ones used in the Greek public school buildings. This will in essence form an additional part of the school's IoT infrastructure.
- In the case of Ellinogermaniki Agogi, additional sensors similar to the ones already installed by GAIA will be available to monitor the building, along with the existing BMS. In addition, students and teachers of IT classes in the secondary school of Ellinogermaniki Agogi, in collaboration with experts from the consortium and especially Staffangymnasiet in Sweden (see above), are strongly motivated to experiment with creating their own sensor boxes by assembling and programming education-friendly hardware components, thus adding to the school's IoT infrastructure.

Both approaches will help to enrich the outcomes of the project and enable final outcomes to be more adaptable to the diverse European educational field.

Participatory Metering

Certain procedures and aspects related to energy consumption in school buildings are difficult to integrate into our envisioned system, due to a number of reasons such as the following:

- Although they can contribute significantly to the overall building energy consumption, the associated processes and policies do not, or cannot, change frequently or in real-time.
- The equipment to monitor such factors, or its installation, is either quite invasive or encompasses significant costs, negating fundamental factors in GAIA's design, such as quick return on investment and non-invasiveness.
- To a certain degree they can be monitored "manually", i.e., using crowdsourcing methods.

In such cases, GAIA will utilize educators and students to "map" their environment, and track certain parameters using software provide by GAIA aimed specifically for such aspects. Procedures like tracking heating costs, fuel purchases or other parameters contributing to the energy consumption of a school building will be organized through such GAIA services and applications.

Specifically regarding building heating, there are additional factors limiting the integration of existing systems and school processes. E.g., in the school in Prato heating is administered by external municipality services and is not directly managed by school authorities. Although GAIA will contribute data showing the conditions inside the building to respective authorities, it is a factor that cannot be managed within the project directly. Moreover, in the case of the public schools participating in the project in Greece, in many cases the installed heating infrastructure is quite antiquated and completely heterogeneous. In most sites, it would require an invasive and costly installation, designed specifically for each school site, negating the goals of the project for replicability and reusability in the developed GAIA solutions. Therefore, we will resort to participatory metering methods in such cases, complemented with suitable IoT infrastructure wherever possible.

Gamification in GAIA's Design

Gamification will play an important part in GAIA's software ecosystem, so it also had a significant impact while designing aspects such as the IoT infrastructure for school buildings. As mentioned previously, IoT real-time data from the real world, can potentially make for a more interesting proposition for educational activities regarding energy and sustainability. Gamification intends to make this even more personal, adding a joyful flavor to the overall experience, along with making it more personal and challenging. This is the reason that gamification serves as the unifying point between the whole GAIA software ecosystem and the educational dimensions of the project.

Along with these facts, it also affected the design described in this document. As an example, it had an effect on the design of the educational lab kit, and also participatory metering and crowdsensing. Crowdsensing and gamification are two concepts that can be intermixed to produce better results in both fields. In some ways, the education lab kit is a "light" version of several gamification aspects that will be implemented in GAIA, such as a set of "sensing quests", where students will be asked to "map" their school environment in terms of specific environmental parameters. Moreover, the concept of assembling IoT sensor boxes, as described in Chapter 5 *is* to a certain degree a form of gamification, where a certain task has to be completed to achieve a certain activity status.

Furthermore, gamification often requires real-time data, where available; this comes in contrast with other GAIA cloud requirements, e.g., although IoT data can be generated by our IoT design with great granularity, i.e., only a few seconds, the vast number of sensing points in each country means a lot of storage is required, along with processing to retrieve and process data, etc. Thus, a balance between storage, processing and end-user requirements has to be achieved. We opted at the current stage of the project to have a 1 minute granularity in our data, in order to be able to be detailed enough. However, this can change at any point in the future, if actual system requirements lead us to do so.

Finally, installation in shared places and classrooms, where it is easier to engage a larger number of end-users (students) was chosen in order to aid the gamification aspects of the project. Instead of focusing only on smaller student groups, such as specific classes, we chose to engage larger groups in order to have a greater number of students involved directly with the project.

The Educational Lab Kit

Complementing participatory metering aspects, we have included in our design an Educational Lab Kit. It aims to streamline the concepts mentioned above, regarding crowdsourcing, or the assembly of IoT devices during classes in Staffangymnasiet. It will include both already assembled devices and commercial IoT parts to enable students to complete classes and lab tutorials regarding energy and sustainability, along with implementing crowdsensing quests (also related to the gamification component of GAIA), where using suitable devices they will "map" their respective school building over specific parameters, e.g., energy, insulation, etc. The Educational Lab Kit is discussed in greater detail in Chapter 5 of this document.

3. GAIA Trial Sites

In this chapter, we describe the trial sites that will be involved in GAIA, i.e., the educational buildings in Greece, Italy and Sweden. We provide a summary for each building, discussing several building properties, along with facts regarding the actual day-to-day operation of such buildings. Essentially, we provide here a short building profile, in order to give to the reader a good idea of the scale associated with each GAIA trial site.

In Greece, 12 schools are participating at this moment in GAIA:

- Ellinogermaniki Agogi, one of the largest private schools in Greece.
- 54th Preliminary School of Patras.
- 55th Preliminary School of Athens.
- 27th Preliminary School of Piraues.
- Preliminary School of Lygia Lefkadas.
- Preliminary School of Megisti.
- 8th Gymnasium of Patras.
- Gymnasium of Pentavrysso.
- 1st Gymnasium of Rafina.
- 1st Gymnasium of Nea Filadefia.
- Experimental Gymnasium of Patras.
- 2nd Technical Lyceum of Larisa.

In the coming weeks, an additional school from Greece is expected to join GAIA.

In Italy, 1 school in Prato and 1 university in Rome are participating in GAIA:

- Gramsci Keynes School in Prato.
- 3 buildings in the University of Rome “La Sapienza”.

In Sweden, the Söderhamn technical high school “Staffangymnasiet” participates in the project.

Each trial site description contains facts regarding the construction of the respective building(s), number of staff and students, levels of education involved, existing infrastructure, GAIA infrastructure already deployed, building floor maps, and photos to showcase actual school environments. As already mentioned, an analytic list of the currently available data sources originating from the IoT infrastructure already installed for the project in the trial sites included in this chapter, is detailed in Annex I of this document. Such descriptions serve as a good introduction to GAIA’s trial sites, as well as provide a link to the design principles discussed in the previous chapter. We also provide a summary about previous activities of the participating schools with respect to European or national research projects. More analytic and updated descriptions will be made available in the near future on the project’s website.

Gramsci Keynes School in Prato

The Gramsci Keynes School is an upper secondary school that offers three curricula: a scientific lyceum, a technical institute of building construction, a tourism economic institute.

General Details		
[A. Gramsci – J.M. Keynes	Tel.	+39 0574 630201
Via di Reggiana 106 - 59100 - Prato (PO)	Fax	+39 0574 630716
http://www.istitutogk.it	Email	info@istitutogk.it

In Italy, the upper secondary school lasts five years and provides students with the skills for accessing a university or higher educational institution. The Liceo scientifico (Scientific lyceum) focuses on scientific studies, while also covering humanistic studies. The program usually includes the following subjects: Italian, Latin, history and philosophy, English, mathematics, physics, chemistry, biology, earth science and computer science. Technical institute provides a highly qualified specialization and prepares students to work in a technical or administrative capacity in agriculture, industry or commerce. The technical institute of building construction is specialized in building design and management.

The total number of students is 1410. Hereafter we provide more detailed information.

Technical institute of building construction

	Number of classes	Number of students
First year	4	101
Second year	4	84
Third year	2	50
Fourth year	3	59
Fifth year	3	51
Total	16	345

Tourism economic institute

	Number of classes	Number of students
First year	5	136
Second year	6	124
Third year	5	114
Fourth year	3	70
Fifth year	3	61
Total	22	505

Scientific lyceum

	Number of classes	Number of students
First year	7	166

Second year	6	117
Third year	5	94
Fourth year	5	107
Fifth year	3	75
Total	26	559

In Italy, upper secondary school is for students from 14 to 19 years of age.

Class	Age
First year	14-15
Second year	15-16
Third year	16-17
Fourth year	17-18
Fifth year	18-19

The school has 132 teachers and 28 employees in the technical and administration staff.

Research projects on environmental sustainability

Environmental sustainability In 2006/2007 nine classes have been involved in a project, under the supervision of Prof. Lisetti, entitled "Consuming less means consuming for all" (Consumare meno per consumare tutti) with the goal of making students aware of the importance of the rational use of natural resources, in order to preserve the natural ecosystem. The students realized some multimedia content, available for download on the school web site[1]. The students, organized in classes, have produced different types of multimedia content: game[2], posters[3], and presentations[4].

Waste collection in 2014, a separate waste collection approach has been adopted in the building of the school and other two schools in the surroundings, promoted by the Municipality of Prato and ASM, the waste management company in Prato. Within this initiative, also some lectures introducing the new modality of waste collection have been organized in the schools and a game delivered as an app via smartphone tablet and PCs. The game consisted of questions on the waste collection topic and prizes for best performing students were 6 tablets[5].

The "ecologic school" In 2008-2009, the "ecologic school" is an initiative for implementing in the school good practices for separate waste collection and energy savings. The actions include lectures on the topic and the monitoring the implementation of good practices.

[1] http://www.istitutogk.it/progetti/consumare-meno-consumare-tutti
[2] http://www.istitutogk.it/sites/default/files/file/0809/progetti/consumare/gioco.zip
[3] http://www.istitutogk.it/sites/default/files/file/0809/progetti/consumare/manifesto.pdf
[4] http://www.istitutogk.it/sites/default/files/file/0809/progetti/consumare/acquamadre.pdf
[5] http://www.asmprato.it/comunicati/ecoquiz-lunedi-15-dicembre-le-premiazioni

Photos of the building's interior and exterior

Figure 3 View of the exterior of the building, main entrance

Figure 4 View of the exterior of the building, entrance of the block containing the auditorium, the cafeteria and the gymnasium

Figure 5 View of the exterior of the building, walkway connecting the main block with the classroom blocks

Figure 6 View of the central electricity panel

Figure 7 Lighting in the hall

Figure 8 Radiator in the hall

Figure 9 View of the interior of the building, a typical classroom

Figure 10 Lighting in a classroom

Figure 11 Computer lab room

Figure 12 View of the electricity panel in a computer lab room

Figure 13 Auditorium

Figure 14 Gymnasium hall

Building Remarks

The school building is located in the semi-peripheral area of Prato, a town of 187.000 inhabitants, close to Florence and is made of 4 blocks. The main central block contains the hall and at the first floor the offices of the administration and technical staff. Two blocks contain classrooms and laboratories, organized in three floors. A fourth block is an independent building connected to the main one through an aerial walkway. This block contains the canteen at the ground floor and the auditorium and a small gymnasium hall at the second floor, and also a gymnasium hall which is two floors high, with tribune seats and changing rooms. The main central block and one of the two classroom blocks have been completed in 1988, while the other two blocks have been completed in 1999. The gross floor area is 12.166,00 m^2. The bearing structure is made of reinforced concrete. The external walls are made of slabs of concrete and expanded clay. The whole building surface is exposed and stands free on all sides. Glazing covers 40% of external surface.

Overview of the operating hours and days of the building in the 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 till the late afternoon (using classroom 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.

The school is closed in the following periods:
- one week at middle august
- weekends and public holidays

For instance, in 2016 the school will close 13 days (public holidays) + 104 days (weekend). The total is 117 days. The ordinary education activity begins at mid-September and ends at the beginning of June (e.g. June 10 2016). In the first half of September and the second half of June examination and targeted education activities can take place for small groups of students. The administration and technical activities are always running when the school is open.

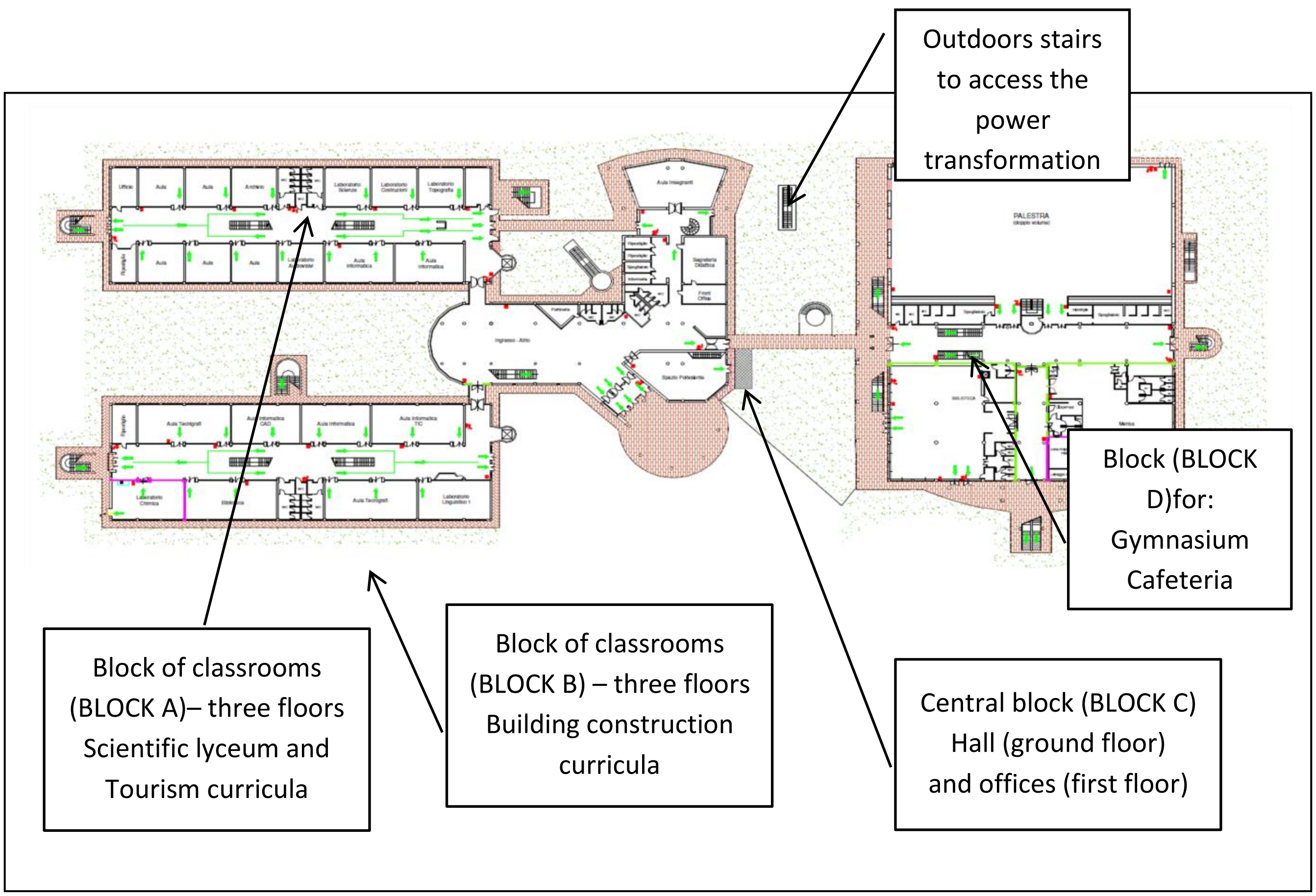
The total number of students is 1500. The school has 132 teachers and 28 employees in the technical and administration staff. Students usually arrive at 8:00 and leave at 14:00. Once a week, students of commercial and tourism curricula stay at school till 16:00 (on Monday in 2015/16). The administration staff enters at 8:00-9:00 and leaves at 17:00-18:00. Teachers have lectures for 18 hours/week. Each teacher enters and leaves the school according to its personal schedule. The technical and custodian staff enter at 7:00-8:00. Between 7 and 8 am staff of the school do the cleaning (maximum 8 persons). In the afternoon an external company comes to do additional cleaning.

Regarding other groups of people using the facility, **s**port associations use the gymnasium hall in the afternoon and the evenings. Some persons attend professional education classes in the afternoon (on average twice a week). The school building closes at 19:00.

The heating is regulated according to the schedule defined by the Public Administration according to the climatic zone. Prato is in the D climatic zone. Heating is on from 1 November to 15 April. The heating can be on for maximum 12 hours/a day. The school may send specific requests to the Province of Prato for extraordinary turning on or off. In Annex III, an official letter from the Province of Prato is included, outlining the policies and the respective restrictions. During the night, the lighting in the hall is on and the outdoor lights (lighting with automatic twilight switch).

Planned Sensor Installation

In this section, we provide a brief introduction of the sensing infrastructure that is being deployed in the school of Prato. For the sake of clarity we provide hereafter the plan of the school enhanced with labels for identifying the affected building blocks.



Energy consumption meters

At the power transformer cabinet:

- The output of the existing meter (ABB B24 111-100), measuring the overall energy consumption, will be collected via ModBus protocol.
- One meter will be placed to collect the output of the circuit labelled QG, serving the blocks A+B+C in the Figure.
- One meter will be placed to collect the output of QS, serving block D.

An electric switchboard is located in the hall (Block C), serving blocks A, B and C, with the following main circuits:

- One circuit for each floor of blocks A and B.
- One circuit for each of the two lifts.
- One circuit for the offices (located in the first floor of block C).
- One circuit for lighting in the hall.
- One circuit for motive power in the hall.

Here we will deploy the following sensors:

- One meter for collecting the output of the main switch for Block B ground floor and one for the first floor (two switches, three-phases 63 A).
- One meter for lighting in the hall– 1 switch single-phase 25 A.

As regards classrooms, we focus on block B (building construction curricula)
Each floor has a switchboard. A circuit in the switchboard can control a group of two or more classrooms. In the Switchboard at Block B, Ground Floor we will install: one meter for measuring the energy consumed by two laboratories for lighting; One meter for measuring the energy consumed by two laboratories for motive power. In the Switchboard at First Floor of Block B we will install one meter for measuring the energy consumed for lighting and fans in a group of three classrooms.

Environmental sensors

Three classrooms will be equipped with environmental sensors, i.e., temperature, relative humidity and luminosity sensors. These classrooms are located in the block B building (i.e. Building construction curricula), first floor. A weather station will also be installed in an appropriate location (roof or external terrace).

Rome, Palazzo Servizi Generali – Building Details

Moving on with our trial site description, we will describe the Palazzo Servizi Generali building of "Sapienza, University of Rome". We will provide some details on how it is structured, focusing on the part will be used during the project.

Figure 15: An external view of the Building

The building is used as front and back office for the student secretariat. All faculties' secretariats are in this building. It does not contains lectures hall. The building has seven floors including two basements. First two floors are used for front and back office. In the last floor (the 5th one) we have the terrace, whilst third and fourth floor only contains administrative/technical offices, one data center, archive and four reading/PC rooms. The table below, details the number and the type of rooms in the building.

Room Type	Number
Secretary	29
Administrative/Technical Office	105
Data Center	1
Archive	8
Reading/PC Room	4

A large number of people use the building daily. Because of the building's size, it is difficult to focus on the entire building, but only on a small part of it. Secretariat front office follows this timetable:

- Monday, Wednesday and Friday from 08:30 to 12:30
- Tuesday and Thursday from 14:30 to 16:30

Secretariat back office instead open at 08:00 and close at 18:00. According to the number of person in row, personnel at the counters vary between one and six.

Fig. 2 shows the planimetrics of the First floor of the building it has a balcony giving the access to the student secretary front offices (visible in Fig.3). The first floor serves the law faculty, Engineering, Political Science and Architecture. The rest of the locals in the planimetry are used for the back-offices

Figure 16: First floor planimetry

Figure 17 External view of the Building First Floor (the door at the right is the entrance of the secretary office of the Faculty of Political Science)

Actually no power meter have been installed yet in the building. We plan to install them during the project, on:

- The general electric panel to figure out the electrical consumption of the entire building.
- The general electric sub-panel of the first floor to understand how the plan affects the total building energy consumption.
- In a specific area compound by front and back office , if the electrical plant allows to do that to analyze what happen in terms of energy consumptions when the offices are empty (front offices, visible in figure 4 and 5, as stated before, are populated few hours a day and mainly from students).

The device we plan to install is the NanOMeter, being the best solution *(i)* to avoid to interface it with the IT infrastructure network and *(ii)* for its speed in the "start-up" of the system and the management of the sensed data.

Figure 18: Interior of the Secretariat of the Faculty of Law

Figure 19: Interior of the Secretariat of the Faculty of Engineering

Rome, Faculty of Economics Building Details

In this document we will give a general description of the *Faculty of Economics* building of "Sapienza, University of Rome". First, we will provide a brief overview of the building, describing the structure and internal configuration. Then, we will highlight the next installation steps and the area that will be involved in the GAIA project. The building was designed by Gaetano Minnucci and opened for the academic year 1969 – 1970, when activities and services which had previously taken place in various locations around Rome were brought together in one building.

Figure 20: Exteriors of the Faculty of Economics Building

The *Faculty of Economics* is one of the 11 faculties of "Sapienza", University of Rome. Over the last few years the Faculty of Economics has had an average student population of 10,000 with a high percentage of students coming from outside Italy. At present, undergraduate courses are scheduled on a three-year system**,** followed by a two-year master degree course.

The *Faculty of Economics* has a staff consisting of 185 teachers (63 full professors, 57 associate professors, 65 researchers) and 61 administrative technicians, which are complemented by research fellows, fellows, graduate students, interns, etc. In particular:

- Full Professors: 63
- Associate Professors: 57
- Researchers: 65
- Administrative technicians: 61

Figure 21: Entrance of the Faculty of Economics Building

Next two figures (Figure 3 and Figure 4) show the planimetry of the ground floor of the building that is the one we are going to deal with in the GAIA project.

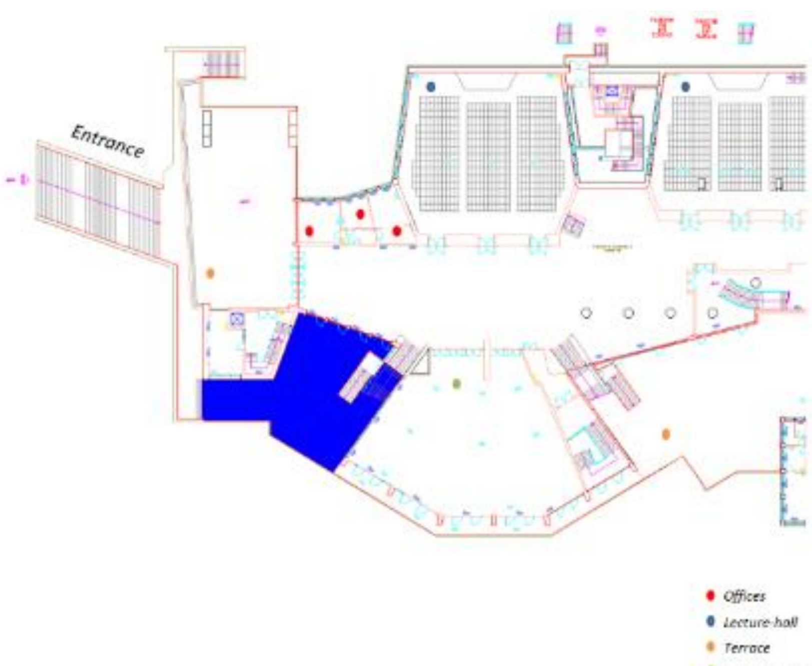


Figure 22: Ground floor (part 1)

Figure 23: Ground floor (part 2)

Commonly workers enter the offices at 09:00 and exit at 18:00; in the other hand, lectures could start at 8:30 and end at 22:30, because the university provides many evening lectures for working students. Entry and exit times are flexible, however the great part of the people is in the building both in the morning and in the afternoon. Therefore, usually there is activity in the floor from 08:00 to 22:30. Saturday and Sunday all floors are closed.

Figure 24: IV Lecture-hall

At the moment, there are not active installation in the building, although the consortium has already planned how and how many OVER devices will be used in the *Faculty of Economics* building. In particular, we are going to install 8 NanOMeters, in order to provide a complete power consumption metering. One device will measure the entire building energy consumption; 5 NanOMeters will provide the metering of each floor in the building; in this way, we will have a detailed overview of the energy behavior of the building. The remaining devices will be installed in the ground floor in order to have additional data for the GAIA project. We plan to monitor the most energy consuming power circuits and/or the most important parts of the floor. Specifics on what will be monitored, will be decided during the installation phase, according to possible encountered limitations due by how the electrical plant has been made.

Rome, Orthopedics Building Details

In this section, we will describe the Orthopedics building of "Sapienza, University of Rome". We provide some details on how it is structured, focusing on the part that will be used during the project. The Orthopedics building forms part of a series of structures designed by Arnaldo Foschini from 1933 to 1935. The building's architectural style combines classical and rationalist elements, emphasizing its position beside the central avenue and the functional nature of the building.

Figure 25: external view of the building

The rooms in the Orthopedics building are mainly used for the teaching activities of the Faculty of Medicine and Surgery and some hospital ward. Regarding GAIA trials, we will mainly focus on the fourth floor, which is currently under energy monitoring. The fourth floor of the building contains technical and administrative offices with a small set of meeting rooms and some shared areas (corridors and relax area with automatic dispensers). Offices are in charge of the "Building Management" of the entire Sapienza University of Rome.

Fig. 2 shows the planimetry of the fourth floor of the building. It has two receptions at the sides of the floors, a print area (n. 31) and a relax area with vending machines (number 6). The rest of the building is mainly compound by 20 technical/administrative offices sized for 2 employees each and some meeting rooms.

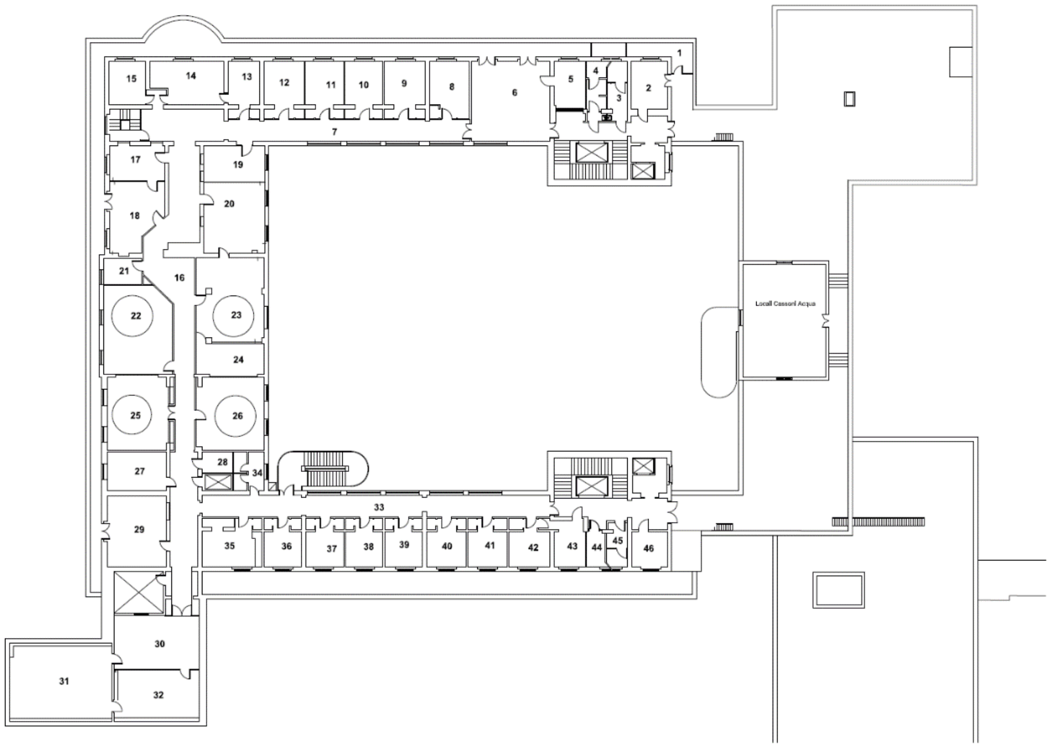


Figure 26: planimetry of the fourth floor of the Orthopedics Building

Access to the floor takes place only by means of a lift and is restricted to authorized personnel. Here, workers perform task completely different from the ones performed in the rest of the building (mainly teaching and medical activities), handling all the Construction Area Management of the "Sapienza, Università di Roma". Commonly workers enter the offices at 09:00 and exit at 18:00. Entry and exit times are flexible. Usually, there is activity in the floor from 08:00 to 19:00. Saturday and Sunday all floors are closed.

Currently, in the building there is an active installation compound by 8 OMeter, 2 NanOMeter and 1 OBox.

- The NanOMeter (visible in Fig 28) is used, one for the entire floor and the other one for the left side of floor building. In this case making the difference between the two NanOMeters is also possible deduce the energy consumption data of the right side of the floor.

Figure 27: NanOMeter installed in the building

- 8 OMeter forBusiness (visible in fig. 29), for a total of 32 power lines monitored, mainly constituted by lights and electrical socket. In particular we are monitoring 22 lights circuit and 10 electrical sockets circuits

Figure 28: OMeter and OBox installed in the building

- 1 OBox forBusiness (visible in fig. 29) to remotely manage the devices connected to the OMeters.

Due to security problems, it has not been possible directly interface the OBox with the network of the building. Therefore, it is used a router with 3G connection on board. NanOMeter does not suffer of this problem because it natively exploits his GPRS on board connection. First installation, without NanOMeter, has been done in March 2015 even if data are not completely available due to connectivity problems mentioned above. The new installation, with the router 3G has been performed in February 2016. Only the fourth floor of the Building is currently under monitoring. Given the high granularity with which the floor is currently being monitored, we do not expect to further install new devices in the building. To the best of our knowledge the building has never been used in previous research projects.

Söderhamn technical high school complex - Staffangymnasiet

Staffangymnasiet is a local organization for Upper Secondary School in the city of Söderhamn. The Upper secondary school is organized in three sectors, and there are altogether around 800 students and 100 persons in the staff. The students studying in 12 programmes, 5 preparing for higher studies, or 6 vocational training. The school has around 45 classes in total, 15 per level.

The social studies program focusses on sustainability and both the technical and the electrical program has a focus in the curriculum on sustainability.

Regarding the overall operational schedule of the school:

- The operating hours of Staffangymnasiet are between 6am and 6pm, five days per week, Monday to Friday.
- Students use the building for 176 days per year, August to June, while teachers for 194 days per year, August to June. Administration staff work year round, 225 days/person and most of them are on vacation in July.
- The cleaning staff start their work at 6am and works until 3pm. Some of the administrative staff and janitors start at 7am and end the day at 6pm. Teachers and students start their classes at 7:45am and will have classes until 5pm. The cafeteria is open between 7am and 3pm every school day.
- The municipality's ICT group for primary and lower secondary school have their office and one education room in our school.
- The front door is open between 7am to 4:30pm, every school day. The school building closes at 9pm.
- Overall, there are around 800 students, 90 teachers, 4 janitors/building mangers, 8 cleaning staff, 2 nurses, 2 student study consultants, 1 social worker, 5 cafeteria staff and 6 at principal's office, including principals.

The part of the building that will be used in the project is the science building containing laboratories for chemistry, physics, biology and design (CAD). There are two laboratories for each subject, except for design that only has one room. There are two ordinary classrooms in the building and two staffrooms. There are rooms connected to the laboratories for preparations and smaller rooms for students when they work with group-based tasks, or study by themselves during gaps in the schedule. There are staircases and halls as well in the building, but there is no lift. The basement is used by the municipality's ICT group mentioned above.

There are mainly 11 teachers working and teaching in the building. There are 6 classes (natural sciences and technological programs), containing around 160 students who have most of their classes in the building, but all of the school's students take at least one course in science during their three-year period. The rooms for biology is almost fully booked during the day and the chemistry is the least used part in the building. It is used around 30% of the time. Physics and design are used more frequently, but not as often as the biology rooms.

The swedish school year starts for the teachers in the middle of August and for the students one week later. There is a one-week holiday in October and two weeks during Christmas. During the spring period there are two holidays, one in February and one during Easter, one week each. The school year ends in middle of June, for both the students and teachers.

Regarding specific features of the building:

- Windows: Two and three-glass windows in all of the buildings. Some of the three-glass windows is gas filled.
- Lighting installations: Fluorescent lighting in almost all of the classrooms and in hallways. Some have LED lighting.
- Heating installations: Central heating in the building based on water radiators. The building is connected to the district heating in the city.
- Materials used in the construction: The old part of the school building (1860 and 1910) is made out of bricks. The newer part is made of concrete (1960).

Also, regarding the central heating system, the currently utilized schedule has the following goals set:

- Monday: 04:00-15:00, 20 °C in the building
- Tuesday – Friday: 05:00-15:00, 20 °C in the building
- All other hours: 17 °C in the building

Regarding existing infrastructure, a centralized BMS is utilized to monitor and control various processes in the building, such as lighting, heating and ventilation. However, this system is fairly antiquated by information technology standards and has limited connectivity for external systems readily available. GAIA will bridge, to a certain degree, existing end-user and system interfaces, in order to integrate data gathered by this system into its own software ecosystem.

Regarding the hardware part, although there are available meters in the building, they are “tied” to the BMS and are difficult, or impossible to interface with. Since Staffangymnasiet is a technical school in essence, as also detailed in other sections of this document, we are going to take advantage of this fact:

- Students are going to ”build” IoT sensor boxes, based on GAIA templates, which are also going to be open source (see also Chapters 5 and 6).
- Data will be gathered through such sensor boxes and participatory metering procedures.

This approach presents an addtional challenge to GAIA, since it will involve students and educators in a more active role in the project.

Photos of the building's interior and exterior

Exterior and surroundings

South side

East side

North side

Classrooms

Facing south and north in the newer building.

Facing east in the newer building.

Facing west in the newer building.

Facing south in the old building

Library


Hallways




Staff rooms

Aula

Ellinogermaniki Agogi Description

EA is one the largest private schools in Greece and covers all stages of school education, from pre-school to upper secondary. In the Greek educational system, the primary school includes six years covering the student age range from 6 to 11 years. Secondary education is divided into the lower secondary school (Gymnasio) and the upper secondary school (Lykeio). The lower secondary school (Gymnasio) includes three years covering the student age range from 12 to 14 years. The upper secondary school (Lykeio) includes three years covering the student age range from 15 to 17 years.

In year 2015-2016 there are approximately 1,030 students in EA's primary school, and approximately 610 students in EA's secondary schools, with 25 students per classroom on average. We expect for the school 2016-2017 numbers to be similar. EA's primary and secondary schools will take part in the activities of the GAIA project. In particular, current plans, based on links to the curriculum and teacher motivation, foresee that year 6 of primary school (~11 year-olds; 154 students in school year 2015-2016) and year 2 of upper secondary school (~16 year-olds; 87 students in school year 2015-2016) will be the two focus groups for the case studies, while other years from the primary and secondary schools may also be involved. It is also noted that there is a strong interest of the school in involving students and teachers of secondary IT classes in experimenting with creating their own sensor boxes by assembling and programming education-friendly hardware components, in collaboration with experts from the GAIA consortium and especially the Swedish school, thus adding to EA's IoT infrastructure.

EA operates a Research and Development Department within its structure. Through this, in the last 15 years EA has participated in more than 120 research and development projects in the wider field of innovation in education. Details of the activity of the Research and Development Department can be found at the website of EA[6].

Similarly to the school in Soderhamn, EA's building utilizes a BMS to monitor and control several processes. GAIA is going to develop interfaces to this BMS in order to integrate the produced data into its own information systems. Regarding the hardware side of the infrastructure, we are going to utilize both a participatory metering approach as in Soderhamn, along with installing additional IoT infrastructure to provide a more complete hardware substrate for GAIA.

[6] http://www.ea.gr/ea/main.asp?id=600&lag=en

Photos of the building's interior and exterior

Figure 29 Photo of the building's exterior

Figure 30 The interior of the building, the primary school's library

*Figure 31*Typical primary school classroom in EA's building

Figure 32 View of the building's corridors (first floor)

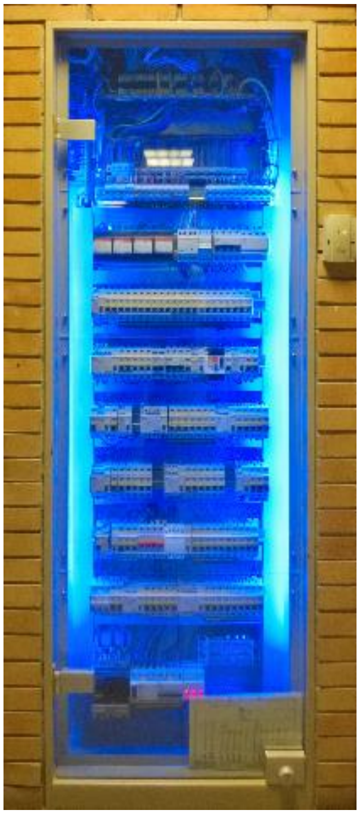


Figure 33 Several electricity panels are visually accessible to students in order to aid in physics and electronics classes

Figure 34 The building complex also houses a large swimming pool

Overview of the Greek public schools participating in GAIA

The participating Greek public schools have some common characteristics regarding their daily routine, e.g., working hours, days off, classroom availability to external groups, lighting and heating. The majority of schools are open from Monday to Tuesday, from 8:00 to 14:00, however, this time varies from school to school with small deviations. On average, primary schools are open with students more or less 203 days per year. Almost all of the schools have the same days off, e.g., Christmas and Easter holidays (4 weeks totally), 2 National days (28/10, 25/3), 1 day for the celebration of an event (17/11), 1 Holy day for the education (30/1), 1st of May, 1st day of the Lent, 1 Holy day for all the Orthodoxies, 1 day off the day which is dedicated in the Saint of the city (Patron Saint), 1 day off for excursion, 5 days off for small walks close to school (these days the schools don't have lectures, but students are present in the school for at least 2 hours), and almost 2 months for summer holidays.

Moreover, in several cases the schools are available to other groups of people after classes, i.e., to parents, sports teams, etc. Additionally, the school staff for cleaning and the buffet are present in the building both before and after school working hours. Also, headmasters of the schools follow the same schedule regarding the heating of the school, in Greece. Only the cold days the heating is on for 2 hours each morning and they try to have some lights on during the night for security reasons.

Figure 35 A map giving an overview of the location of the GAIA Greek public schools

In the following subsection we provide some details about the participating schools, but since this set of schools share many common characteristics, we provide an overview of the Greek educational system and related aspects in Annex II of this document. The description included in this section aim to give the reader a summary of the buildings and the installations so far. In the following paragraphs, we additional give some characteristic examples of features for some of the participating schools from Greece.

1st Junior High School of New Philadelphia

Working hours: 08:15 - 14:10 regularly, the responsible person for the buffet goes every day earlier on the morning and the cleaner is later on the school (12:30 - 16:30). 4 days per week a group works out for 3 hours.
Outdoor lighting: The lights on the yard turn on automatically every night.
Heating: Manually the cold days the heating is on for 1-2 hours.

1st Junior High School of Rafina

Working hours: 08:15 - 14:10 regularly, the responsible person for the buffet goes every day earlier on the morning and the cleaner goes later. After the end of the courses, some students stay up to 15:30 for extra projects that the school runs, and the choir has rehearsals twice the week up to 15:30.
Building usage: the class for the demonstrations is given to local groups or others for performances, and the yard is given for cultural events during the summer period.
Outdoor lighting: Manually some lights during the night are turned on.
Heating: Manually the cold days the heating is on for 1-2 hours.

8th Junior High School of Patras

Working hours: 08:15 - 14:10 regularly, the responsible person for the buffet goes every day at 07:30 a.m. (it is estimated that consumes 40KW every day).
Building usage: The school is in the same building with the Triantios School which is office and is open every day (in summer too). Perhaps an evening school is going to work from the next school year.
Outdoor lighting: Manually some lights during the night are turned on.
Heating: Manually the cold days the heating is on for 1 hour. It is estimated that the school consumes 2000 lt per year, and the very cold days 80 lt the day.

Modal Experimental Junior High School of Patras

Working hours: 08:00 - 16:00 regularly, the responsible person for the buffet goes every day at 07:15 a.m. and the buffet works each evening from 18:30 – 22:30. The cleaner comes every day at 07:00 a.m.
Building usage: The local authorities provide the gymnasium with the lighting 3 hours every day and 3 hours on Saturday. A classroom is provided for 2 hours every Saturday at the Greek-German Association of Patras for the learning of German language.
Outdoor lighting: 10-15 economy lights are on in the yard during the night.
Heating: Manually the cold days the heating is on for 1-2 hours.

54th Primary School of Patras

Working hours: 08:00 - 14:00 regularly, and the all-day school up to 16:00.
Building usage: Parents can use the school building for their activities e.g. choir, art works, etc., for 2 hours after 16:15 2-3 days per week.
Outdoor lighting: a floodlight from 19:00-07:30 the winter, 20:00-07:30 the spring/summer.
Heating: Manually the cold days the heating is on for 1 ½ hours (08:00-09:30), two air conditions in the teachers' offices.

9th Primary school of Patras

Working hours: 08:10 - 16:00 regularly, the responsible person for the buffet goes every day at 07:15 a.m. and the cleaner comes every day at 10:00-18:00. The head teacher occupies 20 students every morning from 07:00-08:00 (morning zone). It has been calculated that the school works 203 days per year (without Saturdays with students and teachers) and 45 days (Saturdays where parents, students and some teachers are present in the school).
Building usage: 3 classrooms are provided to the school parents every Saturday at 09:00-13:00).
Outdoor lighting: permanent headlights which are on with the set of the sun and are off with the rise of the sun. 2 lights in front of the buffet are on every night.
Heating: Manually the cold days the heating is on for 1-2 hours.

55th Primary school of Athens

Working hours: 08:10 - 16:00 regularly, the cleaner comes every day at 07:30 a.m.
Building usage: The school maybe be used in the frame of "Open Schools" for refugees this year.
Outdoor lighting: There is lightning in the staircases when there is electricity power outage.
Heating: Manually the cold days the heating is on for 3-4 hours.

Primary School of Lygia (Leukada)

Working hours: 07:45- 16:00 regularly, the responsible person for the buffet goes every day at 07:100 a.m. and the cleaner comes every day at 15:00-18:00.
Building usage: The school is used the same hours from the pre-primary school.
Outdoor lighting: The lights on the yard turn on automatically every night.
Heating: Manually the cold days the heating is on from 07:00-09:45 a.m.

Junior High School of Pentavryssos (Kastoria)

Working hours: 08:00 - 14:00 regularly, the cleaner comes every day at the afternoon.
Building usage: The school is used periodically from the parents' association the afternoon.
Outdoor lighting: The lights on the yard turn on automatically every night.
Heating: The cold days the heating is on during the school hours and 2 hours the afternoon

Description of 8th Gymnasium, Patras

The current GAIA IoT infrastructure in the school is detailed in the following table.

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

Greek Gymnasiums have 3 different educational levels, being in between the 6-grade Primary schools and the 3-grade High schools. The 8th Gymnasium in Patras has 33 teachers for 199 students, distributed as following:

Grade	Students
1st	84
2nd	58
3rd	57

The Power meter measures the Power Consumption of all the building. The building includes 2 different schools, one during morning hours and the other (a technical school) during noon hours.

Photos of the building's interior and exterior

Figure 36 View of the central building corridor on the 1st floor

Figure 37 View of a typical classroom in the building

Figure 38 The roof of the building

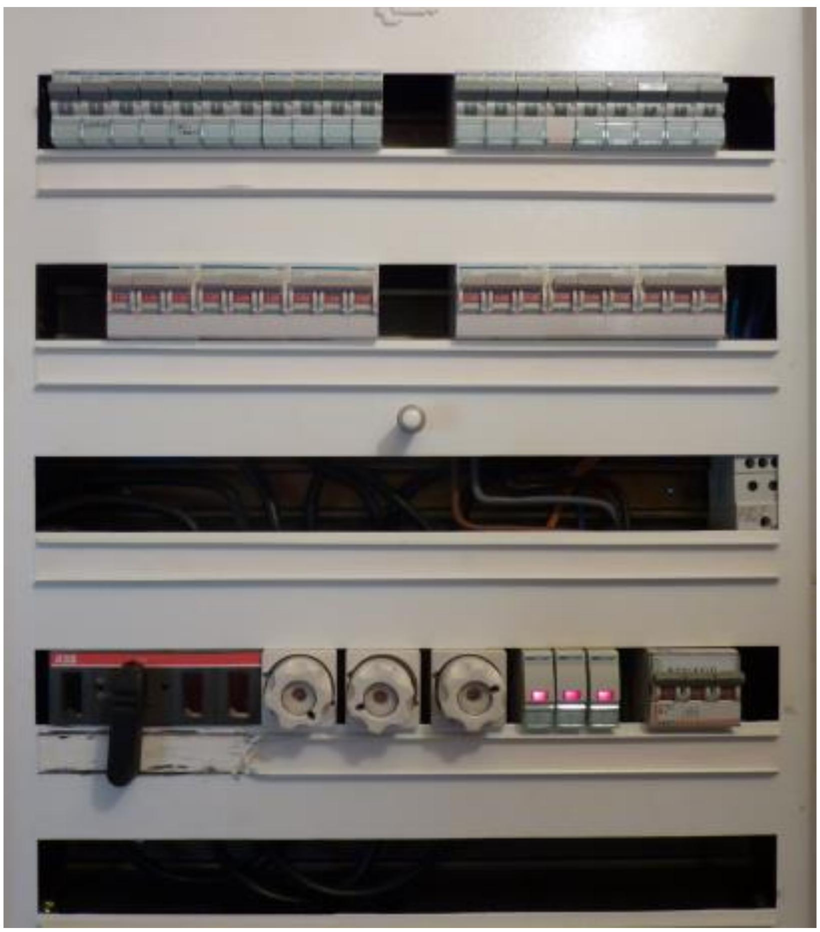
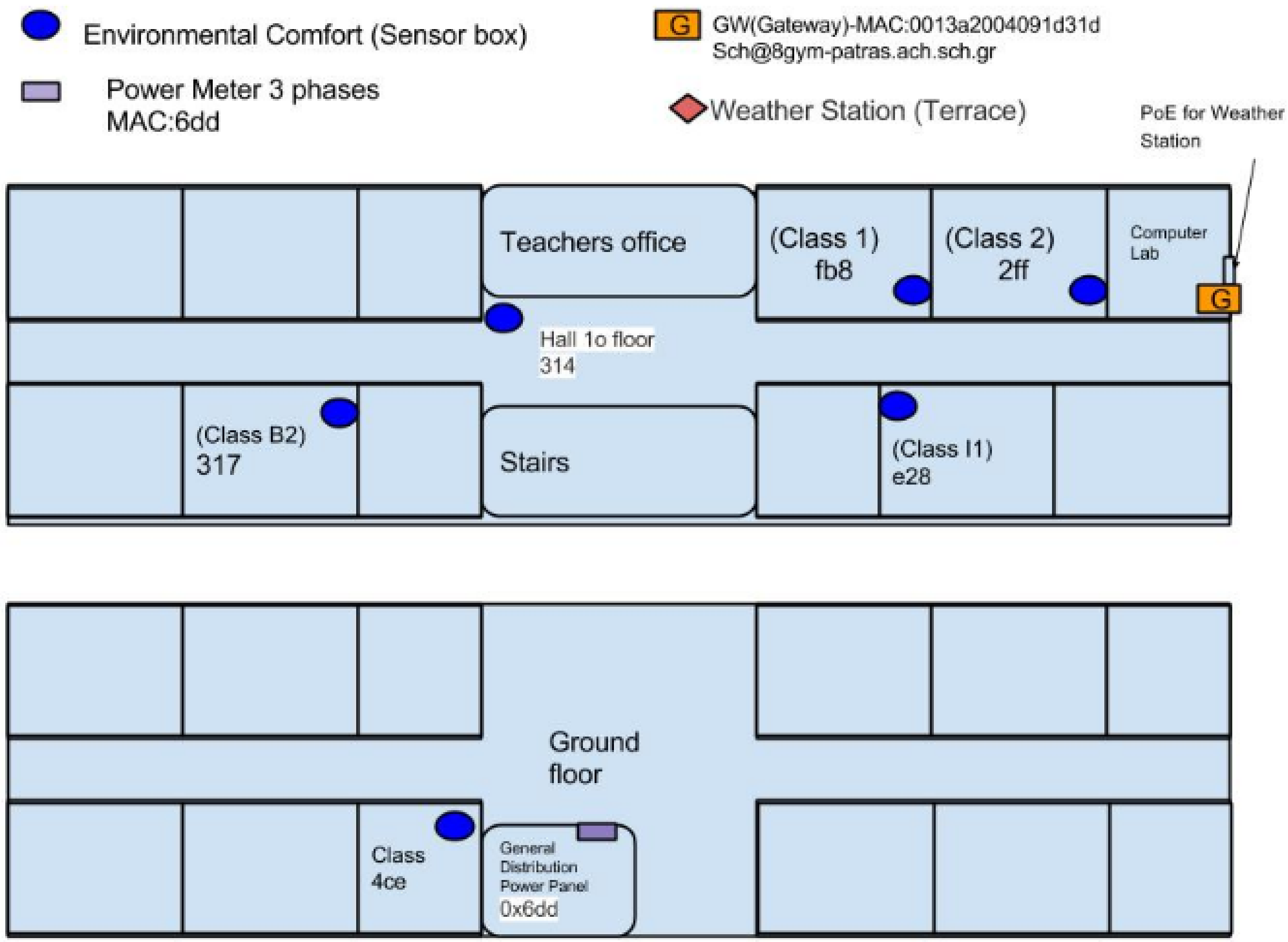


Figure 39 The central electricity distribution panel of the building in the ground floor

Figure 40 View of the central corridor on the ground floor

Figure 41 The weather station placed on the building roof

Building Floorplan



Description of 54th Elementary School, Patras

The current GAIA IoT infrastructure in the school is detailed in the following table.

Overview of IoT devices available		
Gateway (XBee communication with Sensor units)	Yes	2
Environmental Comfort units (Sensor Box)	Yes	6
Weather Station (Arduino)	Yes	1
Atmospheric Conditions Unit (Libelium)	Yes	1
Radiation meter Unit (Libelium)	Yes	1
3-phase Power Meter	Yes	1

In Greece, Primary schools have 6 different grades. The school has a staff of 35 teachers and 165 students, divided in different classes as follows:

Grade	Students
1st	27
2nd	43
3rd	22
4th	28
5th	25
6th	20

Photos of the building's interior and exterior

Figure 42 The installed power meter at the central electricity panel

Figure 43 View of the central electricity panel

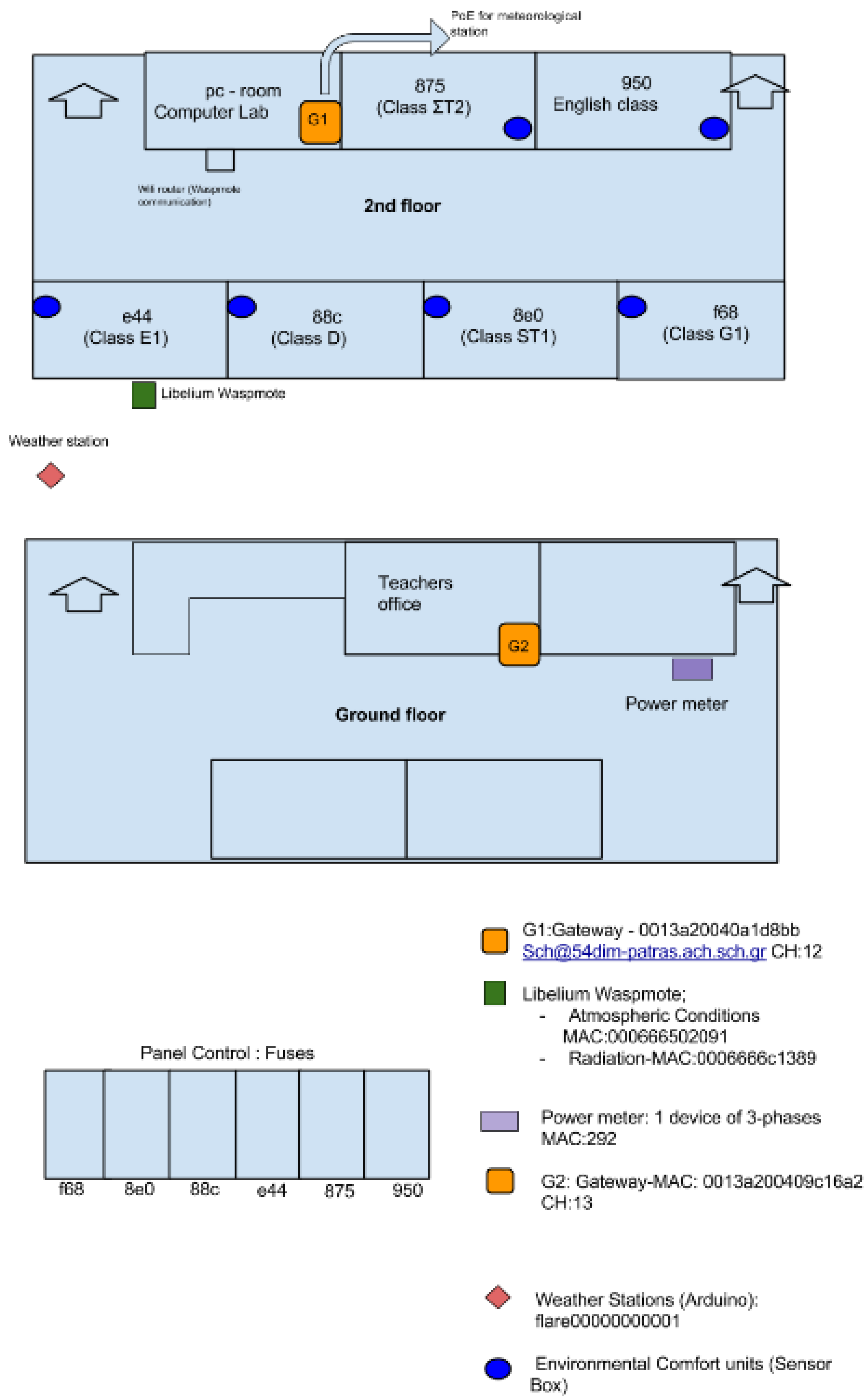
Figure 44 Typical classroom in the building with thick walls, metal door and small windows looking into the central corridor

Figure 45 The weather station installed on an unused flag mast

Figure 46 Close view of the sensor box

Figure 47 Another installation of a sensor box inside a classroom

Building Floorplan



Description of Experimental Gymnasium, Patras

The current GAIA IoT infrastructure in the school is detailed in the following table.

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	5
Weather Station	Yes	1
Atmospheric Conditions Unit	Yes	1
Radiation Meter Unit (Libelium)	Yes	1
Power meter	Yes	1 (Meazon)

Greek Gymnasiums have 3 different educational levels, being in between the 6-grade Primary schools and the 3-grade High schools. The Experimental Gymnasium in Patras has 22 teachers for 179 students, distributed as following:

Grade	Students
1st	60
2nd	59
3rd	60

Figure 48 Panoramic view of the building's 2nd floor balcony

Figure 49 The computer lab of the school

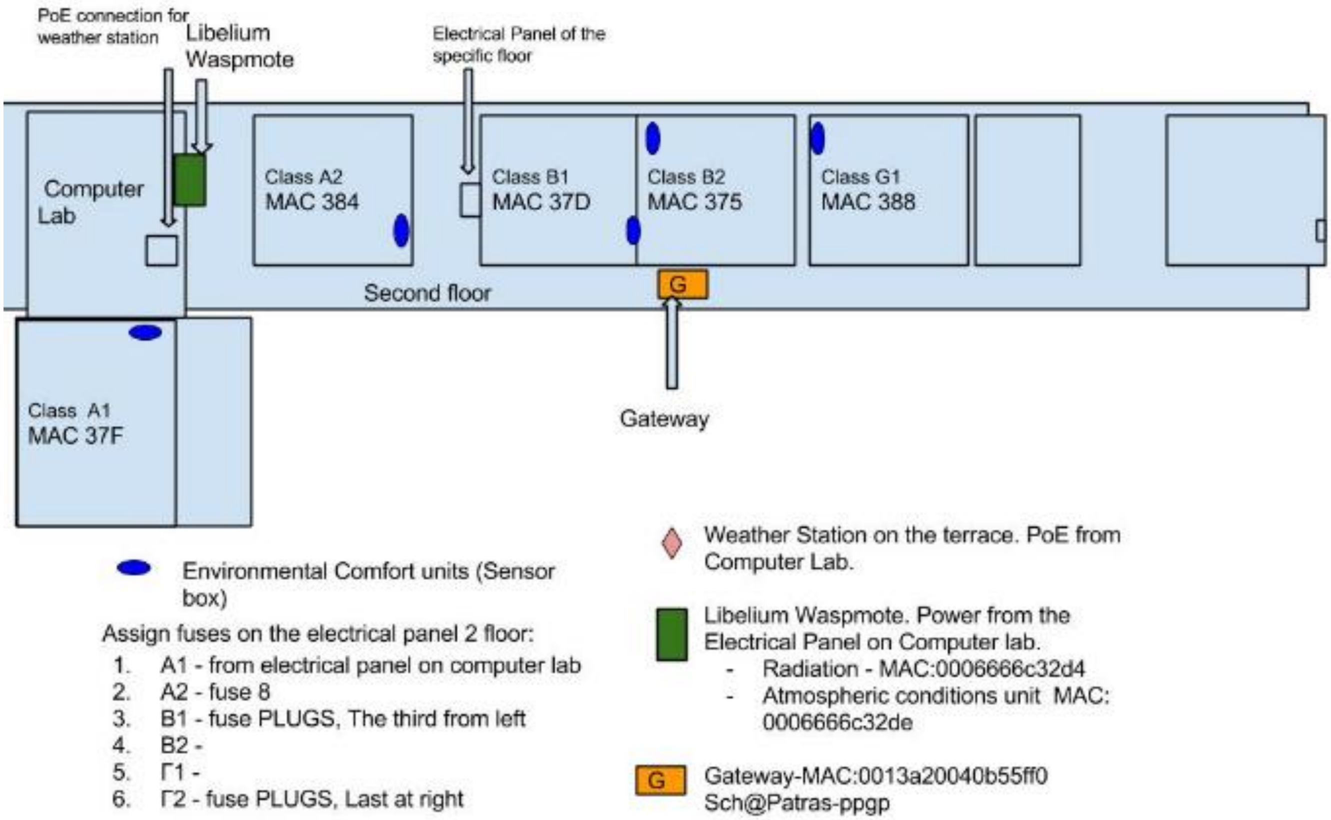
Figure 50 A typical classroom in the building

Figure 51 A sensor box is installed on top of the blackboard

Figure 52 Some classrooms also have a smart board integrated

Figure 53 The weather station as seen from ground level

Building Floorplan



Building Remarks

CTI will install a second power meter device to monitor the Computer Lab classroom in the coming weeks.

Description of Pentavrysso Gymnasium, Kastoria

The current GAIA IoT infrastructure in the school is detailed in the following table.

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	8
Weather Station	Yes	1, Arduino
Atmospheric Conditions Unit	Yes	1
Radiation Meter Unit (Libelium)	Yes	1
Power meter	Yes	2 (3-phase (1) and 1-phase (1))

Greek Gymnasiums have 3 different educational levels, being in between the 6-grade Primary schools and the 3-grade High schools. The Gymnasium in Pentavrysso has 19 teachers for 44 students, distributed as following:

Grade	Students
1st	11
2nd	15
3rd	18

Photos of the building's interior and exterior

Figure 54 View of the central electricity distribution panel inside the building

Figure 55 Exterior view of the building

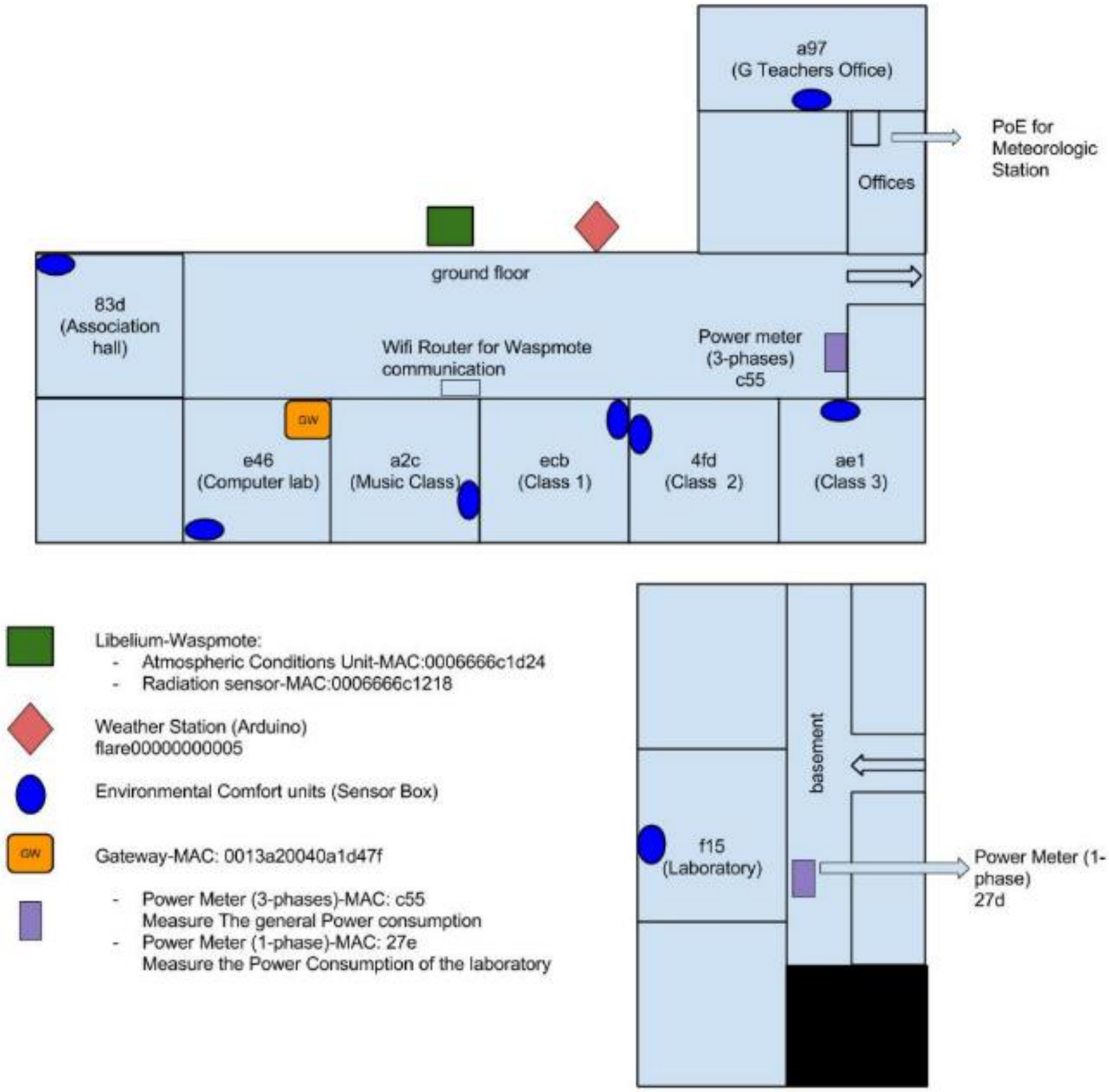
Figure 56 The racks with the networking equipment of the school

Figure 57 View of the computer lab room

Figure 58 Close-up of the installed weather station

Figure 59 View of the building's corridor

Building Floorplan



Description of Primary School, Ligia, Lefkada

The current GAIA IoT infrastructure in the school is detailed in the following table.

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	5
Weather Station	Yes	1, Arduino
Atmospheric Conditions Unit	Yes	1
Radiation Meter Unit (Libelium)	Yes	1
Power meter	Yes	1, 3-phase
Solar Panel	Yes	1, Blue solar

In Greece, Primary schools have 6 different grades. The school has a staff of 18 teachers and 117 students, divided in different classes as follows:

Grade	Students
1st	24
2nd	20
3rd	15
4th	23
5th	14
6th	21

This is the only building that has a solar panel installed – it was installed during the previous Greek research project “Green Mindset”. The solar panel is connected to the Green Mindset SW platform.

Photos of the building's interior and exterior

Figure 60 View of the exterior of the building

Figure 61 View of the interior of the building, a typical classroom

Figure 62 View of the interior of the building, a typical classroom

Figure 63 View of the interior of the building, a typical classroom

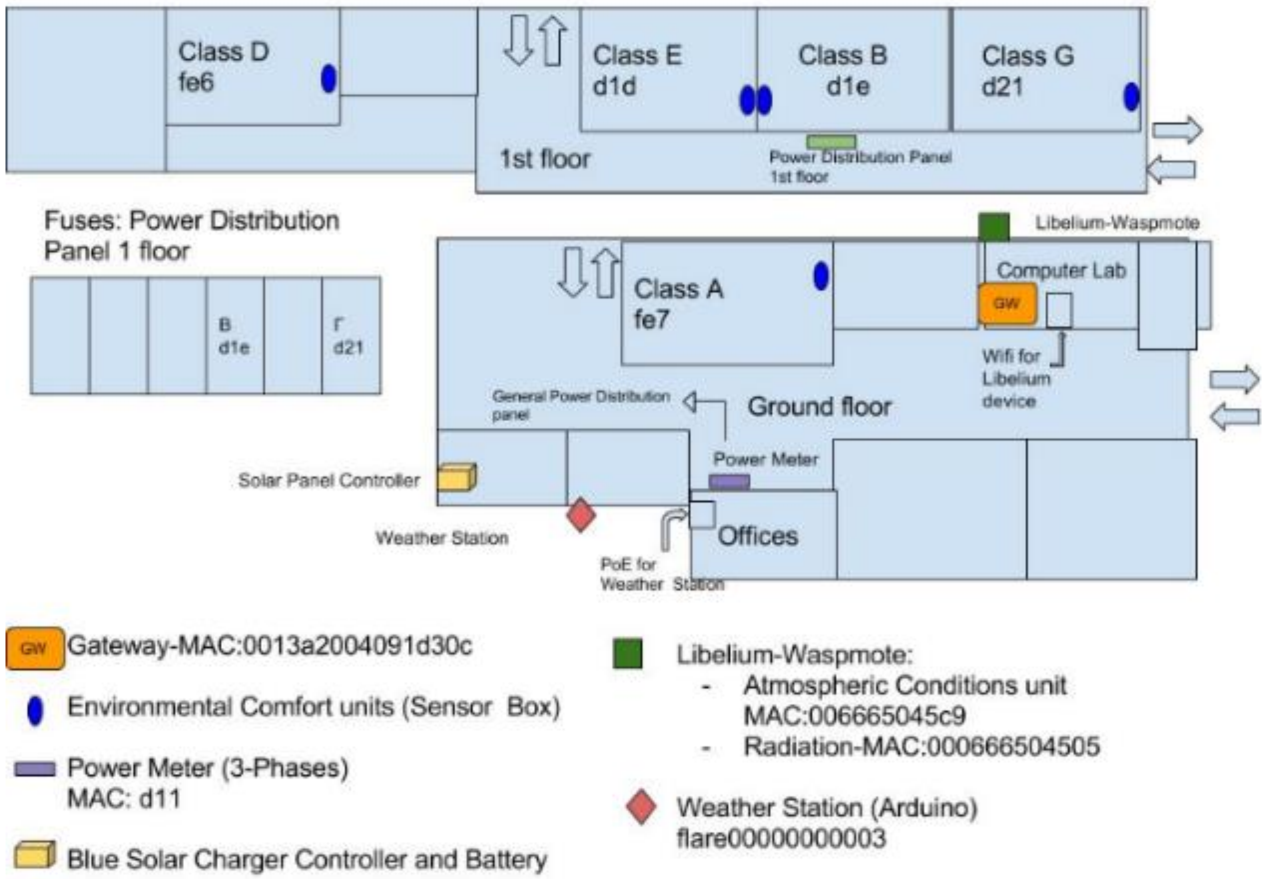
Figure 64 View of the interior of the building, the central corridor on the 1st floor

Figure 65 The weather station installed on the roof

Figure 66 The air quality module installed in the building's exterior

Figure 67 A solar panel is installed on the roof of the building

Building Floorplan



Description of Primary School, Megisti, Kastelorizo

The current GAIA IoT infrastructure in the school is detailed in the following table.

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	4
Weather Station	Yes	1, Synfield
Atmospheric Conditions Unit	Yes	1
Radiation Meter Unit (Libelium)	Yes	1
Power meter	Yes	1

In Greece, Primary schools have 6 different grades. The school has a staff of 8 teachers and 18 students, divided in different classes as follows:

Grade	Students
1st	4
2nd	1
3rd	3
4th	4
5th	1
6th	5

Kastelorizo is a tiny island with only 492 inhabitants. It is the easternmost part of Greece.

Photos of the building’s interior and exterior

Figure 68 View of the exterior of the building

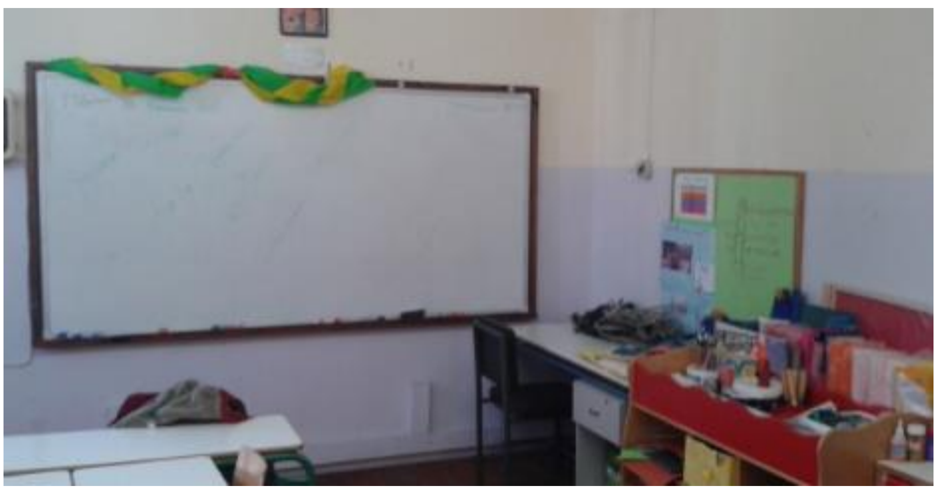


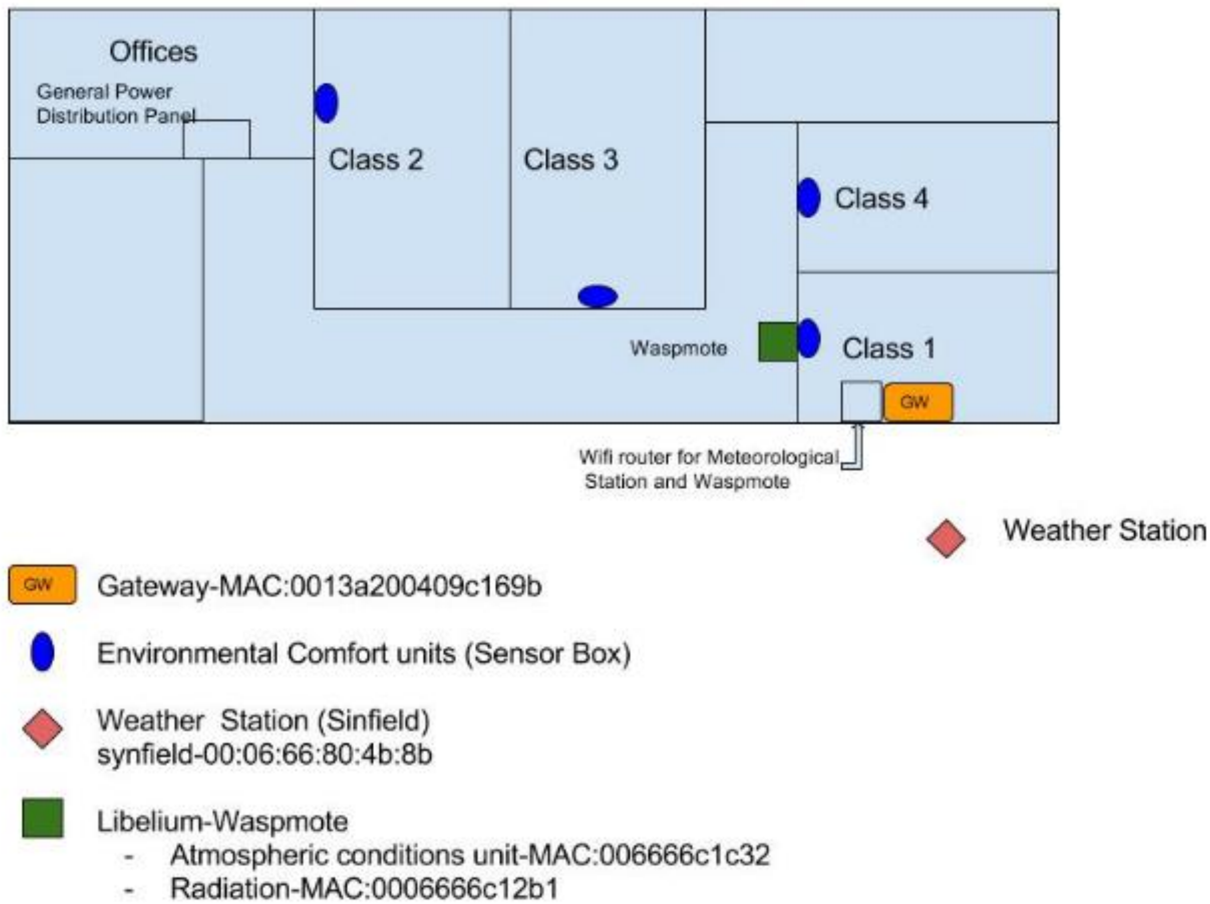
Figure 69 View of the building's interior

Figure 70 View of the building's interior

Figure 71 View of the building's interior

Figure 72 The weather station installed on the building's roof

Building Floorplan



Description of 55th Primary School Athens

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	2
Sensor units (Sensor Box)	Yes	5
Weather Station	Yes	1, Synfield
Atmospheric Conditions Unit	No	
Power meter	Yes	1, 3-phase

In Greece, Primary schools have 6 different grades. The school has a staff of 21 teachers and 137 students, divided in different classes as follows:

Grade	Students
1st	20
2nd	30
3rd	18
4th	20
5th	21
6th	28

Photos of the building's interior and exterior

Figure 73 View of the exterior of the building

Figure 74 View of the building's exterior

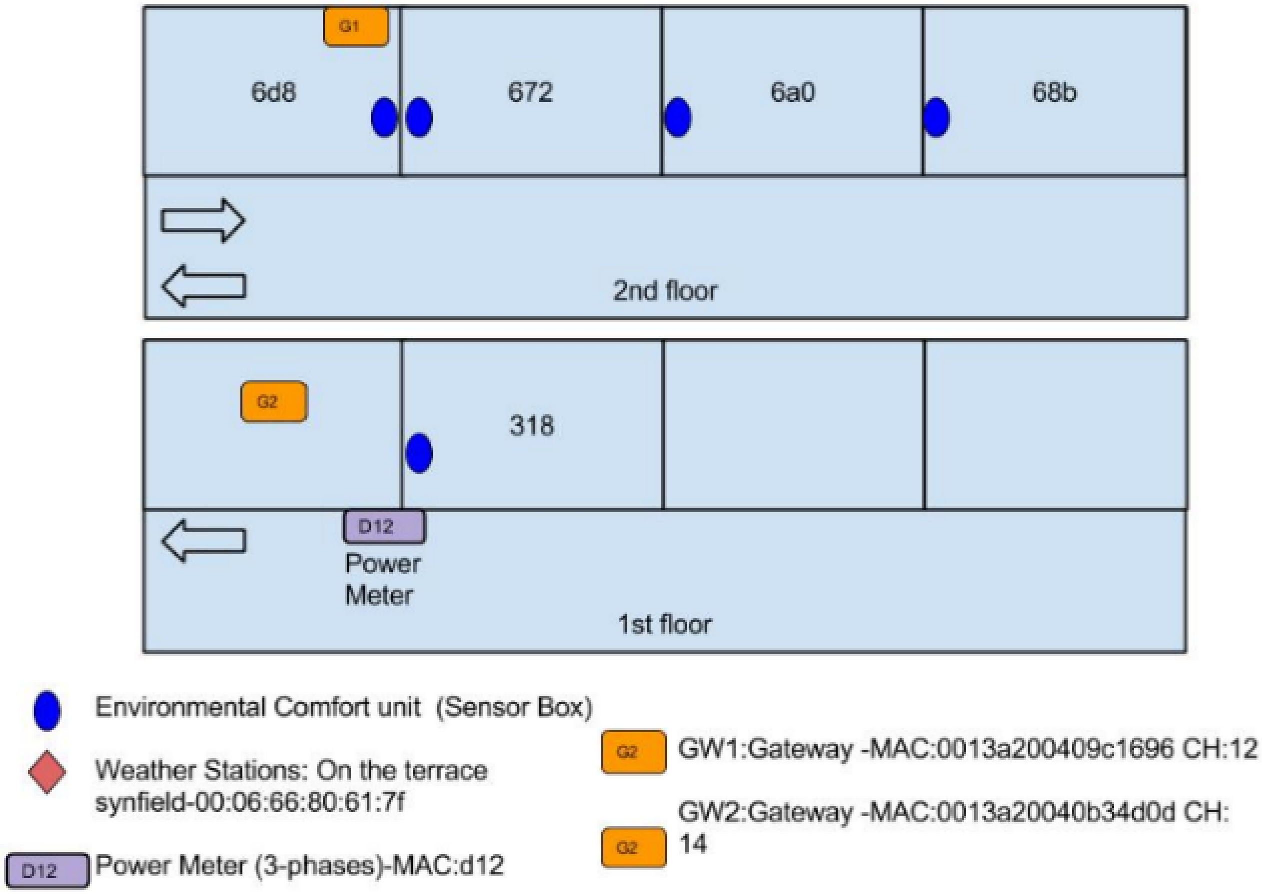
Figure 75 View of the building's interior

Figure 76 View of the building's interior

Figure 77 Exterior view, balcony

Figure 78 The Synfield weather station installed on the roof

Building Floorplan



Description of 2nd Technical High School, Larissa

The current GAIA IoT infrastructure in the school is detailed in the following table.

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1
Sensor units (Sensor Box)	Yes	6
Weather Station	Yes	1, Synfield
Atmospheric Conditions Unit	No	1, Libelium
Radiation Meter Unit (Libelium)	No	1, Libelium
Power meter	Yes	1, 1-phase

In Greece, technical high schools have 3 different grades. The school has a staff of 57 teachers and 212 students, divided in different classes as follows:

Grade	Students
1st	57
2nd	86
3rd	69

This is a technical high school that also has electrician and computer technician classes, so it could also host activities related to the project.

Photos of the building's interior and exterior

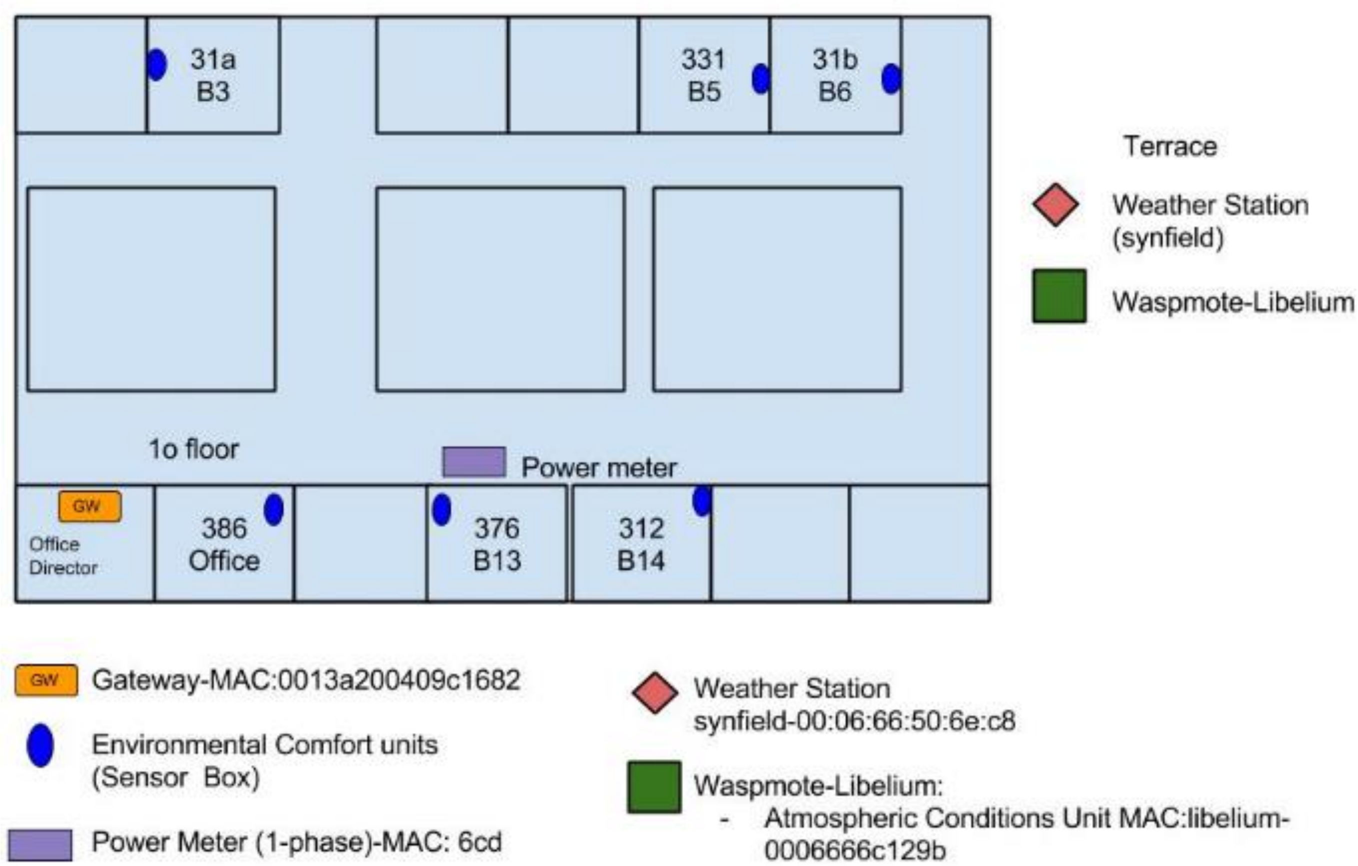
Figure 79 View of the exterior of the building

Figure 80 View of the building's interior

Figure 81 View of the building's interior

Figure 82 View of one of the classrooms

Building Floorplan



Description of 1st Gymnasium, Nea Philadelphia, Attica

The current GAIA IoT infrastructure in the school is detailed in the following table.

Overview of IoT devices available		
IoT Gateway (XBee communication with sensors)	Yes	1, Meazon 3G-enabled
Sensor units (Sensor Box)	Yes	5
Weather Station	Yes	1, Arduino
Atmospheric Conditions Unit	Yes	1, Libelium
Radiation Meter Unit (Libelium)	Yes	1, Libelium
Power meter	Yes	2, 3-phase

The school has a staff of 29 teachers and 251 students, divided in different classes as follows:

Grade	Students
1st	73
2nd	88
3rd	90

Photos of the building’s interior and exterior

Figure 83 View of the exterior of the building

Figure 84 Another view of the building's exterior

Figure 85 View of the building's interior

Figure 86 View of one of the classrooms

Figure 87 View of the computer lab in the school (2nd floor)

Figure 88 View of the library in the school (ground floor)

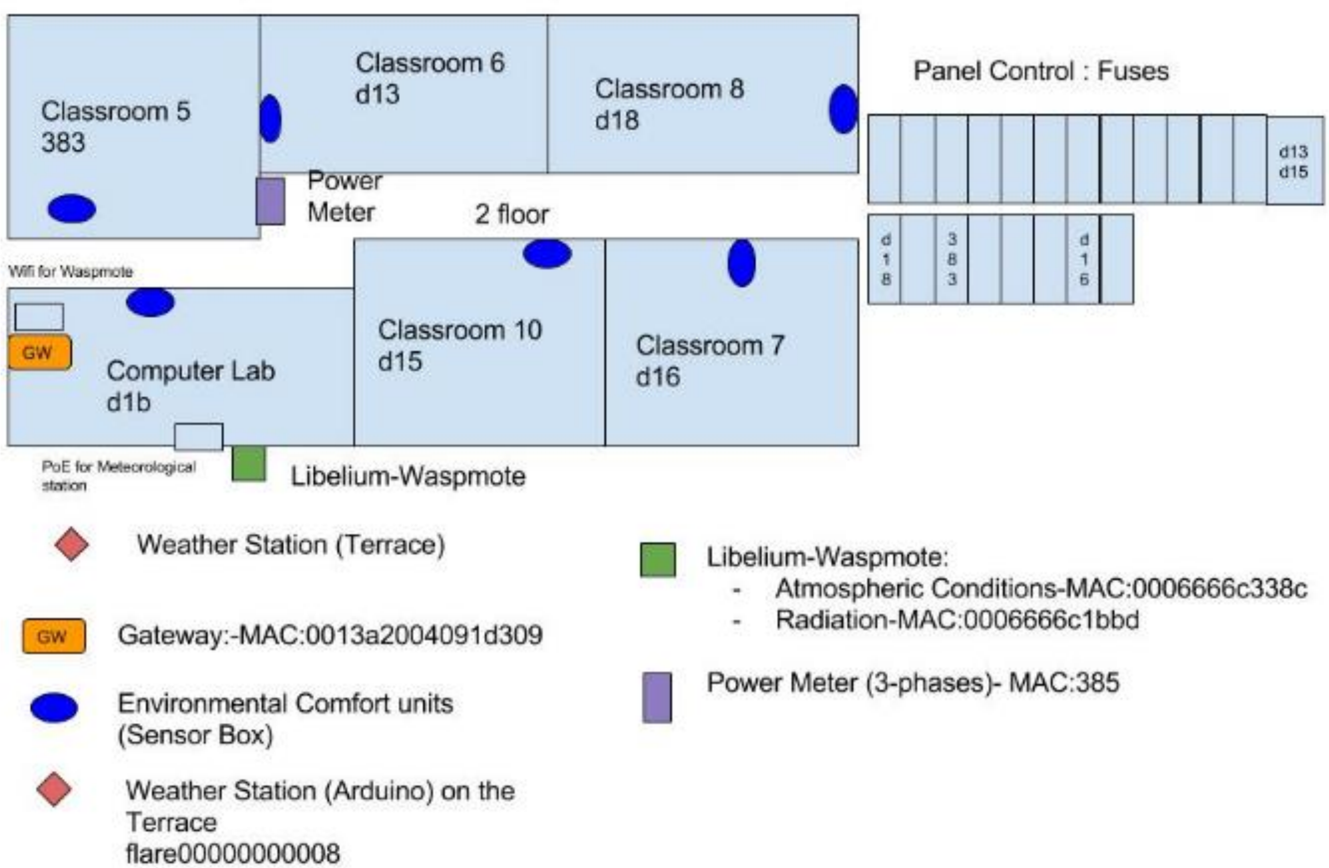
Figure 89 Distribution panel and power meter at 2nd floor

Figure 90 The Libelium atmospheric conditions box (2nd floor)

Figure 91 The weather station installed on the roof of the building (roof of the 2nd floor)

Figure 92 The 3Ph power meter installed inside a distribution panel

Building Floorplan



Description of 1st Gymnasium, Rafina, Attica

The current GAIA IoT infrastructure in the school is detailed in the following table.

Overview of IoT devices available		
Gateway (XBee communication with sensors)	Yes	1, Meazon
Sensor units	Yes	3, Temperature, Humidity, Motion
Weather Station	Yes	1
Atmospheric Conditions Unit	Yes	1
Radiation Meter Unit (Libelium)	Yes	1
Power meter	Yes	3

The school has 378 students, divided in different classes as follows:

Grade	Students
A	130
B	137
C	109

Photos of the building’s interior and exterior

Figure 93 View of the exterior of the building

Figure 94 View of the building's interior

Figure 95: View of one of the classrooms

Figure 96 View of the chemistry lab in the school (1st floor)

Figure 97 View of the auditorium (under re-construction) for school's events (ground floor)

Figure 98 The Libelium atmospheric conditions box (ground floor)

Figure 99 The weather station installed on the roof of the building (roof of the 1st floor)

Figure 100 *Installations of power meters in the building's electricity distribution panels*

Temperature/humidity sensor in computer lab

Motion sensor in computer lab

Motion sensor in B2

Temperature/humidity sensor in B2

4. GAIA metering technologies

In this chapter we proceed with describing the contributions of the SME partners participating in GAIA, along with third party metering technologies which have been integrated to GAIA's ecosystem. Regarding the consortium's own technologies, in this chapter we include details about:

- Synelixis' SynField IoT solution, which have been deployed in several Greek school buildings and will also be installed in other buildings participating in GAIA in the near future.
- OVER's IoT solution, which has been utilized thus far in the La Sapienza University of Rome's buildings participating in GAIA.

A large part of GAIA's currently installed IoT infrastructure in Greece has been designed by SparkWorks in cooperation with CTI, and will be made available as open source hardware. The related details are included in the following chapter, which discusses the open source contributions of the project.

Regarding third party metering technologies, GAIA utilizes IoT nodes from two external vendors, namely IoT power meters and sensor boxes from Meazon, and environmental sensor from Libelium. Details about the utilized technologies are included in this chapter as well. We also expect in the future to have even more third party technologies integrated into GAIA, so this metering technologies list will grow further. The document will be updated accordingly to reflect such additions.

Overview

SynField is the SYNELIXIS's new and economical solution which caters information on what happens in the place it is installed (both environmental conditions but also whether a system of your choice is on). More information can be found in Synelixis' website[7]. While the majority of current deployments is in farms (worldwide), it is equally capable of monitoring the conditions in any place it is installed (see photo). The sensed data are gathered in SYN's cloud infrastructure where they are processed. As **SYNELIXIS develops SynField (and is not just a reseller)** we can customize the solution to the user's need. Its applications include (indicatively):

- **Statistical processing of recorded environmental conditions and system operations** (start-stop time): SynField collects the readings of the installed sensors and makes them available to the user through a graphical interface. The user can select the time period for which the sensed data are shown, the sensor that collected the data, can opt to view the readings of multiple sensors on a single chart and many other options.

[7] http://syngreen.synelixis.com/index.php/en/products/synfield-main

- **Clear view of all your field/area of interest:** Installing additional wireless sensors, SynField can inform you of the conditions holding in different locations across your field. As the user knows his place better than anyone else, he/she can select the most sensitive points and install there additional sensors. This way you can have a clear view of what's happening.
- **Mitigate Risks receiving alerts:** SynField notifies you under specific circumstances through an SMS, e-mail or phone-call. You are prompted to define the circumstances that you want to trigger the alarm and the message that you will receive. If temperature drops, you will be notified and you can remotely take action. The user can define the rules upon which he/she may receive alerts (e.g. the temperature is below a threshold set by the user and the humidity is above another threshold).

SynField system

The SynField system typically comprises:

- A **central SynField device** installed in the farm/area of interest at the point suggested by the user. This device hosts the heart of SynField which communicates with SYNELIXIS Cloud Server over 2G/3G mobile network connection (or over WiFi), with the relays for controlling your automation systems and with the sensors (through wires or wirelessly in the ISM band). This device is mounted on a pole and it can be powered at 6VDC through hybrid lead-battery photovoltaic system which can be provided by SYNELIXIS.
- **Environmental sensors**: In its basic version, SynField comes with a high accuracy and wide range ambient temperature wired sensors and soil moisture. SynField basic system can be augmented by additional sensors either to create a more complete view taking into account additional parameters or to create a more detailed temperature map. SynField can integrate wind sensor, wireless temperature sensors, wireless solar radiation, leaf wetness and soil electrical conductivity sensors.
- SynField powerful cloud-based software that gathers the sensed data at SYNELIXIS Cloud server, statistically processes them to present a graphical view to the farmer, executes the user-defined rules for controlling the irrigation and other systems and offers a simple yet powerful user interface. Due to its cloud-based architecture, SynField can store large volumes of sensed data and events (e.g., turn ON and OFF events), supports multiple areas (possibly located tens of km apart from each other) per user and an almost infinite number of independent programs/rules with dozens of set points.

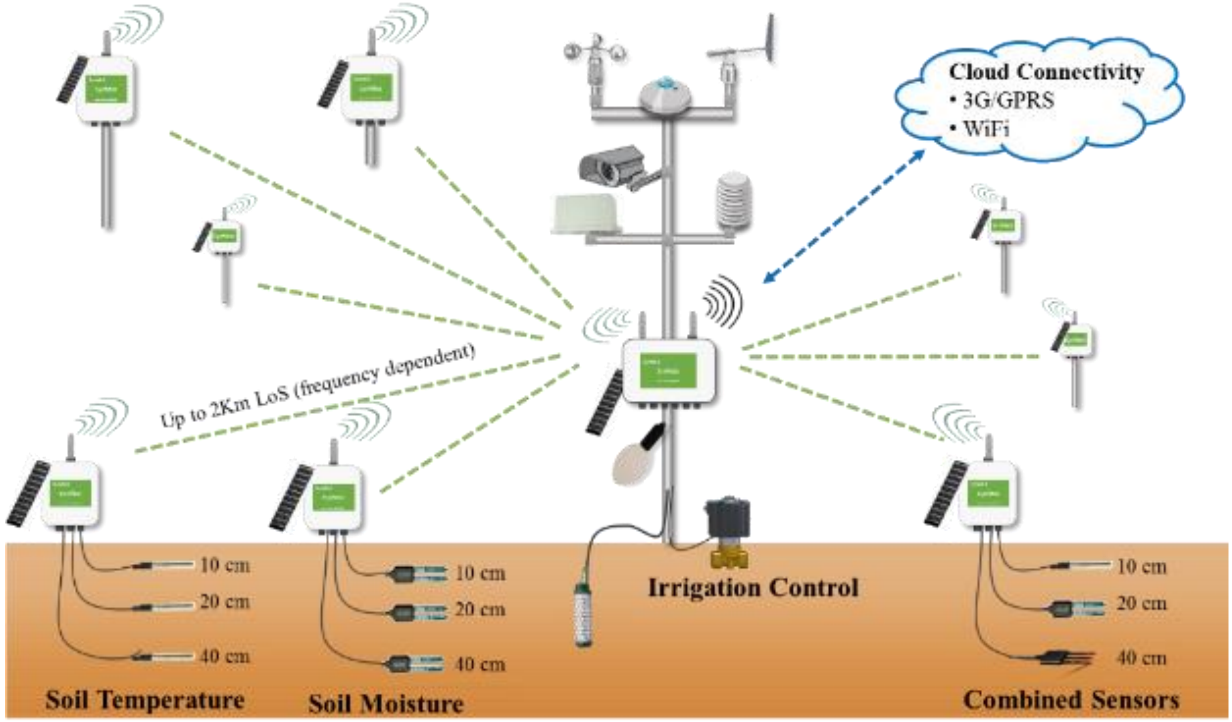


Figure 101: The SynField System

With respect to the integrated sensors (of interest to GAIA), the technical details follow:

Air Temperature sensor

- Resolution: 0,1 °C
- Range: -40°C to 50°C
- Measurement speed: 10ms
- Power: 2.5 VDC/2 mA, to 3.6 VDC/7 mA

Solar radiation sensor

- Spectral Range: 380-1120 nm
- Accuracy: 5%
- Operating Temperature: -40°C to 60°C
- Field of view: Hemispherical, 180°

For the rest of the sensors, details regarding their technical characteristics can be found in Synelixis' website[8].

[8] http://syngreen.synelixis.com/index.php/en/products/synfield-main?id=36#1-air-temperature

Over Platform: a more detailed description

The document deals with the description of the products developed by Over and the software platform used to handle the consumptions data acquired from them and the several functionalities available. In the first part of the document we will detail the features of each device whilst in the last chapter of the document we highlights how the entire system works and how is realized a typical installation in one or more buildings.

Figure 102 OMeter for Business

Over OMeter

The *OMeter* (figure 1) is an advanced “PLC – Programmable Logic Controller” designed and created by *Over.* A PLC is << a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery […]>>. Its hardware is modular and expandable; generally, it has a CPU, a power supply and input/output boards. A PLC runs a certain program and elaborates analog and digital inputs that come from sensors and are directed to actuators.
Concerning the power supply, the *OMeter* needs 13.8 V – 15 V DC and has a typical current draw of 200mA. It is possible to wire to the *OMeter* at most 16 inputs and 8 outputs. Examples of input connections are wall buttons, switches and sensors whilst examples of output connections are lights, sockets, shutters etc. Outputs maximum power is 3,5kW. Each output in fact is equipped with a PCB/Plug-in Finder magnetic latching relay (40 series) with rated current of 16A and maximum peak current of 120A, $AgSnO_2$ as contact material and a power meter with a measurement accuracy about $\pm$1%. The meter incorporates two 16-bit delta-sigma ADCs with a programmable gain up to 16. The output waveform data is available at up to 14 kHz with 16-bit ADC output and 20-bit multiplier output data.

The OMeter is available in two different versions depending on the context where it is installed; **atHome** is suitable for residential installation, while **forBusiness** targets industry automation and monitoring. The two version mainly differ from the total amount of power managed by the device; 4.5 kW in the case of an **atHome** version, 12 kW in the other case, beside that some other hardware protection necessary for guaranteeing service continuity in case of **forBusiness** version.

Concerning its functionality, OMeter can:

- Turn on and off electrical appliances. OMeter does not need an internet connection to achieve the basic electrical plant functionalities.
- Configure outputs. Outputs can be seen as “direct”, “timed” (i.e. a timed light is switched after the expiration of a customized time) or “shutter” (in this case two outputs are used, one for the opening and the other one for the closing of the shutter).
- Catch inputs variations and communication with other OMeters. As we said before, we can have different kind of inputs: buttons, switches or even sensors. Basically the OMeter is able to sense the variation of any inputs and automatically send a message to an output or a group of outputs to activate or deactivate it/them.
- Meter each output. Because each device is connected independently, OMeter is able to understand its consumption. In particular, it provides measurements on current, voltage and “cosφ[9]” and from this values it can calculate active, reactive and apparent power. According to the AEEG (Italian Regulatory Authority for Electricity Gas and Water) Resolution 180/2013/E/EEL, the “cosφ” value has to be greater than 0.95, if you want to avoid penalties. For this reason is something to carefully monitor by an energy manager. The OMeter is also able to supply, for each output, the average energy data of the last 15 minute. Energy data are sent on a percentage or on a time based notification. In the first case, it sends a data only if the value differs from the previous one by the percentage set. In the second case instead, the data is periodically sent with a possible granularity until to five seconds. Typically, to avoid too much messages on the bus the consumption data are sent using the percentage notification based.
- Communicate with the OBox. The communication with the OBox is bidirectional: the OMeter sends information about consumption and state of the device; the OBox can ask the OMeter to do actions (i.e. actuations).

Over OBox

The OBox (figure 2) can be considered as the core of the entire Over platform. It is a single-board computer capable of running ARM Linux OS. It is the gateway of the system. Some of its technical hardware specifications are the following:

- Dual-core A20 Cortex-A7 processor
- Dual-core Mali 400 GPU
- 1GB DDR3 RAM
- 4GB NAND FLASH memory
- 100Mbit native Ethernet
- MicroSD and SD/MMC card connector
- LCD monitor

[9] Cosφ is the cosine of the phase angle between voltage and current. For linear loads, it is equal to the “power factor”, that is the ratio between “active power” and “apparent power”.

Figure 103: OBox - forBusiness version

As far as its output interface, the OBox provides a three wires bus connector, to connect it to the EDS bus (more details bellows), where all the OMeters are connected and an Ethernet port which is used to remotely provide all the functionalities of the system. In particular the OBox:

- Allows a complete control and supervision over all devices.
- Stores and processes energy consumption provided by each OMeter and shows them to the users. The visualization tool provides the users with the possibility to analyze data in a specific time interval and related to the total consumption of the plant or a single device or a group of them. The system provides information about the average cosφ, the cost in euro and a consumption breakdown in the three existing time slot. In case of report related to the total consumption of the plant, it also generates a rank of the most energy-consuming devices.
- Implements energy saving policies - the Eco-standby algorithm for example is able to automatically turn off a device which goes in the standby state.
- Allows to define customized rules and scenarios.
- Handles the load control functionality. In order to avoid energy blackouts by the energy supplier when the energy power overcomes the admitted threshold, it is possible set a priority list of devices to switching off.
- Handles ip webcam with the possibility to real time visualization and registration in the internal nand or on MicroSD.
- Manages the alerting system (email/sms).
- Allows the plant software reconfiguration.

All those functionalities are accessible by means of a responsive web interface, deployed in the OBox itself. Remote connection is available using the cloud platform Ghost without the need of a public IP. An android application is available too, with the same set of functionalities plus a vocal command interface which makes the system usable by both able-bodied and disable people.

Over NanOMeter

The NanOMeter (figure 3) is a small device for monitoring energy consumption in both single-phase and three-phase systems. It can be mounted in each electrical panel together with appropriate current transformers. In order to facilitate the installation, it is also equipped with internet connection on board (GPRS modem and sim exploiting the Vodafone cell-network). To be able of performing energy monitoring the use of current transformers is mandatory. Depending by the context in which the product will be installed it is possible using:

- Current transformers Open-Core. Single-phase current transformer, related primary current 0-400A, open-core, secondary Current 5A, accuracy class: cl 0,5-1, size 50,5x80,5 mm
- Current transformers passing cable. Single-phase current transformer, related primary current 0-400A, passing cable/bus bar passing, secondary Current 5A, Accuracy class: cl 0,5-1, size 50,5x80,5 mm

Figure 104: Over NanOMeter

It also has an EDS port to which we can connect until to three different EDS devices – an actuation and sensing device, such as the OMeter, an EDS temperature/humidity sensor or a pulse counter. EDS[10] (see also the following subsection) is a standard adopted since 1999, allowing to use any type of wire, also single-wire, and is free from interference even if passed between 230V lines. It can be spread up 1.2 Km without repeaters and it's not bound to a particular physical topology: it can be wired in star pattern, cascade or both. Compared to the other bus types available, it is particularly versatile. The monitoring solution in this way can be completed, focusing not only on energy data but also on the temperature and water/gas consumption.

The device sends each minute voltage, current and cosφ to the cloud platform that in turns is responsible to calculate apparent, active and reactive power. Data, whose transmission is not successful due to connectivity problems, are compressed and sent again as soon as the connectivity permits to do. The web application, deployed in the amazon EC2 cloud platform, offers additional high level functionalities such as:

- Real-time visualization of the quantities monitored
- Historical visualization with selection of the period and the granularity data of interest
- Repartition of the consumption data on the different NanOMeter compound the sub-levels of the NanOMeter selected
- Configuration panel for setting NanOMeter and Current Transformers options
- Visualization/configuration of the user profile information
- Self-reading of the electricity meter provider to have more accurate energy bills (not based on estimated consumptions but on effectives ones)

[10] EDS system, http://www.worlddatabus.com/website/sistema-eds.html

- Notification system, based on email and SMS to advise end user about power peak or power cut

The sensed data are also viewable on the LCD display on board of the device. The display continuously shows the GPRS signal power, the instantaneous power on each line of the system and the total energy monitored (in kWh) from the first time of its installation.

More in detail, the NanOMeter is equipped with three different micro-controllers for (i) EDS communication, (ii) energy data acquisition and management and (iii) GSM communication. The kind of microcontroller used are PIC24 16-bit, 128KB Flash memory, 8 KB ram, with 64 Pin package. It has a meter for each phase (same type used in the OMeter), which use 16-bit ADC output and 20-bit multiplier output data. It has a triple redundant power supply: 1) internal battery guaranteeing, depending from the GPRS signal conditions, at least an autonomy of 4 hours, 2) alternate current (220V/380V), and, 3) direct current (12V-16V), through the EDS bus port.

EDS Bus System

EDS stands for “En-Decoder System” and is an open source protocol developed during the ‘90s by World Data Bus7. It needs only three wire to achieve the communication:

- GND. Common return path (0 V).
- VCC. Power supply (12 V) that refers to GND.
- DATA. Single wire that provides the exchange of signals and refers to GND.

While the VCC-GND are meant to give power supply to a device that is able to communicate with EDS protocol, DATA-GND provide the real communication of the network. EDS system uses fixed length messages for the communication inside the network. Each message is made by eight fields of 1 byte (8 bits); therefore, the size of the exchanged message is of 8 bytes (64 bits). Fields follow a little-endian order of bytes; therefore, we have that the least significant bit is at the lowest address. As detecting error mechanisms the protocol, first uses customized metadata to identify start and end of the transmission and second, use the checksum byte, generated according to a specific function, to figure out whether a message is corrupted or not.

EDS protocol works at the following conditions:

Bit Rate	**Actuation time**	**Max length of the bus**
1200bps	60ms	2000m
2400bps	30ms	1600m
9600bps	10ms	1200m

By default, the EDS system uses the communication with the highest bit rate (9600 bps). This choice is due to the low actuation time[11] that we have with this speed. In fact, in home and buildings automation

[11] *Actuation time* is the time that elapses from the execution of the request of the action and the action itself. According to the *Doherty threshold*, if a human being’s command is executed and the answer is given in less than 400ms, the user is not able to distinguish the change anymore.

environments, we need the network to be really reactive to the user requests. Of course, if we are dealing with very large buildings that could exceed the maximum length of the bus (e.g. hotels, factories, etc.), we have to use a device as a repeater of the messages between two sub-networks.

Architecture and System Design

Generally, a typical infrastructure (fig. 4) is made up of one *OBox* and many *OMeter* depending by the number of the physical locations and the physical devices that have to be controlled and monitored. Usually the infrastructure is completed with several NanOMeters. Typically at least one NanOMeter is installed in the general electrical box to be sure that energy consumption are properly billed. More than one NanOMeter can be installed when we want to monitor big area of the building or when we have high current absorption (e.g. one NanOMeter for each floor of the building or for the more energy consumption power lines such as the HVAC systems).

OMeters and the *OBox* are connected to each other by means of the EDS bus - three simple cables (two for the power supply and one for the data exchange). Then, the *OBox* is connected to a router through an Ethernet cable that allow the users to locally and remotely access the web interface. Remote access is guaranteed by means of the Over cloud platform, *Ghost.*

NanOMeters are not physically connected to each other. They send data through the GSM modem to the cloud platform. The existing relationship establishing how the NanOMeters are hierarchical organized, are set via software during the configuration phase. The architecture is fully scalable thanks to the services provided by Ghost, deployed on an instance of the Amazon EC2. Ghost guarantees a simple, scalable and unified system for the data management. It is used both for data collection and remote access allowing the user to remotely access and control the electrical plant.

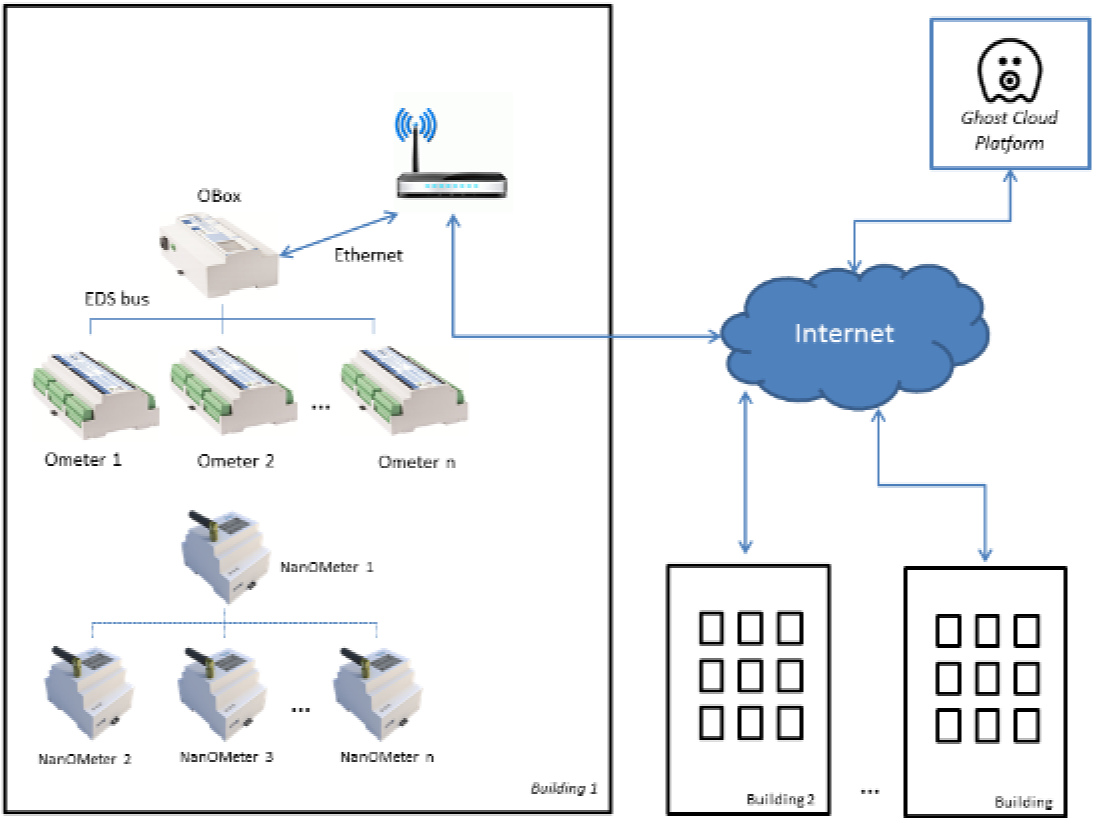


Figure 105: System Architecture

Meazon IoT metering and sensing platform

Meazon[12] is an energy-focused SME, with a line of hardware IoT products complemented by a robust IoT software ecosystem, which aim to bring the benefits of the emerging Internet of Things to the energy efficiency sector. Meazon's line of IoT products in general follow a standards-based approach, along with having a number of specifications useful for public buildings such as schools. Furthermore, the company has flexibility in its product lineup along with experience from past installations in large buildings, which helped the consortium to solve several issues present due to the construction or layout of some school buildings in Greece.

Meazon metering and sensing devices have been installed in 3 public school buildings in Greece. The following list includes the type of actual devices installed:

[12] http://meazon.com/

- Meazon Gateway[13] and Meazon Gateway Advanced: an IoT gateway with WiFi only or 3G capabilities (Advanced), responsible for connecting to the IoT infrastructure.
- DinRail 3-phase power meters[14]: a non-invasive power meter with ZigBee wireless connectivity, installed at the electricity distribution panel of the respective school buildings.
- Meazon Bizy plug[15]: a wireless-enabled plug that enables remote measurement and control of electrical appliances inside a building.
- Temperature/Humidity/Motion Sensors[16]: wireless (ZigBee) sensing units, which can be easily installed or be relocated inside classrooms and other school facilities.

GAIA has worked closely with Meazon to interconnect their system with the one currently in development by GAIA. Since both largely use standards=based components, this is also a showcase that GAIA's envisioned approach works, i.e., a variety of IoT devices from various vendors could potentially constitute the IoT layer of GAIA, avoiding lock-ins with very specific hardware providers.

Handheld Thermal Cameras

In recent years, advancement in sensor technology have made possible the availability of handheld thermal cameras with reasonable accuracy and cost. Combined with the rising market for smartphone and tablet accessories, a number of smartphone compatible thermal cameras are available in the market. Such devices pair with a smartphone or tablet in order to augment their imaging capabilities and provide innovative capabilities. Such accessories to a large degree can replace professional equipment, which usually come with a high cost, and in the context of GAIA can help in:

- Aiding to "map" school environments, in a manner similar to the way energy audits are conducted by energy inspectors.
- Help in shaping certain aspects of the participatory metering and gamification activities of the project, by having a device with reasonable cost that can be available for everyone to use.

[13] http://meazon.com/portfolio_category/meazon-gateway/
[14] http://meazon.com/portfolio_category/meazon-dinrail/
[15] http://meazon.com/portfolio_category/meazon-plug/
[16] http://meazon.com/portfolio_category/meazon-sensor/

- Contribute with actual measurements from the school surroundings, paired with location and other context, thus making for rich information context.

GAIA is actively looking into such technologies and products, having acquired a FLIR One Thermal Camera[17] Accessory for Android. This thermal camera module pairs with a smartphone turning it into a device capable of scanning temperature in its surroundings. The consortium is investigating ways of integrating such modules into its software ecosystem as well.

Waspmote Smart Outdoor Environment Meter

For monitoring outdoor conditions we are additionally using the Waspmote Smart Environment device. It basically monitors environmental parameters such as atmospheric pressure, the concentration of a number of gases, and the pollution on the outdoor places of the building. It is based on the Waspmote Gases 2.0 board[18] provided by Libelium, which allows to have 5 gas sensors sampled at the same time, regulate their power and the amplification of the output signal for each one. GAIA has complemented this basic board with additional components, such as batteries, chargers, and a weather proof casing, in order for it to be easily deployed in real world settings. GAIA is using currently this device in a number of Greek public schools.

Main Hardware elements

Type	Element Name	QTE
Board	Waspmote Pro V1.2 (ATmega 128I)	2
Board	Waspmote Gases 2.0	1
Boards	Waspmote Radiation	1
Communication	WiFly RN-171	2
Communication	External Antenna and cable	2
Sensor	Geiger-Müller tube J305ß	1
Sensor	Humidity Sensor – 808H5V5	1
Sensor	Temperature Sensor – MCP9700A	1
Sensor	Atmospheric Pressure Sensor - MPX4115A	1
Sensor	Carbon Monoxide (CO) Sensor – TGS2442	1
Sensor	Carbon Dioxide (CO_2) Sensor – TGS4161	1
Sensor	Molecular Oxygen (O_2) Sensor – SK-25	1

[17] http://www.flir.eu/flirone/ios-android/
[18] http://www.libelium.com/downloads/documentation/gases_sensor_board_2.0.pdf

Sensor	Ammonia (NH_3) sensor – TGS2444	1
Sensor	Air Contaminants Sensor - TGS2602	1
Enclosure	IP66 Enclosure	1
Enclosure	CG-12 Cable Gland Series	2
Battery	1x6600 mA/h rechargeable battery	2
Power	Power supply 5VDC 2A	1
Cable	Mini USB cable	2

5. GAIA Educational Kit Design

In this section, we will discuss an additional part of the design that has not been addressed in the DoW of GAIA previously. More specifically, we explain the general design of an educational GAIA lab kit, which is meant to complement the rest of the hardware and software components in the following general manners:

- It will comprise a set of IoT hardware equipment meant to aid in implementing a “hands-on” approach, in terms of the technologies used, in the schools participating in GAIA.
- It will also help to potentially establish communication channels with other, non-participating in GAIA schools, which will further augment the impact of the project.

More precisely, we aim to provide in the future an additional means of interacting with the project and further increasing the end-user engagement, alongside the other feedback options that will be produced by GAIA, such as the gamification platform and the Web Portal. Overall, it will include already assembled IoT devices, commercial or GAIA-designed, together with other IoT hardware components that can be used to assemble custom IoT devices, which can enable:

- Monitoring of real-world parameters, in a way similar to the stable IoT infrastructure installed inside GAIA school buildings, but which will be done in a more “personalized” and direct manner through the educational kit devices.
- Communication with GAIA ecosystem software services, in similar ways to the ones used by the infrastructure, also providing a clearer picture of how the overall system works.

This set of hardware components will be complemented by educational scenarios and lab courses related to GAIA, which will help the students to get a better grasp of GAIA’s subjects and goals by utilizing a “hands-on” approach. This approach could include the use of already assembled devices, as well assembly of IoT devices by the students themselves, along with code to program such devices (based on GAIA-provided templates) and “play” with the possibilities available by using such platforms.

A set of examples to envision such an approach is included at the end of this section. However, the development of the actual respective material will take place alongside the development of the educational material, in the forthcoming months of the project. For this reason, the examples included here are only indicative of the envisioned use of the kit.

As mentioned above, the potential end-users of this kit are educators and students at both GAIA and other non-related schools. On the one hand, such lab courses are meant to complement the core of the GAIA ecosystem, educational material and game, thus it will not be necessary for the kit to be used continuously by a single group of people, e.g., only a specific school. On the other hand, several schools in Greece have already expressed their interest in participating to the project in some way, but they cannot be covered by the existing budget to install GAIA infrastructure at the respective buildings. The educational kit could be designed to address this situation without incurring significant costs to the project and to such schools.

Therefore, a mobile, reusable hardware lab kit compatible to the infrastructure already used in GAIA seems like a perfect fit for the above characteristics, and in parallel it will help the project to increase both the end-user engagement factor, as well as the impact of its educational community dissemination aspects.

What will it include

Regarding the actual components of the educational kit, it will in general be in line with the hardware use for GAIA's IoT infrastructure and what is being used currently in similar educational actions and hackerspaces all over the world. More specifically, the kit will include:

- Arduino-compatible devices
- A number of sensors, including temperature, humidity, light, movement, particles, gases, noise
- A number of Raspberry Pi devices, or similar platforms,
- A thermal camera compatible with smartphone interfaces, such as the FLIR thermal camera module.
- A tablet or smartphone device to ease interfacing with the abovementioned devices.
- A portable projector to enable groups of end-users to engage with the lab activities, without requiring other UI infrastructure such as monitors or smart interactive boards.

Overall, the idea behind the include hardware, and GAIA's hardware in general, is that it is meant to be replicable and extensible. In this way, interested schools or educational institutions can replicate it on their own, or modify it, without requiring GAIA's intervention and utilize the existing educational material without additional costs.

Examples of envisioned educational scenarios/activities

We now include some examples to showcase the overall concept of the educational kit.

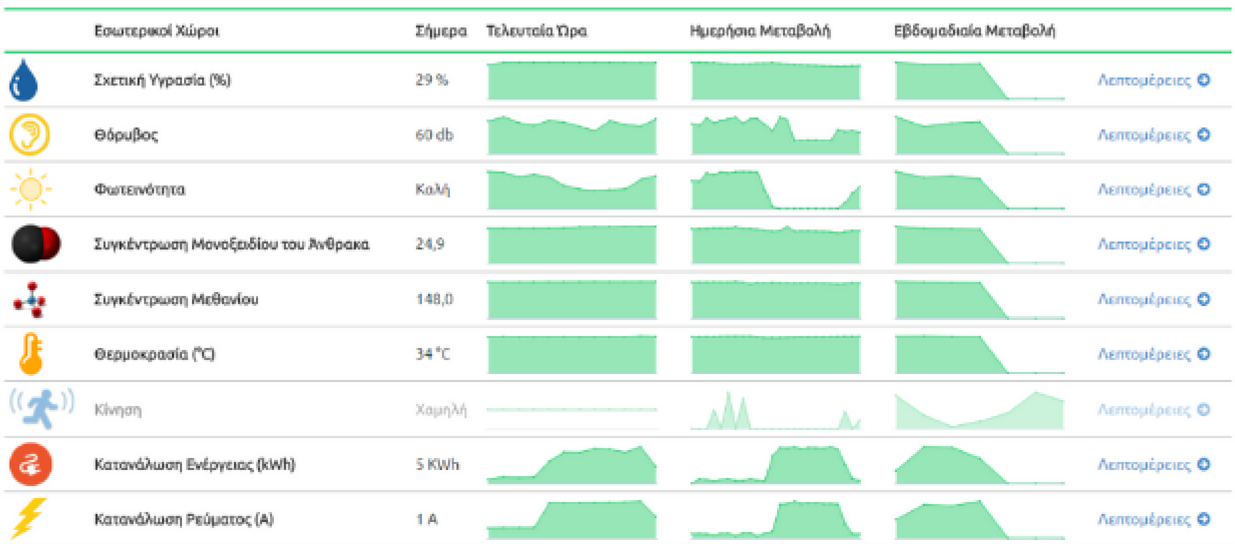
Raspberry Pi Monitor

This tutorial describes how to create a screen where information about the deployed sensing infrastructure and other GAIA related statistics on a single monitor. The installation is pretty straight forward and can be performed by students and/or teaching staff without any specific knowledge requirements. The setup is based on the well-known Raspberry Pi platform, a miniature and low cost PC. The hardware requirements are:

- Raspberry PI board (e.g., a Raspberry PI 3),
- Wi-Fi or Ethernet connection,

- GAIA account, and
- Computer monitor/TV with HDMI or DVI input.

To setup the monitor one will need to install an operating system on the SD card and plug it in the Raspberry PI. A preinstalled image can be provided by GAIA or directly from the Raspberry PI website. After the installation of the operating system, students or the teaching staff need to configure the browser of the operating system to load the statistics page of GAIA for the specific school building and set it to start automatically when the device is restarted (e.g., when the power is out). And that's it, information about the sensors installed like the current power consumption, atmospheric conditions, etc., are available for everyone. A visual example of how the monitor could appear is presented in the following figure.

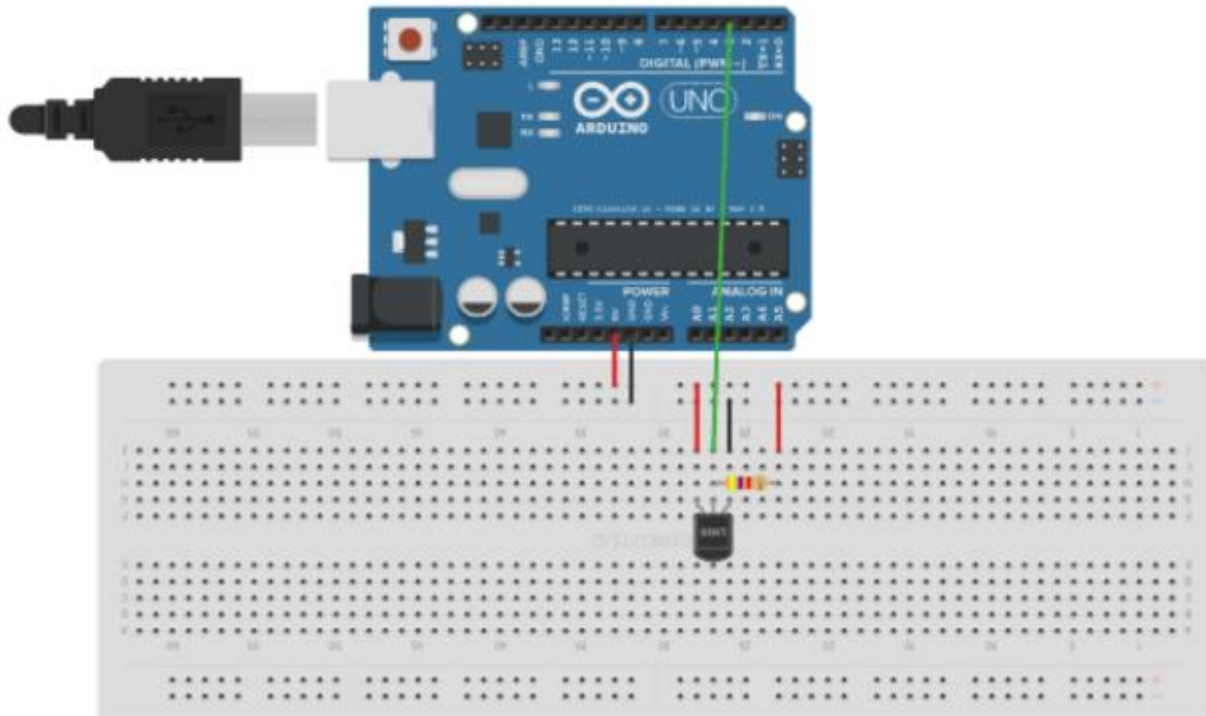


Arduino data node for GAIA

Students can easily learn how to measure the conditions of their environment together with simple concepts of electronics and computer programming using the extremely popular and easy-to-use Arduino platform. In order to organize that, teachers need to have access to the following:

- Arduino devices (preferably Ethernet or Wi-Fi),
- Simple Sensors (e.g., thermometers, luminosity sensors, hygrometers or barometers), and
- Wi-Fi or Ethernet connectivity (in order to upload the data to GAIA),

An example circuit connecting a temperature sensor with an Arduino is presented in the next figure. The code to establish the ability to read the data from the thermometer as well as publishing them to GAIA is no more than 30 lines and similar projects are taught in classes in many schools (even primaries) all around the world already.



Thermal Camera & School Heatmap

Another activity that can be performed inside the school in order to increase the awareness of students on the energy behavior of their building is the use of the FLIR thermal camera for Android in order to record images of the school building. These images can be used to help students identify and understand how heat or cold is dissipated and moves inside the building. Similar images can be taken in different hours of the day or during the whole school year to see the changes during cold and hot days. Images can then be uploaded on the GAIA website and be compared the ones from the other school buildings participating in the project. For this the hardware requirements are:

- FLIR Camera, and
- Compatible smartphone.

6. Open source contributions of GAIA

As stated in the previous chapters of this document and mentioned in the DoW document, GAIA places a special focus on open source technologies. This focus extends to two directions:

- Utilize existing specific open source technologies, which are commonly used in the IoT field, in order to keep costs in check and avoid potential vendor lock-ins.
- Produce results in an open source manner, making certain software and hardware components freely available through GAIA's website and other online repositories.

The advantages of the first directions are obvious, especially in an area where there are multiple vendors currently competing with closed solutions. The GAIA consortium believes that a standards-based approach should be followed throughout the project in order to maximize potential interaction with third party groups and technologies. In this spirit, the design discussed in this document foreshadows standards-based solutions, in both the hardware and software planes.

Regarding the second direction, we envision the use of GAIA's results from the educational community and European SMEs in certain aspects, and their use of them to promote or advance their own solutions, or base new products on the knowledge produced by the project. Since GAIA is aiming at the educational field, it follows an integrated approach: *we design our ecosystem in a way that it will not only serve as a technological solution, but also be useful on the educational plane*.

For this reason, a number of GAIA's results will be made open-source; the specifics of the open source license used for the project will be decided in the coming months. Details will be made available on the project's website and on popular online repository platforms, e.g., GitHub. It is important to note that this approach also relates to the Educational Lab Kit of GAIA; this open source policy and argumentation is the starting point for its creation and progress in the course of the project. The IoT hardware detailed in this section will be used as the base on which the actual kit will be realized.

Regarding actual results, we discuss here a set of IoT hardware co-designed and developed by SparkWorks and CTI for the Greek public school buildings, i.e., it is a solution already deployed in real-world settings and is currently operational, producing data for the GAIA platform. This hardware consists of:

- An IoT power meter,
- An IoT sensor box, and
- An IoT weather station.

We provide several details here regarding their design and implementation; full details regarding these specific hardware components, along with the respective software will be made available online in the following months, as mentioned above.

Power Consumption Meter (3-Phase)

The Power Consumption Meter device is responsible for measuring the apparent power and the Average Power consumption in school buildings remotely. So far, it has been installed at the general distribution board of a set of Greek public school buildings and uploads the specific measurements by sending the readings through a wireless network to an IoT gateway, which is responsible for communicating with the GAIA cloud infrastructure.

The common method to transfer power to public buildings, such as schools, is 3-phase electric power. Three separate single phase supply, with a fourth neutral wire, provides a constant voltage necessary for the most common property groups which are single-phase load and particularly in the EU, 3-Phase 4-Wire 400Y/230 V system is used [hw1]. For measuring the total power consumption, three independent meters are required, one for each phase. The apparent voltage is considered a constant 230VA and the apparent current on each phase is calculated using a SCT-013-030 current sensor [hw2], which has been clipped on each phase wire. The total apparent power consumption is commonly assumed to be the arithmetic sum of the calculated VA ratings of each individual line separated. Notice that the Apparent Power measurement method has been chosen in order to avoid the use of a VAC sensor, mainly due to their invasive character. The SCT-013-030 clip is an electric device that is clipped around on a wire and measures the amount of current that passes through it by reading the alternating magnetic field induced on the core of the sensor. Therefore, the distributed electrical panel is not altered, which greatly simplifies the installation process, one of GAIA's design goals.

The design board connects the 3 current sensor outputs to an Arduino microcontroller. The 3 current phases are sampled as different inputs and the digital processing for each one is being performed on the Arduino microcontroller. As a result, the apparent current on each phase is computed on the Power Meter device and upload to the cloud where the respective Total Apparent Power and Average Power is calculated. A simplified version of the EmonLib library [hw3] [hw4] has been used to sample the output voltage of each SCT current sensor and digital process the signals. A correct average reading is guaranteed when it is calculated within a sample window with at list 10 cycles of the AC signal. Sampling with N=1024 guarantees this premise. The calibration constant was chosen based on the specific electronic configuration of the utilized sensors. After the voltage sampling and the Analog to Digital conversion, the 3 digital signals are filtered on software for removing the constant bias that was added to couple the original sensors outputs with the Arduino range inputs and the RMS current value (Apparent Current) is calculated. The power consumption meter sends the current consumption wirelessly via an XBee radio transceiver, while the processing, analysis and data presentation is done by the software.

Main Hardware elements

Type	Element Name	QTE
Micro controller	Arduino Pro Mini - 5V/16MHz	1
Communication	XBee (XBee pro) 1mW Wire Antenna-Series1 (802.15.4)	1
Power	Power Supply 5V 1A	1
Boards	XBee Explorer Regulated	1
Boards	PCB 3-sensor-jacks	1
Boards	PCB Arduino board	1
Enclosure	Z-108F- Enclosure: for DIN rail mounting	1
Sensor	Non-Invasive AC Current Sensor (30A MAX) 82122-A (model: SCT-013-030)	3
Components	SMD capacitor 10uF	3
Components	SMD resistor 10k	6
Components	Audio Jack 3.5mm	3
Components	Pinhead male	1
Components	Pinhead female	1
Components	Clemens 1A	2
Components	Pluggable terminal block	1
Cable	Jumper Wire - 0.1", 5-pin	1

Operational characteristics

Specifications	
Microprocessor	Arduino pro micro with ATMega328 (8-bit micro controller)
Dimensions	70mm x 90mm x 65mm
Body Colour	Grey
Power Supply	AC 85 – 265V, 50 – 60 Hz
Casing	Din rail mounting Z108F
Operating Temperature	-25 – 60°C
Relative humidity	40% ~90% RH
Sensing	3 Split core current transformer SCT-013-030 Voltage output type.

	One for each phases current measure.
Sensing range	0.1A-30A on each phase
Remote data sample rate	30 sg
Networking	Wireless 802.15.4 XBee Pro
Software	COAP, MQTT
Power consumption	Lower than 100mA normally

Sensing-Current	
Input Current	0 – 30A , 50/60 Hz
Turns Ratio	Np : Ns = 1: 1800
Output Voltage	0 – 1 V
Built in sampling resistance(RL)	62 Ω
Non-linearity	±1%
Resistance Grade	Grade B
Work Temperature	-25 °C – 70 °C
Dielectric Strength	1500V AC/ 1 min 5mA
Core Material	Ferrite
Fire resistance property	In accordance with UL 99- VO

Networking	
Type	Wireless 802.15.4
Operating Frequency	ISM 2.4 GHz
Antenna	Integrated
Topology	Point-to-point, Point-to-multipoint, Peer-to-peer
(XBee)Transmit Power Output	60mW (+18dBm)
RF Data Rate	250.000bps
Receiver Sensitivity	-100dBm (1% packet error rate)
Indoor/ Urban Range	Up to 100ft (30m)
Outdoor RF Range	Up to 300ft (90m) if within line-of-sight
Number of Channels	16 Direct Sequence Channels
Addressing	PAN ID, Channel and Address
Multihop Capability	Maximum 16 hops
Security	128-bit AES Encryption

Environmental Comfort Meter

The Environmental Comfort Meter device collects different aspects that affect the occupancy comfort such as thermal and visual comfort, as well as noise exposure by sensing different environment parameters. Also, a PIR sensor is included that detects motion in order to measure the rate of occupancy of the space.

Thermal comfort is the human satisfaction level with the surrounding thermal conditions and depends on air temperature and relative humidity (percentage of water vapor in the air), among others less significant aspects. LM35DZ and the HIH-4030 sensors are included on the device in order to measure the temperature (in ºC) and humidity (in %RH). Notice that the humidity sensor is strongly correlated with the environmental temperature. Because of this, both sensors are exposed out of the meter's casing, in order to reduce their exposure to the residual temperature produced by different elements of the device inside the box. For example, important sources of temperature are the transformer and voltage converters, and the heater circuit for Metal Oxide gas sensors included in the device.

Visual comfort is related to measurement and perception of light that is required to be precise with the terms and metrics used. Building regulations and standards use Illuminance to specify the minimum light levels for specific tasks and environments. Illuminance is described as the amount of light falling on a surface and is measured in Lux (lumen/m^2).

The noise exposure levels inside classrooms is an interesting parameter to be taken account for buildings such as schools. In order to detect poor classroom acoustics due to background noise and/or reverberation in the classroom, a Sound Pressure Level sensor (SPL) has been included. The SPL is an effective logarithmic sound pressure measurement of a sound relative to a reference value. SPL levels are commonly measured in decibels (dB) above a standard reference level of 20µPa, considering the threshold of human hearing. Actually, each sensor module response is represented with a unique specific characteristic function, which also can change with time use. Different sensors will read different measurements from the same noise and on different moments. A calibration process relabels the dB scale for each microphone and reduces this effect by fixing the reference of each sensor to a background value.

For detection of gases such as CO and CH_4, two different metal oxide semiconductor sensors have been included on the device. These kinds of sensors have been chosen because of their low cost, low power consumption (less than 1W) and their simple and cheap measurement circuits. However, certain issues such as high cross-sensitivity to temperature and humidity, limit their use to mainly detection.

Main hardware elements

Type	Element Name	QTE
Micro controller	Arduino Pro Mini - 5V/16MHz	1
Communication	XBee (XBee pro) 1mW Wire Antenna-Series (802.15.4)	1
Power	Power Supply 5V 1A	1
Boards	XBee Explorer Regulated	1
Boards	PCB Arduino-sensor board	1
Sensor	LM35DZ temperature sensor module	1
Sensor	Humidity sensor- HIH-403 Breakout	1
Sensor	OPENJUMPER OJ-CG306 Sound Sensor Module	1
Sensor	Mini Photocell	1
Sensor	PIR Module	1
Sensor	Methane (smoke sensor) Gas Sensor – MQ-2 module	1
Sensor	Carbon Monoxide Sensor – MQ-7 module	1
Enclosure	Transparent Plastic Box	1
Components	SMD resistors	3
Components	Pinhead male	1
Components	Pinhead female	1
Components	Clemens 1A	1
Components	Screw for plastic	4
Cable	Jumper Wire - 0.1", 3-pin	3
Cable	Jumper Wire - 0.1", 4-pin	2

Operational characteristics

Specifications	
Microprocessor	Arduino pro mini with ATMega328 (8-bit micro controller)
Dimensions	90mm x 127mm x 34mm
Body Colour	Transparent
Power Supply	AC 85 – 265V, 50 – 60 Hz
Case	Transparent plastic enclosure
Operating Temperature	-25 – 60 °C

Relative humidity	40% ~90% RH
Sensing	Temperature, Humidity, Luminosity, Sound Level, Motion, Methane, CO
Remote data sample rate	30 sg
Networking	Wireless 802.15.4 XBee Pro
Software	COAP, MQTT
Power consumption	Lower than 100mA normally

Sensing-Temperature	
Sensor	LM35 (Calibrated Directly in Celsius Centigrade)
Linear, analog output, Sensitivity	+ 10-mV/ °C Scale Factor
Accuracy	0.5 °C (at 25°C)
Measurement range	2°C to 150°C
Voltage operation	5VDC
Non-Linearity	±¼°C Typical
Current Drain	Less than 60-µA
Self-Heating	0.08°C in Still Air
Low-Impedance Output	0.1Ω for 1-mA Load

Sensing-Humidity	
Sensor	SparkFun Humidity Sensor Breakout - HIH-4030
Near Linear, analog output	VOUT=(VSUPPLY)(0.0062(sensor RH) + 0.16), typical at 25 ºC
Temperature compensation	True RH = (Sensor RH)/(1.0546 – 0.00216T), T in ºC
Accuracy	-3.5 to +3.5 % RH
Measurement range	0 to 100 %RH
Voltage operation	4-5.8VDC
Operating Temperature	-40 to 85 °C
Current Drain	Less than 200-µA

Sensing-Luminosity	
Sensor	CdS Photoconductive Photocells
Linear, analog output, Sensitivity	0.75 Ω/lux
Accuracy	Luminosity levels
Measurement range	Luminosity levels from 0 to 200

Voltage operation	5VDC
Spectral Range	400 to 700 nm
Continuous Power dissipation	100 mW/°C
Operating Temperature	-30 to 75 °C

Sensing-Sound	
Sensor	OPENJUMPER OJ-CG306 Sound Sensor Module
Voltage gain (Vs=6v,f=1KHz)	26 dB
Voltage operation	5VDC
Microphone impedance	2.2 KΩ
Microphone Frequency	16-20 KHz
Microphone S/N ration	54 dB
Current Drain	4-8 mA (Vcc=5V)

Sensing-Motion	
Sensor	PIR Motion Sensor
Digital Output Signal	0, Vcc (Output high when motion detected)
Sentry Angle	120°
Voltage operation	3.0-5.5VDC
Current Drain	100uA (max)

Sensing-CO	
Sensor	MQ7 Gas sensor
Surface resistance of Sensitivity Body Rs	2-20kΩ (In100ppm CO)
Measurement range	20ppm to 2000ppm
Voltage operation	5VDC-+0.1
Relative humidity	Less than 95%RH
Consumption	About 350mW
Operating Temperature	-20 °C to 50 °C
Preheat time	Not less than 48 hours

Sensing-Methane

Sensor	MQ2 Gas sensor
Surface resistance of Sensitivity Body Rs	3-30kΩ (1000ppm isobutene)
Measurement range of Methane	5000ppm to 20000ppm
Voltage operation	5VDC-+0.1
Relative humidity	Less than 95%RH
Consumption	About 800mW
Operating Temperature	-20 °C to 50 °C
Preheat time	Over 24 hours

Networking	
Type	Wireless 802.15.4
Operating Frequency	ISM 2.4 GHz
Antenna	Integrated
Topology	Point-to-point, Point-to-multipoint, Peer-to-peer
(XBee)Transmit Power Output	60mW (+18dBm)
RF Data Rate	250.000bps
Receiver Sensitivity	-100dBm (1% packet error rate)
Indoor/ Urban Range	Up to 100ft (30m)
Outdoor RF Range	Up to 300ft (90m) if within line-of-sight
Number of Channels	16 Direct Sequence Channels
Addressing	PAN ID, Channel and Address
Multihop Capability	Maximum 16 hops
Security	128-bit AES Encryption

Weather Station

The Weather Station device provides information regarding rain, wind speed and direction. A sensor kit that includes a wind vane, cup anemometer and tipping bucket rain gauge [hw5] is coupled to an iBoard component [hw6]. This sensor uses sealed magnetic reed switches and magnets, making it easy to interface with. The voltage provided by the wind vane is mapped to the specific direction (16 different positions can be indicated). The anemometer encodes the wind speed by closing a switch with each rotation. To read the times that the switch is closed, the most accurate method is generate and interrupt each time and measure the number of interruptions per 30 seconds. The same method is used to read the times a momentary button closure is activated by emptying the full rain bucket (each full bucket corresponding to 0.2794 mm of rain). Then the wind velocity in m/sec and the rain in mm can be easily calculated. The device is enclosed inside an IP65 box that guarantees a weatherproof rating that provides complete protection against contact with internal electronic or electrical components for outdoor installations. The Weather Station is commonly placed on the building terraces and rooftops. In instances where the WiFi signal is not good enough to connect the device to the cloud then a communication basic on Ethernet is implemented. Power over Ethernet POE-15[hw7] facilitates the installation by providing the board with power and networking through a single Ethernet cable.

Main Hardware elements

Type	Element Name	QTE
Micro controller	iBoard	1
Power	Power Over Ethernet Kit	1
Boards	PCB weather board for iBoard	1
Sensor	Weather Station (Wind Vane, Cup Anemometer, Tipping Bucket Rain Gauge)	1
Enclosure	IP66 Enclosure	1
Enclosure	CG-12 Cable Gland Series	3
Components	SMD semiconductor BAS16HT1G - Diode	6
Components	SMD resistor 1k	8
Components	SMD resistor 10k	1
Components	RJ11; socket	1
Components	Pinhead male	1
Cable	Ethernet cable	1-100m

Operational characteristics

Specifications	
Microprocessor	Arduino board with ATMega328 (8-bit micro controller)
Dimensions	115mm x 90mm x 57mm
Body Color	Gray
Power Supply	AC 85 – 265V, 50 – 60 Hz on POE (power over Ethernet)
Case	IP66 waterproof enclosure
Operating Humidity	5%RH to 90%RH (PoE kit limit)
Operating Temperature	-10 – 60 °C (PoE kit limit)
Sensing	Rain level, wind speed and wind direction
Remote data sample rate	30 sg
Networking	WIZnet Ethernet

Software	COAP, MQTT
Power Consumption	Lower than 100 mA (normally) - 500mA (Max)

Sensing-Wind Direction	
Sensor	Wind vane
Linear, analog output	Voltage divisor for each 16 different positions
Accuracy	-8° - +8°
Measurement range	360°
Voltage operation	5VDC

Sensing-Wind Speed	
Sensor	Cup-type anemometer
Output switching per 30 second	1 switch per second equivalent to 2.4Km/h
Voltage operation	5VDC

Sensing-Rain Level	
Sensor	Self-emptying tipping bucket type
Output switching per 30 seconds	1 switch is equivalent to 0.2794 mm of water
Voltage operation	5VDC

Networking	
Type	Ethernet IEEE802.3af compliant
Protocol	Arduino Ethernet library
Topology	Point-to-point
PoE: Efficiency DC/DC convert	70%
PoE: Low Output ripple and noise	Lower than 100mVpp

7. GAIA platform for data aggregation

This chapter aims to comprehensively detail the API exposed by the GAIA platform. Data produced by IoT devices are retrieved through API calls and used by the application layer of the GAIA platform. Several applications will be deployed with the aim to involve as many users as possible, making them more aware of what is happening in the building in terms of energy and climate data.

GAIA Architecture

The GAIA platform aggregates data coming from multiple sites and multiple hardware platforms. This platform is based on Spark Works IOT Platform which allows clients to connect any hardware device by implementing a device driver. Spark Works offers an event processor engine which generates real time and historical analytics that can be accessed using Spark Works DATA API.

Spark Works Architecture

To facilitate integration between the existing hardware and software technologies, the exchange of the information occurs through APIs Mappers. Spark Works offers two separate types of API Mappers for integrating with external services and to retrieve IoT sensor data:

- Polling API Mapper
- Message Queue API Mapper

Both solutions will be used in the context of the GAIA EU project in order to integrate with data originating from IoT installations.

The first solution (*Polling API Mapper*) is based on polling. A usage example is the following:

Synelixis Weather Stations are installed in a subset of school buildings of the project. Data produced by the Synelixis Weather Stations are accessible through the SynField application that provides historical information through a RESTful API provided by the SynField backend. In order to integrate Synelixis Weather Stations in the GAIA platform the SynField API Mapper was implemented for the SynField API based on the Polling API Mapper. The SynField API is polled every fixed number of minutes (5) for updated data. When new data are found, they are formatted to the internal format of the SparkWorks/GAIA Platform and forwarded to the SparkWorks Processing/Analytics engine for processing and analysis using the AMQP protocol. The data are then processed and can be accessed from the SparkWorks/GAIA Data API.

Similar implementations based on the Polling API Mapper will be in used to integrate IoT devices provided Synelixis, OVER and the existing BMS systems installed in EA and Söderhamn public buildings.

The second solution is used when a pub-sub solution exists in the external service that is going to be integrated. In that case, the external service is capable of publishing the IoT data (generated or gathered) to an MQTT endpoint. The API Mapper is then able to receive new measurements asynchronously and format them to the internal format of GAIA Platform. The data are then forwarded to the SparkWorks/GAIA Processing/Analytics engine for processing and analysis using the AMQP protocol. The data are then processed and can be accessed from the GAIA Data API.

Messages inside the MQTT broker can be transferred in multiple formats ranging from plain text to any open or proprietary protocol. Messages from Meazon devices are transmitted in plain text, while the SparkWorks devices communicate using CoAP with the Mapper implemented.

For the Meazon devices, the plain text messages use the following simple format: the topic of the message refers to the device and sensor that generated the message while the actual payload represents the value generated. For example, if a sensor with a hardware (MAC) address "124B00061ED466" publishes a temperature value of 20 degrees, the topic is "124B00061ED466/temperature" and the message "20". For the SparkWorks devices, all devices deployed operate as CoAP servers. The API Mapper communicates with the wireless network and establishes a subscription with all of their resources using the CoAP Observe extension. All sensors then forward their sensors' measurements following the CoAP protocol specification. When the connection with a device is lost the API Mapper requests a new subscription and the device starts transmitting messages to the API Mapper again.

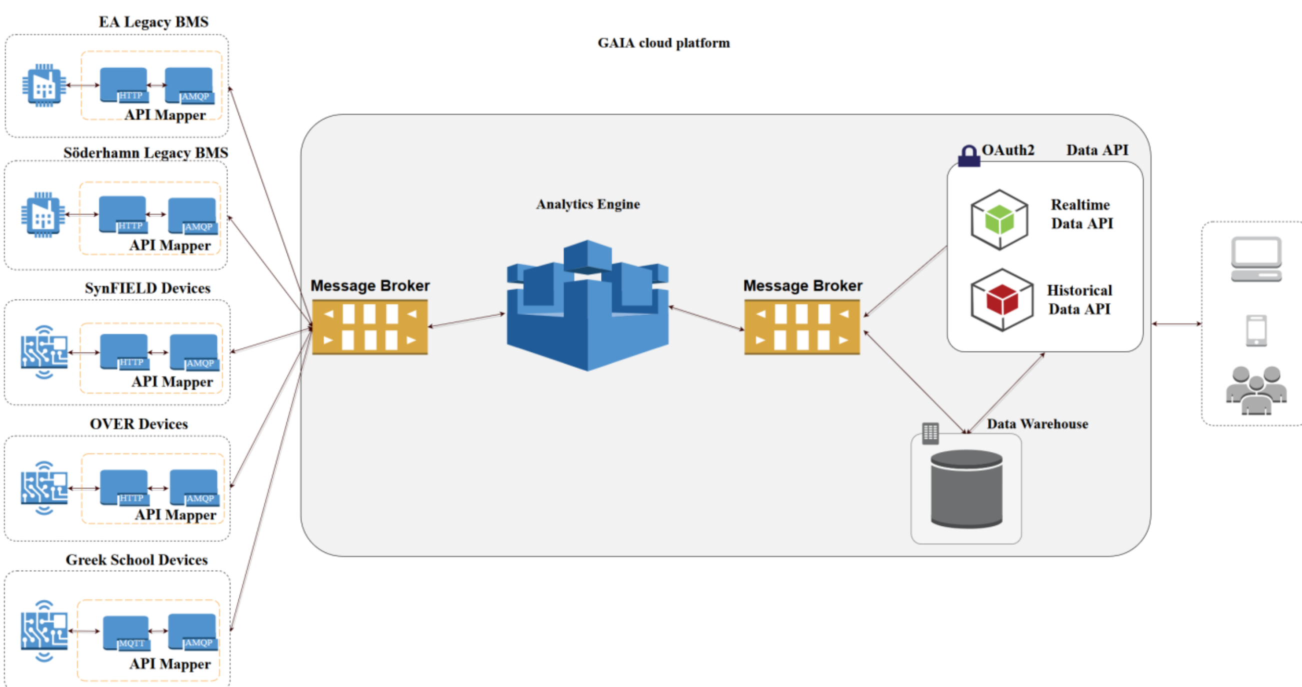


Figure 106 GAIA Cloud Platform API Architecture Overview

The above figure gives an overview of the different APIs/subsystems that will be integrated in GAIA, in order to form the GAIA cloud platform. We provide more details regarding the specifics of this architecture and the APIs in the following sections.

SparkWorks/GAIA DATA API

The SparkWorks/GAIA platform provides a unified API for retrieving data from multiple sites and multiple hardware platforms transparently. Each hardware device integrated to our platform is mapped to a Resource. Resources are self-described Entities in GAIA Architecture and are also software/hardware-agnostic. The Data API acts as a wrapper function and hides much of the lower-level plumbing of hardware specific API calls for querying and retrieving data and provides a common API for retrieving historical or Real Time Data from Gaia Resources in a transparent manner.

SparkWorks/GAIA DATA API Description

This section of the document contains the main module specification.

Authentication and Authorization

SparkWorks Data APIs use the OAuth 2.0 protocol for authentication and authorization.

Before using Data API, users should create an account and register a new client. The endpoint for creating new user account and for authentication/authorization is:
https://sso.sparkworks.net

The User Management console where users are able to manage their account or register new Clients is on the following URL:
https://accounts.sparkworks.net

In order to use Data API a user should first register a new OAuth 2.0 Client. Upon registering an application, the user is provided with two tokens (public and secret) for interacting with the GAIA Platform. For each request thereafter the client application generates an access token that is used as a Bearer authorization header on all HTTP requests.

Non-Functional Specifications

The following non-functional specifications need to be supported by the component as described in the table below.

REQ ID	Description	Notes
DS.NF1	The component communicates with other components in the system and externally via means of an interface that is the same to both; no difference should be observed if the component is accessed externally or directly.	
DS.NF2	The component uses a REST API to provide external access	

DS.NF3	The external users of the system (clients) use a library that provides a fluent interface with respective objects to communicate with the DATA Service without being exposed to the underlying REST API
DS.NF4	The interfaces exposed to either the external client or the direct invocation (internal) clients should be considered to support *Atomicity, Consistency, Isolation, Durability* (ACID). Relevant design choices should be made to enforce this.

Component API

The following sections document the available application programming interfaces for the data management. The central concept is that operations are atomic (ACID compliant) and the interface itself is versioned, to allow future versions to coexist and allow graceful upgrades.

API Call: getApiVersion

This call has no incoming variables and only one outgoing to define the supported version

API Signature	Return Value	Notes
getApiVersion()	VersionDTO	Returns a VersionDTO with the relative supported features

Return Value: VersionDTO implements Serializable

Field	Type	Mandatory	Notes
minVersion	Double	Y	Minimum version of API supported, initial should be "1.0"
maxVersion	Double	Y	Maximum version of API supported, initial should be"1.9". In the future, this would be increasing appropriately.
versions	Map<String,String>	Y	A map of "version" → "context URI" that allows multiple versions to be defined and the client to be able to select a known version for use.

Note: check "semantic versioning" to see the concept of version ranges and changes in API/code. (http://semver.org/)

API Call: queryLatestResourcesData

Returns the latest value for the given query.

API Signature	Return Value	Notes

queryLatestResourcesData (QueryLatestResourceDataDTO)	QueryLatestResourceDataResultDTO	One or more queries to be performed

Argument Value: QueryLatestResourceDataDTO

Field	Type	Mandatory	Notes
queries	List<QueryResourceDataCriteriaDTO>	Y	List of queries to be performed

Enclosed Value: QueryResourceDataCriteriaDTO

Field	Type	Mandatory	Notes
resourceId	String	Y	The resource ID that we want readings for

Return Value: QueryLatestResourceDataResultDTO

Field	Type	Mandatory	Notes
results	Map<QueryResourceDataCriteriaDTO, ResourceDataDTO>	Y	The results as per the queries requested – this is a map from criteria to results.

Enclosed Value: ResourceDataDTO

Field	Type	Mandatory	Notes
timestamp	long	Y	The Timestamp of the reading value
reading	Double	Y	The Double value of the reading

Exceptions

Exception Name	Reason	Notes
UnableToProcessQuery	The supplied criteria did not produce results or there is a system error	If query criteria can be satisfied (or return 0 results) a valid response should be provided. This exception handles only lower-level system errors.

API Call: queryTimeRangeResourcesData

Returns subsequent pages of results for the given query

API Signature	Return Value	Notes

queryTimeRangeResourcesData (QueryTimeRangeResourceDataDTO)	QueryTimeRangeResourceDataResultDTO	One or more queries to be performed

Argument Value: QueryTimeRangeResourceDataDTO

Field	Type	Mandatory	Notes
queries	List<QueryTimeRangeResourceDataCriteriaDTO>	Y	List of queries to be performed

Enclosed Value: QueryTimeRangeResourceDataCriteriaDTO extends QueryResourceDataCriteriaDTO

Field	Type	Mandatory	Notes
from	long	Y	Date time in milliseconds
to	long	Y	Date time in milliseconds
granularity	Enum Granularity	Y	Time granularity. Values: 5_MIN, QUARTER, HOUR, DAY, MONTH
resultLimit	Integer	N	The max amount of results to be returned

Return Value: QueryTimeRangeResourceDataResultDTO

Field	Type	Mandatory	Notes
results	Map<QueryTimeRangeResourceDataCriteriaDTO, List< ResourceDataDTO >>	Y	The results as per the queries requested – this is a map from criteria to results.

Exceptions

Exception Name	Reason	Notes
UnableToProcessQuery	The supplied criteria did not produce results or there is a system error	If query criteria can be satisfied (or return 0 results) a valid response should be provided. This exception handles only lower-level system errors.

In this section, we provided details regarding the API exposed by the different devices used in the trial sites. Data produced are retrieved through the API and used by the application layer of the GAIA platform.

We will follow a common template to depict the web services for each available service. Additionally, we will provide information about the HTTP method to use, the URL where addressing the request, type and meaning of the parameter for the request. These APIs enable the communication of the platform with:

- Over system devices bringing energy data in GAIA cloud platform
- SynField systems bringing weather data in GAIA cloud platform.

Each subsection is dedicated to a specific subsystem.

OVER API Description

For each of its products, Over provides an open interface to allow any third part application to programmatically interface with them. The following section aims to illustrate the most useful APIs for the context in which GAIA operates. We will mainly focus on highlighting all the services responsible of getting real time and historical energy data. Therefore a subset of the API are described. These are based on the RESTful architecture, using HTTP methods to send data. This section details all the necessary information to interact with the web services. In particular:

- Authentication API to access the system. The system is accessed through the use of a token with an expiration day that is requested on an encrypted channel (https connection)
- API to get real time and historic energy data. The information is sent with a granularity of a minute to the GAIA cloud platform and then historicized in the database. In this subsection we list all the energy quantities that are possible to retrieve both in real time and in the historical repository.
- Infrastructure data API to get information about the device and the infrastructure such as the setup information of a single or a set of devices composing the measurement network installed at a given site.

For all the methods described, access (username and password) is also provided to allow to anyone to test them through a real device installed in a building. Each web service is documented describing the http method to use, the URL, where the request has been addressed and the type and the meaning of the parameters requested. Finally we also provide an example of a success/error response.

All the following methods refers to the **base URL** of the Over Cloud Platform.

base URL: http://ghost.overtechnologies.com/

For the authentication only, getting the token request is done using the following **base URL**.

base URL: https://ghost.overtechnologies.com/

Conventions

- **Client** - Client application.

- **Status** - HTTP status code of response.
- Examples of the possible responses are listed under 'Responses' for each method. Only one of them is issued per request server.
- All responses are in XML format.
- All request parameters are mandatory unless explicitly marked as [optional]

Status Codes

All status codes are standard HTTP status codes. The below ones are used in this API.

2XX - Success of some kind
4XX - Error occurred in client's part
5XX - Error occurred in server's part

Status Code	Description
200	OK
201	Created
400	Bad request
401	Authentication failure
403	Forbidden
404	Resource not found
405	Method Not Allowed
500	Internal Server Error
501	Not Implemented
503	Service Unavailable

Authentication

All the following methods require an **authentication token** in order to guarantee a secure and private access. The token needs to be added in all the requests as header information; it allows a set of functionalities according to the devices linked to that user..

Token request

This is the only method that does not require the **authentication token**, because it is obtained through this function.

Request

Method	URL
GET	rest/plant/remote_access/port/<nanometerId>

URL parameters

Type	Params	Values
PathParameter	nanometerId	string
Header	username	string
Header	password	string

nanometerId

The id of the NanOMeter.

username

Username of the user that is performing the authentication procedure.

password

Password of the user that is performing the authentication procedure.

Response

Status	Response

200	<root token_session="p097fruqpbf7k0d4u09epu0d4u2pd21hl4ddkco1n7i38dj4qrik" </root>
401	Authentication failed. Please login.
500	Internal server error

Token usage

As specified in the introduction of this section, the token needs to be added in each request. Here is the pair to be added in the header; we will not add this information in the following documentation info.

Type	Params	Values
Header	token_mirror	string

token_mirror

The *token* retrieved in the authentication step.

Real-time energy data

Retrieves the last value of the active energy measured by a certain *NanOMeter.*

Request

Method	URL
GET	energy_data/<type>/nanometer/<id>/last_value

URL parameters

Params	Values
type	string
id	string

type

The type of data we want to retrieve. The types available are: ACTIVEPOWER, APPARENTPOWER, REACTIVEPOWER, VOLTAGE, CURRENT, POWERFACTOR. More than one type can be asked for in the same request, simply by adding the other type after an 'underscore' char. For example:

rest/energy_data/ACTIVEPOWER_VOLTAGE_POWERFACTOR/nanometer/<id>/last_value

id

The id of the *NanOMeter*

Response

Status	Response
200	Simple example with ACTIVEPOWER option. <root> <energy_data timestamp="1455883904863" active_power_TA1="4689.3" active_power_TA2="3875.57" active_power_TA3="3899.11" active_power_TOT="12463.99" /> </root>
401	Authentication failed. Please login.
500	Internal server error

History energy data

Retrieves active energy measured by a certain *NanOMeter* according to a custom interval of time.

Request

Method	URL

GET	energy_data/<type>/nanometer/<id>/<from>/<to>/<granularity>

URL parameters

Params	Values
type	string
id	string
from	int
to	int
granularity	string

type

The type of data we want to retrieve. Types available are:

- VOLTAGE
- CURRENT
- POWERFACTOR
- ACTIVEENERGY
- REACTIVEENERGY
- APPARENTENERGY
- ACTIVEPOWERPEAK
- APPARENTPOWERPEAK
- REACTIVEPOWERPEAK
- TIMESLOT
- MAXACTIVEPOWERPEAK
- MAXAPPARENTPOWERPEAK
- MAXREACTIVEPOWERPEAK

Many of these attributes are trivially identified by their name. By the way, let us add some other information about the more complex ones.

ACTIVEPOWERPEAK, APPARENTPOWERPEAK and *REACTIVEPOWERPEAK* give information about the time and the value of the peaks reached during a certain range of time.

TIMESLOT gives information about the energy time slots; very useful in order to link these data to different cost of the electric energy (at least in Italy).

MAXACTIVEPOWERPEAK, MAXAPPARENTPOWERPEAK and *MAXREACTIVEPOWERPEAK* give information about the maximum value of energy reached during a certain range of time.

As previously mentioned, more than one type can be asked for in the same request, simply by adding the other type after an 'underscore' char. For example:

rest/energy_data/ACTIVEPOWER_VOLTAGE_POWERFACTOR/nanometer/<id>/<from>/<to>/<granularit
y>

Concerning the responses, the example below should give a fair idea of the pattern used by the developers.

id

The id of the *NanOMeter*

from

Timestamp (ms)

to

Timestamp (ms)

granularity

Time granularity. The available parameters are:

- MINUTE
- HOUR
- DAY

Response

200	An example with ACTIVEENERGY, TIMESLOT and MAXACTIVEPOWERPEAK option. <root> <energy_data

	timestamp="1455577200000" active_energy_TA1="3275.23" active_energy_TA2="1945.55" active_energy_TA3="1811.74" active_energy_TOT="7032.52" /> <time_slot_data id="1" active_energy="76427.43" apparent_energy="85014.484" reactive_energy="36231.58017638536" power_factor="0.898993" /> <time_slot_data id="2" active_energy="45247.83" apparent_energy="49652.09" reactive_energy="19866.07634851099" power_factor="0.91129756" /> <time_slot_data id="3" active_energy="51781.438" apparent_energy="59151.324" reactive_energy="28184.494096362585" power_factor="0.8754062" /> <max_peak_power active_power="28882.066" /> </root>
401	Authentication failed. Please login.
500	Internal server error

User general data

Retrieves general data about the user related to the Nanometer.

Request

Method	URL

GET	nanometer/setup_info/<id>

URL parameters

Params	Values
id	string

id

The id of the *NanOMeter*

Response

200	<root> <setup_info user_id="113" user_role="ADMIN" username="gaia" owner="Ortopedia" country=”Italia” city=”Roma” address=”Città Universitaria” label=”GENERALE” pod_code=”pod_number_ortopedia” n_phase_enabled=”3” conversion_factor_TA1=”56” conversion_factor_TA2=”50” conversion_factor_TA3=”42” </root>
401	Authentication failed. Please login.
500	Internal server error

Infrastructure data

Retrieves general data about the user related to the Nanometer.

Request

Method	URL
GET	nanometer/hierarchy/user/<user_id>

URL parameters

Params	Values
user_id	int

id

The id of the logged user that you can retrieve from the *user general data.*

Response

200	<root> <nanometer id="665QN" owner="Ortopedia" label=”GENERALE”> <nanometer id="84NE9" owner="Ortopedia" label=”ALA DESTRA”> </nanometer> </nanometer> </root>
401	Authentication failed. Please login.
500	Internal server error

Synfield API description

Synfield API includes a set of REST web services that give the capability of a registered user to fetch:

- the sections that owns,
- the nodes (either gateway node or/and peripheral one) per section,
- the installed sensors per node,
- the measurements per node (that are derived from the installed sensors).

The host (base URL) and port of the SynField API are:

- *HOST*: api-synfield.synelixis.com
- *PORT*: 80
- *API version*: v1

Therefore, the functionality of these web services can be tested from any rest client using the http://api-synfield.synelixis.com/v1/{path}.

In the following sections, you will find the description for each web service that includes:

- the HTTP method
- the endpoint
- the query parameters (if any)
- the required HTTP headers
- the request payload (if it is necessary)
- the response HTTP status code and data

With respect to the response of web services, Table 2 presents the mapping between HTTP status code and the reason (RFC 2616). Also, the supported data structure of the response is the *JSON*.

Table 2: HTTP status code meaning

HTTP STATUS CODE	HTTP REASON
200	OK
201	CREATED
204	NO CONTENT
400	BAD REQUEST
401	UNAUTHORIZED
403	FORBIDDEN
404	NOT FOUND
405	METHOD NOT ALLOWED
406	NOT ACCEPTABLE
409	CONFLICT
410	GONE
415	UNSUPPORTED MEDIA TYPE
500	SERVER ERROR

Fetch a collection of sections that a user owns

Method: GET
Endpoint: /sections/owner/{*username*}
Query parameters: None
Headers:

- Accept: application/json
- Content-type: application/json
- Authorization: Basic {*token*}

The *username* parameter in the endpoint is the username of the registered user. The *token* is generated from the execution of the base64 algorithm in the string {*username*}:{*password*} (user credentials).

Response
Status Code: 200 OK


```
{
  "response": {
    "sections": [
      {
        "crop_type": "string",
        "elevation": "float",
        "headNode": "string",
        "id": "integer",
        "latitude": "float",
        "longitude": "float",
        "name": "string",
        "peripheralNodeList": [],
        "timezone": "string (country/city)",
        "user": "integer"
      }
    ]
  }
}
```


Keep in mind that the *headNode* attribute is referred to in next web services as *gatewayID*. Since the peripheralNodeList includes a list of peripheral IDs (their type is string), we use the notation *peripheralID* in the next web services.

Fetch a collection of sensors that a head node contains

Method: GET
Endpoint: /gateway/{*gatewayID*}/sensors/
Query parameters: None
Headers:

- Accept: application/json
- Content-type: application/json
- Authorization: Basic {*token*}

The *token* is generated by executed the base64 algorithm in the string {*username*}:{*password*}.

Response
Status Code: 200 OK


```
{
  "response": {
    "sensors": [
      {
        "enabled": "True|False",
        "id": "integer",
        "name": "string",
        "service": "string"
      }
    ]
  }
}
```


Fetch a collection of sensors' measurements in the head node

Method: GET
Endpoint: /gateway/{*gatewayID*}/measurements/
Query parameters:

- limit: non negative integer that declares the number of measurements
- offset: non negative integer that declares the index of first measurement

Headers:

- Accept: application/json
- Content-type: application/json
- Authorization: Basic {*token*}

The *token* is generated by executing the base64 algorithm in the string {*username*}:{*password*}.

This web service returns, by default, a list of 500 measurements (if existing). However, this service supports paging via the limit and offset query parameters.

Response
Status Code: 200 OK


```
{
  "response": {
    "links": [
      {
        "ref": "next",
        "url": "http://api-synfield.synelixis.com/v1/gateway/{gatewayID}/measurements/?offset=x&limit=y"
      }
    ],
    "measurements": [
      {
        "id": "integer”,
        "sensor_id": "integer",
        "service": "integer",
        "timestamp": "datetime (yyyy-mm-dd hh:MM:ss)",
        "unit": "string",
        "value": "float"
      }
    ],
    "name": "string",
    "timezone": "string (country/city)"
  }
}
```


Fetch a collection of sensors’ measurements in the head node at a specific date range

Method: GET
Endpoint: /gateway/{*gatewayID*}/measurements/{*fromDate*}/{*untilDate*}/
Query parameters:

- limit: non negative integer that declares the number of measurements
- offset: non negative integer that declares the index of first measurement

Headers:

- Accept: application/json
- Content-type: application/json
- Authorization: Basic {*token*}

The format of *fromDate* and *untilDate* URL parameters is “*yyyy-mm-dd*”. The *token* is generated by executed the base64 algorithm in the string {*username*}:{*password*}. This web service returns by default a set of 500 measurements (if existing). However, this service supports paging via the limit and offset query parameters.

Response
Status Code: 200 OK


```
{
  "response": {
    "links": [
      {
        "ref": "next",
        "url": "http://api-synfield.synelixis.com/v1/gateway/{gatewayID}/measurements/?offset=x&limit=y"
      }
    ],
    "measurements": [
      {
        "id": "integer”,
        "sensor_id": "integer",
        "service": "integer",
        "timestamp": "datetime (yyyy-mm-dd hh:MM:ss)",
        "unit": "string",
        "value": "float"
      }
    ],
    "name": "string",
    "timezone": "string (country/city)"
  }
}
```


Fetch a collection of sensors’ measurements in the peripheral node

Method: GET
Endpoint: /peripheral/{*peripheralID*}/sensors
Query parameters: None
Headers:

- Accept: application/json
- Content-type: application/json
- Authorization: Basic {*token*}

The *token* is generated by executed the base64 algorithm in the string {*username*}:{*password*}.

Response
Status Code: 200 OK


```
{
  "response": {
    "sensors": [
      {
        "enabled": "True|False",
        "id": "integer",
        "name": "string",
        "service": "string"
        "service_id": "integer"
      }
    ]
  }
}
```


Fetch a collection of sensors’ measurements in the head node

Method: GET
Endpoint: /peripheral/{*peripheralID*}/measurements
Query parameters:

- limit: non negative integer that declares the number of measurements
- offset: non negative integer that declares the index of first measurement

Headers:

- Accept: application/json
- Content-type: application/json
- Authorization: Basic {*token*}

The *token* is generated by executed the base64 algorithm in the string {*username*}:{*password*}. This web service returns by default a set of 500 measurements (if existing). However, this service supports paging via the *limit* and *offset* query parameters.

Response
Status Code: 200 OK


```
{
  "response": {
    "links": [
      {
```

```
            "ref": "next",
            "url": "http://api-synfield.synelixis.com/v1/peripheral/{peripheralID}/measurements/?offset=x&limit=y"
          }
        ],
        "measurements": [
          {
            "id": "integer",
            "sensor_id": "integer",
            "service": "integer",
            "timestamp": "datetime (yyyy-mm-dd hh:MM:ss)",
            "unit": "string",
            "value": "float"
          }
        ],
        "name": "string",
        "timezone": "string (country/city)"
    }
}
```


Fetch a collection of sensors' measurements in the peripheral node at a specific date range

Method: GET
Endpoint: /peripheral/{*peripheralID*}/measurements/{*fromDate*}/{*untilDate*}
Query parameters:

- limit: non negative integer that declares the number of measurements
- offset: non negative integer that declares the index of first measurement

Headers:

- Accept: application/json
- Content-type: application/json
- Authorization: Basic {*token*}

The format of *fromDate* and *untilDate* URL parameters is "*yyyy-mm-dd*". The *token* is generated by executed the base64 algorithm in the string {*username*}:{*password*}. This web service returns by default a set of 500 measurements (if existing). However, this service supports paging via the *limit* and *offset* query parameters.

Response
Status Code: 200 OK

```
{
  "response": {
    "links": [
      {
        "ref": "next",
        "url":"http://api-synfield.synelixis.com/v1/
peripheral/{peripheralID}/measurements/?offset=x&limit=y"
      }
    ],
    "measurements": [
      {
        "id": "integer",
        "sensor_id": "integer",
        "service": "integer",
        "timestamp": "datetime (yyyy-mm-dd hh:MM:ss)",
        "unit": "string",
        "value": "float"
      }
    ],
    "name": "string",
    "timezone": "string (country/city)"
  }
}
```

Integration with third party devices

Regarding the integration of third-party software and hardware ecosystems, GAIA will use the APIs included in this chapter to implement such aspects. As an example that is already in place and functional, as mentioned previously, GAIA utilizes power meters and sensor from the Meazon ecosystem. In order to integrate these devices and the readings they produce, CTI uses the SparkWorks engine to process data generated by smart building installations in the Greek Public School buildings. To integrate a set of sensing devices CTI uses the SparkWorks device mapper templates based in the use case. The mapper templates allow for streaming sensor measurements from the device specific interface to the SparkWorks internal template. A single mapper application is deployed in the CTI infrastructure for each integration performed.

In the Meazon case, measurements from all the deployed sensors are published from each building through either the installed Ethernet gateway node or the sensor itself (in case of a GPRS sensor) to a dedicated MQTT broker provided by CTI. CTI adapted the SparkWorks device mapper to bridge the two systems (MQTT and SparkWorks engine). The resulting Meazon device mapper subscribes for messages to the MQTT broker, converts those received to the SparkWorks format and sends them to the SparkWorks engine for processing. The processed data are stored in the format provided by SparkWorks and all CTI services retrieve them from the Data API provided by SparkWorks.

The template for the device mapper, as well as the implementation of the Meazon device mapper are available open source on Github[19],[20].

[19] https://github.com/SparkWorksnet/device-mapper-template
[20] https://github.com/CTI-ru1/device-mapper-meazon

8. Key Performance Indicators for GAIA

In this section, following the discussion on the design of the numerous GAIA components presented in the previous parts of this document, we continue with a detailed discussion on the ways to validate the performance of GAIA as a whole. We present a set of *Key Performance Indicators* (KPIs), some of which are also included in the GAIA DoW, complemented with a concrete set of additional indicators, which will aid in measuring more reliably the performance of the project, in terms of all of its aspects.

We have included in our list many of the KPIs often utilized in energy efficiency-related projects [EEBuilding, Orbeet, eeMeasure, Balaras], in order to be compatible with previous work on the subject and be comparable in the respective manners. However, since GAIA is based on a multidisciplinary approach, it is essential that we also have an extensive set of performance indicators, e.g., indicators that describe the systemic aspects of the GAIA platform, or how behavioral change aspects actually progress throughout the duration of the project. Fig. 107 summarizes the overall list and categorization of GAIA KPIs. More specifically, the overall goals of GAIA in aspects like energy efficiency, sustainability awareness, education, end-user engagement and real-life validation, in general terms correspond to the following KPI categories:

- *Energy-related KPIs*: this set of KPIs focuses on measuring the actual impact of GAIA on energy consumption in the participating schools, in terms of consumption that is flexible and can be affected, as detailed in the respective section.
- *Environment-related KPIs*: this set of KPIs focuses on measuring the actual impact of GAIA on the environment, together with the energy-related KPIs, mirroring local energy parameters that have an effect on the environment.
- *Cost-related KPIs*: this set of KPIs focuses on measuring the cost efficiency of GAIA, mirroring its overall practicality in terms of performance, costs and sustainability.
- *Human-comfort-related KPIs*: this set of KPIs focuses on measuring the impact GAIA will have on the everyday life of end-users involved, since the project will deal with human participants, of which their comfort/discomfort with respect to the operation of the system is of vital importance.
- *Systemic/technical KPIs*: this set of KPIs focuses on measuring technical aspects of the project and the hardware/software components produced throughout its duration. Since we plan to have at the end of GAIA an open, replicable and efficient solution produced, such KPIs are very important to characterize GAIA.
- *Behavioral change-related KPIs*: this set of KPIs will attempt to measure the actual behavioral change in end-users caused by GAIA throughout its duration. As explained in the respective section, this is an important and complex issue, that needs additional attention also due to the potential effects on the end-users' privacy.
- *Education-related KPIs*: this set of KPIs will measure the educational aspects of the project, including things like the related material produced, but also all educational actions materialized through the activity of the GAIA consortium.

- *Dissemination-related KPIs*: this set of KPIs will measure the effort and overall success of GAIA in terms of disseminating the results of the project in both the research/academic community and the general public.

We continue with a discussion on the original KPIs included in the GAIA DoW document, followed by a detailed discussion on each of the abovementioned KPI categories. This expanded list of KPIs is meant to complement and further specify each of the aspects encompassed by GAIA, as a means to be able to monitor progress of the project in a more pragmatic and specific manner. The details of the measurements of KPIs will be provided in subsequent deliverables. GAIA partners have taken all necessary actions to ensure that the measurement of these KPIs is feasible: a) they have carefully investigated the available infrastructure and defined the additional equipment the enables the measurements and b) they have identified the application requirements that will be met by the GAIA applications.

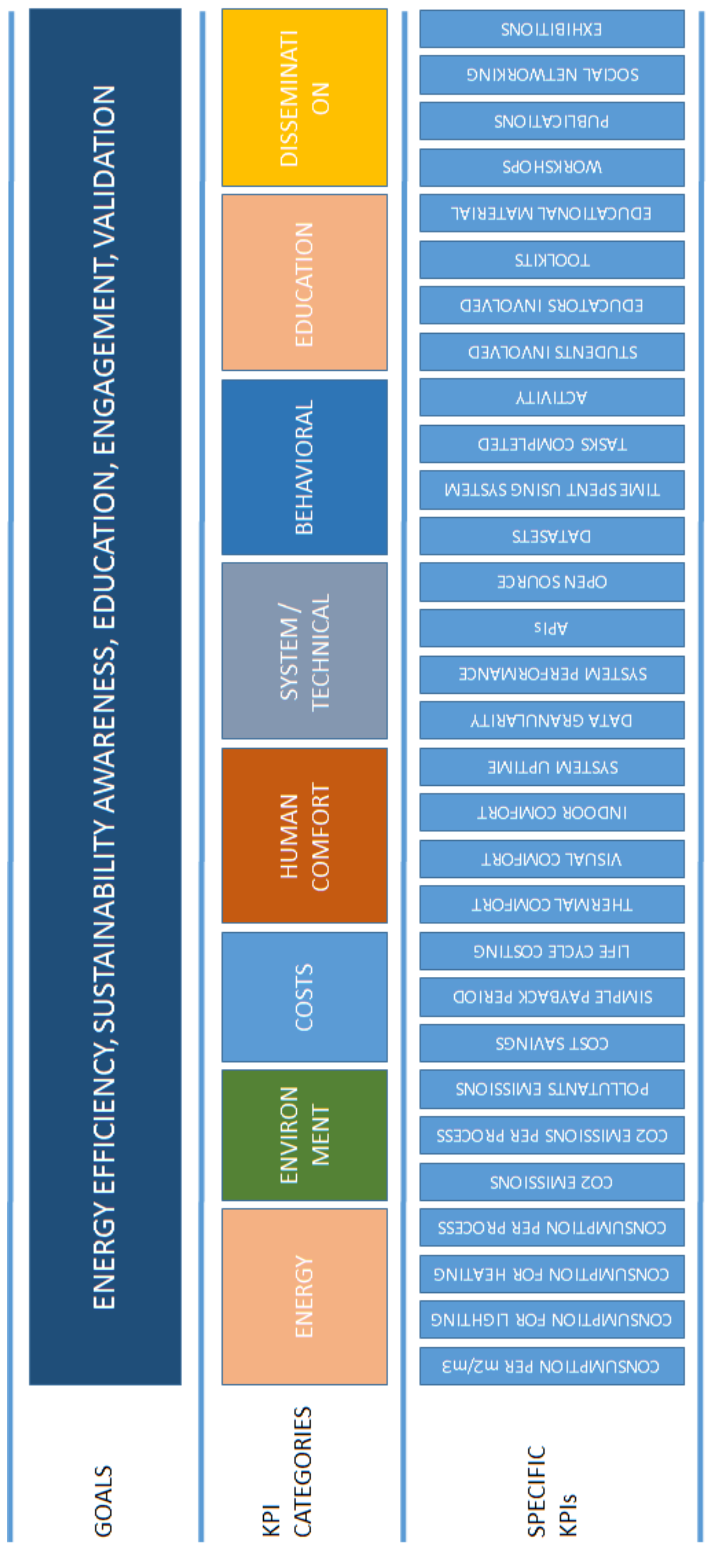


Figure 107 Overview of GAIA Key Performance Indicators

GAIA KPIs included in the DoW

As mentioned numerous times in this document, GAIA aims at educating, engaging and prompting energy efficient behavior in the educational communities. GAIA has defined in its DoW a set of KPIs which are aligned with the workprogramme's target impacts. This set of KPIs is further elaborated in this section, towards defining the scenarios that will be carried out as well as the instruments to measure these KPIs during GAIA trials, which will we be made more specific in the following phases and deliverables of the project. In the following section, we elaborate on each of these KPIs, essentially breaking them down to sub-KPIs and by organizing them into discrete categories, we aim to make them more specific, thus measureable and pragmatic, and at the same time foreshadow in a more concise manner how we intend to actually measure each of them.

Table 3: the KPIs identified in GAIA DoW and their relevance to the expected impacts identified in the workprogramme

a/a	GAIA KPI identified in DoW	Expected impact identified in workprogramme
1	6900 students and educators reached directly during the project	Greater consumer understanding and engagement in energy efficiency
2	An order of magnitude more after the end of the project through established dissemination networks	
3	24 educational sector buildings in 3 countries covering North, Central and South Europe	
4	2 courses, sets of educational material and handbooks will be produced, available in Italian, Greek, Swedish and English	
5	Reductions of over 15% on the energy that can be influenced by the end-users	Systemic energy consumption and production and emissions reduction between 15% and 30%."
6	Develop educational games, mobile apps and social networking tools for fostering energy efficient behaviour (already a contractual obligation)	Accelerate wide deployment of innovative ICT solutions for energy efficiency

Table 4: The KPIs identified in GAIA DoW and the WP responsible for measuring it

a/a	GAIA KPI identified in DoW	Relevant WP
1	6900 students and educators reached directly during the project	WP1 (Task 1.1)
2	An order of magnitude more after the end of the project through established dissemination networks	WP5
3	24 educational sector buildings in 3 countries covering North, Central and South Europe	WP1
4	2 courses, sets of educational material and handbooks will be produced, available in Italian, Greek, Swedish and English	WP1 (task 1.3)
5	Reductions of over 15% on the energy that can be influenced by the end-users	WP4

Energy-related KPIs

We first discuss energy-related KPIs, since energy efficiency and savings constitute a large part of GAIA's goals and activity. We have compiled a list of KPIs that are in line with previous work in energy-efficient related research projects, focusing on having a concise set of metrics that can showcase the progress and results of the project in a coherent and clear manner.

Apart from the KPIs themselves and their interpretation, there are some additional aspects that need to be pointed out at this moment:

- We need to have a period for collecting baseline data, i.e., data for energy consumption and other related aspects from the participating educational buildings. We have already set up an IoT infrastructure for this purpose, which is operational in the majority of the related schools, and we have tried to gather related data from energy utility companies where available. However, there is a need for as much detail and accuracy as possible with respect to such data, in order to have a clearer picture.
- This aspect is further made essential with respect to the fact that GAIA deals with educational buildings, which are utilized by educational staff and students and have specific requirements regarding their operation. In a few words, there are restrictions and specifications, also depending on local geography, culture and national policies, which cannot be overlooked. Such restrictions have their own footprint on the energy consumption of the school buildings, and we will attempt to identify it in the coming months.
- For this reason, with respect to the KPIs, we will aim for energy reductions in the parts that *can* be reduced, i.e., parts of the energy consumption of the school buildings that are flexible.
- Additionally, there is also the aspect of utilizing a normalization factor for the energy-related KPIs (further discussed in this section). In short, parameters like the annual weather conditions can greatly affect energy consumption, especially regarding building heating. We will take into account the variance in weather conditions in order to normalize the achieved results and present a more representative picture.

The following list contains the KPIs for GAIA with respect to energy-related aspects.

Code	Name	Brief description	Validation Methodology	Gaia target
E.1	Primary Energy Consumption per m^2	Building energy consumption related to the floor space	Measured in kWh	15% reduction to the part which can be affected
E.2	Primary Energy Consumption per m^3	Building energy consumption related to the building volume	Measured in kWh	15% reduction to the part which can be affected
E.3	Energy Consumption for lighting	Building energy consumption related to lighting activities	Measured in kWh	15% reduction to the part which can be affected
E.4	Energy Consumption for heating (where applicable)	Building energy consumption related to heating activities	Measured in kWh	15% reduction to the part which can be affected
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	15% reduction to the part which can be affected

The above indicators (while objective and measurable by GAIA equipment) do not consist per se the target KPIs as they do not reveal the part of energy consumption that can be influenced by user behavior. Since GAIA targets “reductions of over 15% on the energy that can be influenced by the end-users”, to evaluate the actual energy reduction brought by GAIA, we first have to measure the part of energy that can be influenced by the end-users without any intervention from GAIA and then to apply different measures in order to assess their effectiveness. This phased approach will be followed to all types of resources used including e.g. electricity, fuel, water, etc.

Phase 1: measurement of reference values. This will be measured at the aid of the building managers. Based on the school descriptions and existing equipment (e.g. smart meters) that have been detailed in separate documents and are summarized in Annex I, we will evaluate the current consumption per resource type. For example, we will measure and use as reference values, the consumed electricity, the yearly measurement of fuel consumed for heating purposes, etc. Then, a more thorough study together with the building managers will be carried out. This is necessary because different regulations per school may apply. For example, in Sweden the desired indoor temperature is fixed, which is not the case in Greece. This means that different parts of the energy consumption can be affected in each school.

Phase 2-X: application of different behavior- shaping means: Different scenarios are described in chapter 8 that will help GAIA achieve its goal of energy consumption reduction. The new values of energy consumption will be compared to those collected in phase 1 to evaluate the achieved reduction.

Details on the existence of equipment that enable their calculation will be provided in dedicated documents per trial site. A first presentation of the currently available equipment and types of measurements is included in Annex I. We subsequently provide an example for the 1st Gymnasium, Nea Philadelphia, Attica.

1st Gymnasium, Nea Philadelphia, Attica

This school consumes electricity (coming from the local DSO) and petrol for heating purposes. (No Photovoltaic panels exist.)

The building consists of two floors (details can be found in separate document). The computer lab is located in the first floor and it spends around 10K€ in electricity and petrol bills.

Target energy consumption reduction: Electricity for lightning, Electricity for computer lab, Fuel for heating

The floorplan of the school is shown in Figure 108.

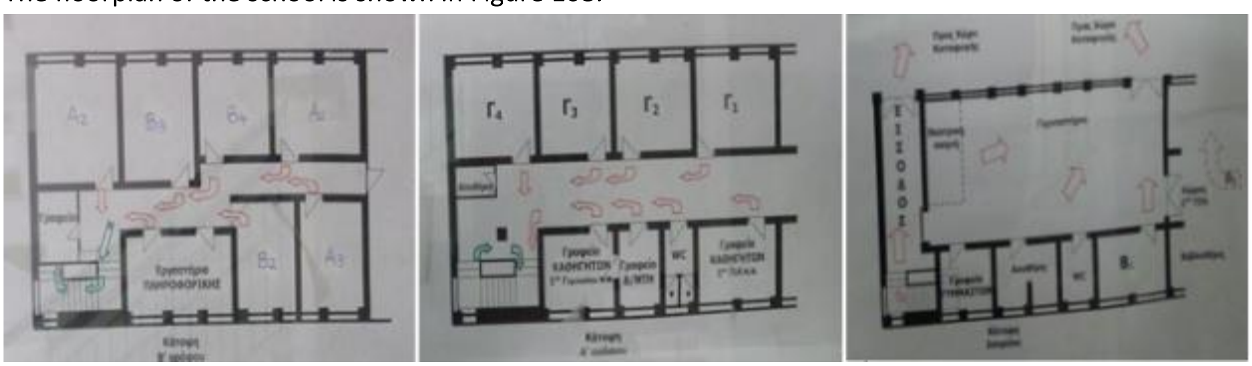


Figure 108: Floorplan of Gymnasium in New Philadelphia, Attica

Main energy consumption meters: overall electricity power meter, power meter of first floor and fuel consumption (bills).

Phase 1: Reference value collection

Electricity

During the first two weeks of September, the computer lab is inactive (as the school year starts on September 12^{th} in Greece). So, the values of the power meter reading in the 1^{st} floor are attributed to “standard” loads which comprise lightning of corridors and bathrooms. Let us denote this value as P(2^{nd} floor, Sept. 1-15). At the same time, the overall power meter of the school measures only “standard” loads such as the lightning of the teacher and principal’s office that have poor nature light. Let this value be denoted as P (total, Sept. 1-15). From September 15 to October 15, the computer lab becomes active.

So, the values of the power meter reading in the 1st floor are attributed to the lightning of the two class rooms of the second floor that have poor natural light. Let this value be denoted as P(2nd floor, Sept. 16-Oct. 15). In November, depending also on weather conditions, the electricity consumed for lightning in foggy days will be monitored. This will result in two readings P(total, Nov. 1-30) and P(2nd floor, Nov. 1-30).

The following equation is expected to hold:

P(total, Nov. 1-30) -P(total, Sept. 16-Oct. 15) = P(2nd floor, Nov. 1-30)- P(2nd floor, Sept. 16-Oct. 15)

Having registered those measurements we can state that:

- The electricity attributed to the computer lab is: P(2nd floor, Sept. 16-Oct. 15)
- The electricity attributed to lightning of the 2nd floor is: P(2nd floor, Nov. 1-30)- P(2nd floor, Sept. 16-Oct. 15)
- The electricity attributed to lightning of the 1st floor is: P(total, Nov. 1-30) – (P(2nd floor, Nov. 1-30)- P(2nd floor, Sept. 16-Oct. 15))

In parallel, to find which part of this **energy could be saved based on human behavior change,** we will ask/motivate:

- the building manager to measure the light intensity and define whether the class room is occupied in November (regularly, in 9.00am and noon every day) and
- professor(s) of informatics to give as the schedule of the computer lab, so as to evaluate whether the PCs are turned off during the breaks, or when there is a void in the schedule for more than the break.

The energy consumption attributed to the human behavior for lightning, is denoted as PLH, will be the percentage of the energy attributed to lightning multiplied by a co-efficient that reflects how many times the building manager founds the room empty or with light intensity above the predefined by rules.

For the electricity consumed from the PCs, denoted as PCH, the part of it attributed to when the computer lab is not active based on the schedule will be considered as subject to reduction. It is worth stressing that turning on-off of the computers in the lab is measurable directly from the smart meter as it brings a significant instant increase/decrease in power consumption.

The total electricity attributed to lightning and computers that can be affected by human behavior is defined as:

PR(EL)=PLH+PCH,

Where PLH stands for Power consumed for Lighting that can be affected by Human behavior and PCH stands for Power consumed for Computers that can be affected by Human behavior.

Phase 2-x: The same parameters will be measured after each scenario application, to assess which part of the energy was saved. For example, to assess the reduction of electricity spent on lightning, we will evaluate P(total, February1-28) and P(2nd floor, February 1-28). Assuming that in February the scenario L1 and L2 are applied, the success factor for economizing electricity spent in lightning of the 2nd floor will be evaluated as follows:

The GAIA KPI for electricity reduction is: (P(total, Nov. 1-30) - P(total, February 1-28)) / PR(EL)

With respect to the heating, in this school there is no thermostat in the building.
Phase 1: One whole school year (or at least two months: December and January) during which the building manager is asked to fill in the fuel consumption values; the faculty members and the students are prompted to register using the GAIA mobile app, the temperature in the classrooms as well as the time during which the heating system is turned on and the windows are open. In the end of this phase, GAIA partners will carry out a study to evaluate the energy that could be saved by human behavior.
Phase 2: 2nd School year, or February and March of the 1st school year: The fuel consumption is measured and the same readings are asked from the building occupants. Again, GAIA partners will carry out a study to evaluate the energy that could be saved by human behavior. A comparison of the two values will results in the GAIA KPI for energy reduction due to heating.

Finally, GAIA will convert the fuel consumption in KWh (there are standard conversion rules) and combine the two factors (electricity- and fuel based) to calculate the overall energy reduction.

Energy-related normalization factor

As mentioned above, energy use for lighting and especially heating depends partially on the weather conditions of each area for each year. As also mentioned previously, GAIA is initially monitoring energy consumption over a period of at least one year, in order to collect related data and form a *baseline* to compare to throughout the duration of the project. This set of baseline data is obviously dependent on the outdoor environmental conditions during the monitored period. Similarly, if during the following year, there are stark differences in light, wind or temperature levels, such variance will have its effect on the monitored energy consumption as well. Since data regarding the weather conditions in GAIA sites are available from both external and GAIA resources (IoT weather stations are already installed at several of GAIA's school buildings), we will utilize such data to form a clearer picture regarding this aspect. We will a normalization factor similar to the ones used in related projects [eeMeasure].

Environment-related KPIs

We continue the discussion, with KPIs related to the environmental impact of GAIA. Following the convention set by other related research projects and EU regulations, the core of GAIA's environmental impact will be calculated based on the quantity of CO_2 emissions saved as a consequence of GAIA's energy consumption reductions in the participating school buildings.

In order to have a reference to compare to, we will utilize the data gathered for forming the baseline reference, as mentioned previously, along with any available data, both from GAIA infrastructure and external sources, to make the separation between different types of energy uses and energy source. In some cases, where possible, GAIA will isolate such energy consumption figures in terms of education or building process, building floor or classroom, or even device, in order to have a higher granularity of reference. This highly depends on the available IoT infrastructure in each building, the capabilities of BMS already installed and other parameters.

There is also the additional parameter of energy mix, i.e., the types of energy sources utilized to produce energy used for each GAIA site, approximations of which can be retrieved from local or national benchmarks. For example, for the Greek school buildings we will utilize the Greek energy benchmark figures available to calculate the percentage of oil in the energy mix and calculate the respective carbon emission result, which can be radically different than the Italian or the Swedish benchmark.

Code	Name	Brief description	Validation Methodology	Gaia target
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	Reduction of emissions as a result of energy consumption reduction
ENV.2	CO_2 emissions per process (lighting, heating, other)	Building energy emissions related to the building volume	Measured in kg of CO_2	Reduction of emissions as a result of energy consumption reduction
ENV.3	Other pollutants related to heating from diesel	Other pollutants related to heating from diesel fuel, including particles like PM_{10}, $PM_{2.5}$, NO_x	Measured in the respective quantities	Reduction of emissions as a result of energy consumption reduction

GAIA has also prepared a list of actions which have positive impact on the environment in the sense of reduction of environmental resources required for the school operation. The following list is considered a living list and will be enriched during the communication with the school communities.

- Recycling-Waste management. Prompt the school communities contribute to intelligent waste management.
    - Separate packages, paper, etc.

    - (Used) Clothes and other (including electronic) assets re-use: initiate a bazaar with low cost lightly used clothes and other assets like bikes, mobile phones, e-readers, books, toys, etc.
    - Electronic devices recycling (tablets, mobile devices, etc.)
- Water management: reduce the volume of water consumed (where applicable)
- Other actions where it primarily depends on the school to implement in the 2nd test year:
    - Reduce the paper use (e.g. for delivering extra exercises or projects to the students)
    - Improve the consumption of slightly processed food at the school (e.g. monitor the quantities of fresh fruits, orange juices consumed by each school community)

Cost-related KPIs

We continue the discussion, with KPIs related to the financial impact of GAIA. Naturally, the impact of calculating the costs to acquire, operate and service GAIA infrastructures and services, and the overall economic aspects of the project are crucial to the success of the project. Although GAIA has a very strong focus on educational aspects, it also aims to be a pragmatic solution and offer concrete advantages to both the schools themselves and to national educational authorities that administer thousands of school building in each country, e.g., the Italian, Greek and Swedish Education Ministries.

There exist various economic indicators that can be used to evaluate the financial performance of an energy-related action, also affected by different designs and options. For GAIA specifically, the project has a rather clear path of calculating costs and benefits, since we will not be directly involved in actions like modifying parts of the building or the building's infrastructure. Although such actions will probably be a result of GAIA's activity during the project's duration, the bulk of GAIA's costs associate with acquiring the IoT infrastructure and operating the whole GAIA ecosystem. Since GAIA activities will be integrated within the participating schools' curriculum and use existing human resources, i.e., the schools' teaching staff, there aren't other significant hidden costs.

Thus, the financial aspects of GAIA and its economic returns focus on the energy savings achieved versus the costs to acquire and operate the whole ecosystem for each school. We have included a set of KPIs that reflect these aspects in a straightforward manner in the following table.

Code	Name	Brief description	Validation Methodology	Gaia target
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	>10%
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	4-5 year SPP typically, different model in the case of OVER which have rent
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	>5%

Human comfort-related KPIs

We continue the discussion, with KPIs related to the impact of GAIA on the comfort of human participants in the respective school buildings. The energy savings goal set by GAIA should be compatible with maintaining the end-user comfort characteristics set by the schools and also other EU and national regulations.

For educational buildings, the end-user comfort levels revolve mainly around thermal and visual comfort, while there are additional characteristics that also help in having an environment that supports the educational procedures and also minimizes discomfort from outdoor and indoor environmental parameters. Thermal comfort refers to end-user comfort attributed to indoor temperature and it usually translates into restrictions like minimum indoor temperature in the wintertime and maximum indoor temperature during summertime. Visual comfort refers to the amount of light available inside the classroom and other building parts, and it is also very important, since it has its effect on productivity and overall building functions. Indoor humidity is an additional parameter that also has an effect on end-user comfort.

There are additional parameters that affect specifically educational communities, like noise levels and air particle concentration inside classrooms. GAIA has already installed or plans to install IoT infrastructure to monitor such parameters in several of the participating school institutions. We will also include such aspects when evaluating end-user comfort, to provide a more complete picture at the end of the project.

The following table includes the respective KPIs, descriptions and goals set for GAIA. We include 2 KPIs marked as optional, due to the fact that they are related to end-user comfort, however, they are not related directly to energy consumption, and the consortium is still evaluating the inclusion of relevant sensing hardware in GAIA's IoT sensor boxes.

Code	Name	Brief description	Validation Methodology	Gaia target
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	Precise formula existing for PMV is complicate, will require approximation
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	Precise formula existing for PMV is complicate, will need approximation
HC.3	Visual Comfort	Amount of light available inside school classrooms	Daylight factor, average level	>500 lux on average

			of minimum illuminance	
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	Lower noise levels in classrooms
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	Lower yearly average number of low air quality incidents

System/Technology-related KPIs

A great deal of GAIA's activity revolves around the development of a software/hardware ecosystem and the respective system components. We aim to produce a useful, efficient and reproducible system that can be used outside of the schools participating in the project, therefore it is essential that we also measure the project's performance in terms of such aspects as well. GAIA will also aim to kickstart activity with third-party solution providers; the IoT infrastructure installed inside schools buildings will not be provided by the consortium partners, but also from other SMEs/enterprises. In order to achieve this, we will work together with such partners and try to produce a common API that can be reused in other projects and ecosystem and serve as a reference to implement similar systems to GAIA.

On top of that, GAIA aims for an open source hardware/software approach, where applicable, i.e., the resources committed to producing such aspects of the project will result in a number of hardware/software components that will be available for all interested third parties, such as schools, SMEs, ministries, etc., to reuse and further develop in the future through online repositories.

Another important outcome of the project will be the related datasets. Currently, there is a shortage of related data available to the research community, and we believe that by releasing such datasets it will help to kickstart a lot of related activity, that is otherwise hindered by unavailability of data. All data will be made available according to the privacy and anonymity guidelines of the project. Indeed, while open datasets about energy consumption in private homes are becoming available (e.g. BLUED[21], REDD[22] and TRACEBASE[23]), there is a shortage on energy consumption datasets on public buildings.

Moreover, since we aim to serve a large community of end-users, it is imperative that we produce an efficient system that supports the GAIA activities in a satisfying manner. Therefore, characteristics like system uptime and data granularity will help to characterize the performance of the produced components.

The following table includes the respective KPIs, descriptions and goals set for GAIA.

Code	Name	Brief description	Validation Methodology	Gaia target
TS.1	System uptime	The percentage of time GAIA services will be available to end-users	Server-side system logging	High availability Platform, minimum uptime is 99%

[21] http://portoalegre.andrew.cmu.edu:88/BLUED/
[22] http://redd.csail.mit.edu/
[23] https://www.tracebase.org/

TS.2	Data granularity	The granularity in which data are being produced by the system and will be available in the future	Use DATA API for validating granularities	5_MIN, QUARTER, HOUR, DAY, MONTH
TS.3	System performance	The performance of the system in terms of response time, throughput, etc.	Server-side system logging	Input 3000 events / sec, Response time less than 3 sec
TS.4	#open APIs	The set of open APIs produced by the project and which will be available as definitions and as services	Number of APIs defined and working properly in M24	3
TS.5	API latency	Latency refers to the round-trip time from a request to a response.	Candidate tools (at M17): Nagios, WebMetrics	3s
TS.6	#open source hardware components	The set of open source hardware components that will be available at the end of the project for use from 3rd parties	Open availability through online repository	4
TS.7	#open source software components	The set of open source software components that will be available at the end of the project for use from 3rd parties	Number of components successfully tested in GAIA trials	5
TS.8	Integration of 3rd-party systems	The set of 3rd party systems, i.e., either commercially available or as open source projects, that will be integrated in the GAIA ecosystem	3rd party systems integrated in M24 of the project	5 Integration of equipment/solutions from OVER, Spark, SYN, Meazon, Honeywell
TS.9	#datasets provided openly	The datasets that will be provided to the rest of the scientific and educational community at the end of the project	The anonymized datasets from GAIA schools	15
TS.10	#open source repositories	Open source online repositories that will be available at the end of the project, e.g., on GitHub	Number of repositories containing	4

			open source code for a specific set of components	
TS.1 1	# applications	The set of applications developed by GAIA (in the framework of WP3). All the applications will be available in four languages (English, Greek, Italian and Swedish)	Availability of the applications in M24	3
TS.1 2	Applications' performance	Different device types supported by GAIA apps Operating Systems supported by GAIA apps	Number of devices and OS in GAIA trials where the GAIA apps are executed	15 2 OS
TS.1 3	App crashes	Average crashes per app loads (an app load is the launch of an app). The typical crash rate is 1-2%, but this varies widely depending on the type of app, its usage, maturity, etc.	Google Analytics or flurry	5%

Behavioral-change related KPIs

The KPIs and aspects discussed in the previous section included dimensions of the project that can be measured and quantified in more or less direct ways, and then be translated into concrete metrics. However, when we move to the aspect of behavioral change, things quickly get much more complicate; there exist certain models for measuring behavioral change in tightly controlled environments, mostly corporate, coupled with either a multitude of IoT infrastructure monitoring in great detail specific areas of a building, or coupled with software services that monitor and record many aspects of human participants' daily activity.

In GAIA, such approaches cannot be easily applied without compromising the student's privacy or interfering with the day-to-day activities in the participating institutions. Moreover, such approaches would raise concerns, in many cases legitimate, with students' parents, the school authorities, or the students themselves. Having the above in mind, we chose to include KPIs that reflect behavioral change in an indirect way, but overall giving a representative picture of the project's performance regarding these aspects.

To further justify our approach, the overall loop describing end-user engagement and participation, together with the feedback from gamification and other project aspects that aim to materialize behavioral change results, is depicted in Fig. 109.

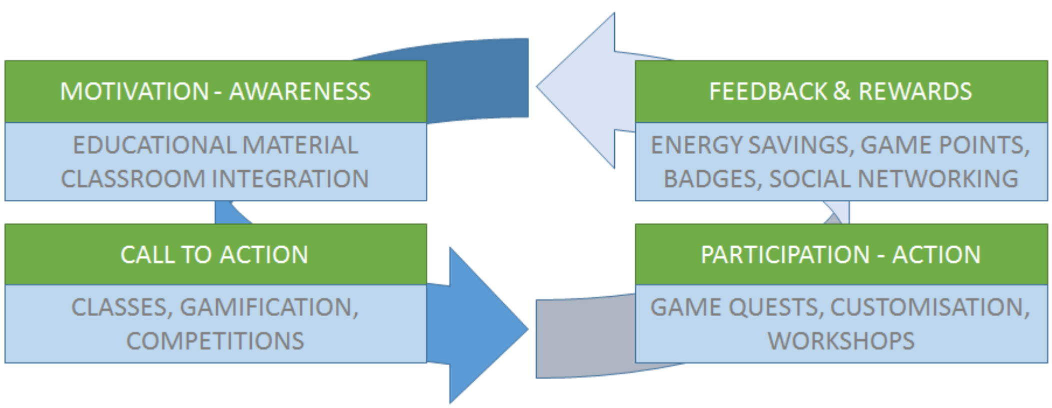


Figure 109 Different aspects of end-user engagement in GAIA

As is shown in this figure, the whole aspect of achieving behavioral changes with respect to energy consumption behavior, revolves around motivation, call to action, active participation in GAIA activities and at the end, through feedback and rewards, by incentivation and intensification to continue engagement with the project and achieve better results over time. Thus, it is evident that apart from the energy efficiency KPIs described previously, which validate the overall GAIA approach, behavioral change is linked to the whole gamification and end-user engagement strategy of the project; if the solution realized is attractive and useful enough to entice end-users to continuously use the platform, then this is an indirect way to measure the overall performance of the project in terms of behavioral change, since any energy savings achieved will involve the active participation of the end-users, which is facilitated through the abovementioned components.

The following table includes the respective KPIs, descriptions and goals set for GAIA.

Code	Name	Brief description	Validation Methodology	Gaia target
GB.1	Time spent using Web portal	The time spent by end-users on the GAIA portal and web interfaces, as a measure of end-user engagement	Use server-side system logging components, monitoring all related activity, while also having in mind privacy issues	7-10h
GB.2	persons using web portal	An estimate of the number of different end-users utilizing the GAIA web portal	server-side system logging (see GB.1)	30-40% of target group (mixed: classroo m activities 100%; voluntary usage 20%)
GB.3	sessions per user	Average number of separated sessions a user engages with the platform	server-side system logging (see GB.1)	30
GB.4	session duration	Average session duration of all users and sessions	server-side system logging (see GB.1)	5-10min
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
GB.6	#sensing quests completed	A measure of the total gaming activities completed by the end-user community	server-side system logging (see GB.1)	50-70%
GB.7	#educators contributing quests	A measure of the engagement of educators with the gamification platform, based on their contributions and customizations	server-side system logging (see GB.1)	8

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%
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

Regarding the overall interaction time calculation in GB.1, we base it on using the following assumptions:

Topics

a) Introduction
b) Heating
c) Transportation
d) Electricity
e) Collaborative use of resources

Core interaction time

5 quests per topic = 25 quests
5 min. interaction time per quest = 125min

Social engagement

1 min per quest = 25min

News reading

Estimation = 60min

Class activities

2 class activities in total
Duration = 1 week (5 days) per class activity
1 quest per day = 5 quests
10 min. interaction time per quest = 50min (1 class activity) / 100min (2 class activities)

Class activity online portfolio

1 portfolio per class activity = 2 portfolios in total
4h per portfolio = 240min (1 class activity) / 480min (2 class activities)

SUMMARY

Core interaction time	125min
Social engagement	25min
News reading	60min
Class activities (average 1,25 class activities)	63min
Class activity portfolio (average 1,25 portfolios)	300min
TOTAL	573min (ca 9h 30min)

Education-related KPIs

As mentioned numerous times before in this document, GAIA has a very strong focus on educational aspects. For this reason, it is essential to also monitor the results of the project in terms of such aspects, which will constitute a great part of its final outcome. In short, the indicators we have included for GAIA focus on evaluating the aspects of the project regarding:

- Students and educational staff directly and indirectly involved with the project, as well as the parents of the students.
- Actions such as workshops targeting specifically the educational community in order to communicate sustainability aspects and ways to actively involve with the project.
- Educational resources committed to the project, showing its integration within the daily life of the schools involved with the project.
- Educational material, such as handbooks, toolkits, lab courses, etc., i.e., material that can be reused in other educational institutions.
- Since GAIA will operate over different countries, we will attempt to produce material for various European countries, in order to highlight our approach and make it available to as many schools as possible.

The following table includes the respective KPIs, descriptions and goals set for GAIA.

Code	Name	Brief description	Validation Methodology	Gaia target
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
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

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
ED.4	#educational workshops organized	Number of educational workshops organized by GAIA directly involving and aiming at the educational community	Organization of workshops	3
ED.5	#educational scenarios and toolkits	Number of educational scenarios and toolkits produced by the project	Availability on the project website	20
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	4
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

Dissemination-related KPIs

A very important aspect of GAIA activities will be centered on disseminating the project results' to the research and academic community, as well as the educational community and the general public. As described in the DoW, we aim to implement a number of actions targeting each one of these communities throughout the duration of the project, and have even began to implement such actions already in the first months of the project. Such actions include:

- Workshops organized for the scientific and educational community.
- Submission of original research work to conferences and journals with review process related to GAIA.
- Newsletters informing the GAIA community regarding the ongoing status of the project, and other processes related to the project's website.
- Joint actions with other related EU research project, or bring the participating schools in contact with relevant EU actions focused on sustainability and energy efficiency.
- Dissemination actions through popular social networking platforms, in accordance with the policies and regulations of each country regarding such aspects.
- Dissemination actions through local and national media to promote the projects' results, in each country.

We believe this is a reasonably holistic strategy to communicate the essence and results of the project, given the resources available and the nature of the project. The following table includes the relevant KPIs, description and goals.

Code	Name	Brief description	Validation Methodology	Gaia target
DRA.1	#workshops organized/co-organized	Number of scientific workshops organized /co-organized by GAIA	Organization of workshops	4
DRA.2	# participants to workshops	Number of participants to scientific workshops organized/organized by GAIA	Count of participants	200
DRA.3	#papers submitted in conferences	Number of scientific reports submitted to international conferences with review process	Count of paper submissions	8
DRA.4	#papers submitted in journals	Number of scientific reports submitted to international journals with review process	Count of paper submissions	3
DRA.5	#newsletters	Number of GAIA newsletters produced by the consortium disseminating GAIA news	Release of newsletters	9
DRA.6	#press releases	Number of press releases issued by GAIA	Count of releases	4

DRA.7	Joint actions with other projects	Actions organized together with other related research projects in order to promote GAIA and sustainability aspects	Organization of actions	3
DRA.8	Bringing together schools and other EU actions	Actions for bringing schools in touch with other similar projects and related EU actions in the context of energy savings and sustainability	Organization of actions	2
DRA.9	Attendance at relevant expos, conferences, symposia, etc.	Attendance of GAIA consortium members at topically relevant expos, conferences, symposia, etc.	Gather info from consortium members	15
DSN.1	#social networking platforms	Number of social platforms where GAIA will have an active and continuous presence	Track and count	6
DSN.2	#social networking users	Number of social networking platform users that will be connected to GAIA presence in those platforms	Track follower numbers, while also having in mind privacy issues	300
DSN.3	Articles in local media	Number of articles submitted by GAIA consortium members to local media	Gather info from consortium members and simple count	5
DSN.4	Articles in online media	Number of articles referring to GAIA published in online media outlets that have a topical interest in the issues GAIA is addressing	Tracking of Hashtag, share, retweet, comment, like, etc.	5

9. GAIA use-cases and scenarios

In this chapter, we describe a set of scenarios that lead to sustainability awareness enhancements and thus, "greener" behavior. These scenarios involve all occupants of the school building and are used to derive the user and system requirements. The list of scenarios is included in Table 5 and described in the next sections. It is worth stressing that the use cases and scenarios will be further elaborated in the next few months (first months of the school year) together with representatives from the schools communities, towards the extraction of detailed requirements that will drive the design and implementation of the GAIA applications. During GAIA trials, a subset of these will be tested in each school. The criteria that will be used to select the scenarios to test in real-life and further details on the GAIA piloting are discussed at the end of this chapter. Thus, the scenarios included in this section are *indicative*, and are included in this section mainly to showcase some of the directions the project will take in the coming months.

Table 5: Use case scenarios considered in GAIA

Scenario ID	Title	Target
Scenario L1	Turn-off the light	Electricity consumption
Scenario L2	Make the most of the natural light	
Scenario L3	Lamps: type and maintenance	
Scenario EL1	Standby	
Scenario EL2	Holiday standby	
Scenario H1	Thermostat-emulation	HVAC
Scenario H2	Thermostat adaptation to outside temperature	
Scenario H3	Thermostat control during vacations and before start-over	
Scenario H4	Change ceiling fan direction	
Scenario C1	Thermostat-wise setting	
Scenario R1	Recycling through reuse	Recycling
Scenario R2	Recycling through waste separation	
Scenario ES1	Water consumption reduction through crowd-sensed leakage detection	Environmental sustainability
Scenario T1	Car/vehicle differences	
Scenario T2	Car pooling	

We organize the description of the scenarios in the following parts:

Part name	Description
Applicability	The GAIA school that the scenario mostly applies. This primarily depends on the installed infrastructure.
Phases	As GAIA aims at evaluating the results of its interventions, we organize the execution of the scenarios in phases. Once a scenario is selected to be trialed, concrete activities will take place in each phase so as to ensure that the evaluation of the KPIs will be possible and as accurate as possible.
Rewards	This part describes initially considered rewards that will be provided so as to motivate the school community. (These will be refined in cooperation with the school managers prior to GAIA trials).

Proposed duration	For the measurements of the results of the interventions to be meaningful, we define a relevant duration (which is in most cases the minimum duration for the results to be reliable). This entry will allow us to schedule the GAIA trials in a way that will enable the evaluation of all targeted KPIs.

Scenarios relevant to electricity consumption

Scenario L1: Turn-off the light

Applicability: All GAIA schools (no GAIA school is equipped with luminosity sensors to turn off the lights)

Phase 1: monitor lightning

All building inhabitants monitor and register in the mobile crowd-sensing app cases where the lights are on in empty places.
The building manager and the teachers can monitor the motion sensor and the energy consumption data to correlate consumption with occupancy.
In the end of two weeks, the building manager inspects all received information and presents to the faculty the results.

Phase 2: “act: turn-off the light”

All members of the communities “turn off the lights” when not necessary and the consumption is registered.
Rewards: A reward relevant to the school life and the educational game will be granted.
Proposed duration: two weeks each phase.

Scenario L2: Make the most of the natural light

Applicability: All GAIA schools

Phase 1: Register situation

All members contribute to register whether there are curtains, blinds and the actual luminosity based on mobile devices (of the teacher).
In the end of the phase, the building manager collects all readings and define course of action.

Phase 2: “Act: turn-off the lights”

Teachers and students are informed about the revealed situations and are prompted to turn-off the lights.
Rewards: A reward relevant to the school life and the educational game will be granted.
Proposed duration: two weeks each phase.

Scenario L3: Lamps: type and maintenance

The GAIA mobile app prompts the building managers to enter the type of lamps per area.
For those types that need maintenance (cleaning, etc.), the app regularly remind the building manager about the maintenance needed.
Assuming that there are better (with respect to energy efficiency) options, the mobile app notifies the building managers that there are better options and the amount of energy they could save.
As soon as an action is taken, it is registered in the platform and rewards are granted to the acting members. For example, the students and families may decide to fund the lamp type change. In this case, the building manager notifies the platform that the whole school community should be rewarded.

Scenario EL1: Standby

Applicability: All GAIA schools

Phase 1: monitor consumption

The building manager and/or faculty and/or students inspect PCs, printers, photocopiers that are on or on standby when not in use. They all register their findings to guide energy efficient behavior.

Phase 2: "act: do not leave on standby"

Students are advised to turn-off the PCs they use and when they do, their teacher registers the action in the platform, through the mobile app.
The building manager or a selected teacher inspects all appliances before leaving the school and registers the appliances found on standby.
Rewards: A reward relevant to the school life and the educational game will be granted.
Proposed duration: three weeks each phase.

Scenario EL2: Holiday standby

Applicability: All GAIA schools

Phase 1: "act: do not leave on standby"

The building manager is reminded about holidays so that he/she inspects all appliances before leaving the school and registers the appliances found on standby. He/she schedules a walk round on the last day before long weekends and breaks when staff and pupils have left the building. A tour of all areas should be made, noting (and turning off) all non-essential equipment. The worst culprits are normally:

- Computer base stations left running
- Computer screens left running or in screen-saver/sleep mode
- Photocopiers in sleep mode
- Point-of-use electric water heaters left running

- Extractor fans left running
- Lighting left on.

To make it easier for the next holiday, essential equipment that cannot be turned off should be labelled and a list drawn up and handed out to staff.

Rewards: A reward is granted to the building manager relevant to the educational game will be granted.

Proposed duration: one school year

Scenarios relevant to HVAC

Scenario H1: thermostat-emulation

Applicability: GAIA schools without thermostat (e.g. Patras Gymnasium)

Phase 1: "monitor heating system turn-on time"

For one week in winter the building manager inspects the temperature in the classrooms and registers them in the mobile app. He is also prompted to register the time during which the heating system is turned-on and the relevant energy consumption (manually measured).

Phase 2: "act: turn-off the heating"

The building manager is triggered either by temperature meters installed in the building or by students or by the temperature sensor of his phone that the temperature has reached 20oC in winter so that he turns off the heating. When the temperature drops below 19o he is again triggered to turn on the heating. In parallel, he/she is prompted to log the turn-on and off time so that GAIA platform can calculate the saving.

Phase 3: "assess savings"

The building manager is triggered to enter the energy consumption data (electricity, fuel, etc.) in regular time periods.

Reward: the building manager and involved teachers/students are rewarded with serious game relevant points.

Proposed duration: one school year

Scenario H2: thermostat adaptation to outside temperature

Applicability: GAIA schools with automated heating systems (e.g. EA)

Phase 1: "Adapt thermostat settings to outdoor temperature"

Upon acceptance, both the faculty and the students are notified about a cold day in winter and they can vote to have the thermostat lowered by 1oC. This gives them the opportunity to dress up appropriately.

The building manager is notified about the result of the vote procedure and adapts the thermostat settings. At the end of the day, the faculty and students are asked about the comfort level.
Reward: the participating community is rewarded.
Proposed duration: two weeks in December.

Scenario H3: thermostat control during vacations and before start-over

Applicability: GAIA schools with thermostat-operated heating systems (e.g. EA, public schools with thermostat-driven heating system turn on and off)

Phase 1: "Adapt thermostat"

The building manager enters the vacation time (in days) and the mobile app advises him/her on the setting he/she should set for the time the school is closed and then for the setting and when to apply them when the school operation starts over again.
Reward: the building manager is rewarded if he has logged in relevant data as well as the fuel consumption in the end of the school year.
Proposed duration: monitor for the whole winter time and trigger actions during all winter breaks including regular weekends.

Scenario H4: change ceiling fan direction

Applicability: GAIA schools with ceiling fans (e.g. public school at Rafina, Greece).

Phase 1: "monitor temperature"

The building manager, teacher and students monitor the temperature evolution in their classroom without having the ceiling fan turned on for one week. Then, the building manager changes the ceiling fan direction and then, they all together monitor the actual temperature data to check the impact of the ceiling fan.
Reward: the building manager, the teacher and the community is rewarded.
Proposed duration: two weeks.

Scenario C1: thermostat-wise setting

Applicability: GAIA schools with air conditioning systems

Phase 1: monitor consumption in May with typical settings

The teacher and students monitor the consumption of the air conditioning system for one week with the currently applied settings and they register the settings as well.

Phase 2: desired temperature setting

The students together with the teacher decide on the desired temperature setting and the building manager is notified to enact the setting.

Phase 3: The saved energy is calculated.

Reward: all participants are rewarded.
Proposed duration: four weeks.

Scenarios relevant to recycling

Scenario R1: Recycling through re-use

Applicability: All GAIA schools

Phase 1:

Define the assets that are appropriate for re-use and assess the relevant quantities that are now sent to waste

Phase 2:

The school community starts to use a web app that enables the owner to declare assets that can be offered for re-use at a very low price.

Phase 3:

Assess over a one-year time the quantities of assets that were re-used and the evolution of the user engagement.
Reward: all participants are rewarded: those that deliver assets get money, those that receive the assets they save expenses.
Proposed duration: one school year.

Scenario R2: Recycling through waste separation

Applicability: All GAIA schools that have not embraced recycling policies or have partially done so

Phase 1:

Define the recycling programs implemented in each country (e.g. in Greece there is a program for separating packages from any other recyclable materials) and inform the school community appropriately (i.e. using appropriate communication means). In parallel, measure the volume of wastes of the school per category for two months (could be the period from the beginning of the school year till end of October).

Phase 2:

The school community starts separating the recyclable materials. The volume of different categories of wastes is evaluated for the next two months.
Reward: some kind of competition internal to the school or among schools can be realized.
Proposed duration: one school year.

Scenarios relevant to environmental sustainability and resource sharing

ScenarioES1: Water consumption reduction through crowd-sensed leakage detection

Applicability: GAIA schools

Phase 1:

Monitor for one year how many leakage or misuse events are detected.

Phase 2:

The school community uses the GAIA crowd-sensing application to declare a detected event. Also, the responsible for taking action is defined before-hand. In the end of the year, the responsible person reports on the number (and possibly severity) of events detected through crowd-sensing.
Reward: some kind of competition internal to the school or among schools can be realized.
Proposed duration: two school years.

Scenario T1: Car/vehicle differences

Applicability: All GAIA schools

Phase 1:

Assess the transportation means used by the school community to reach the school through questionnaires (for two-three months). The aim is to identify potential optimizations

Phase 2:

Educate the community on the impact of each transportation means on the environment either through serious games and/or through dedicated lectures, school projects, brochures.

Phase 3:

Re-assess the transportation means used by the school community to reach the school through questionnaires (for two-three months). Additional measurements may also take place in order to evaluate the KPIs defined in the previous chapter.

Reward: money (e.g. save money spent on fuels for privately owned cars, or save money by offers from the private school for using the school buses), time, green-consciousness measured in some type of eco-points in GAIA apps.
Proposed duration: two school years.

Scenario T2: Car pooling

Applicability: All GAIA schools

Phase 1:

From the above transportation means, isolate the cases where privately owned cars are used.

Phase 2:

Educate the community on the impact of car usage on the environment as well as on the use of a mobile app for car-pooling as an additional tool (next to physical meeting and arrangements among parents and/or teachers).

Phase 3:

Re-assess the extent of car usage and the transportations saved in a framework of two-three months.
Reward: money, time, green-consciousness measured in some type of eco-points in GAIA apps.
Proposed duration: two school years.

Trial set-up and validation mechanism

This section aims at serving as a guideline for the technical implementation of the trials in T4.1 and as a controlling mechanism for the validation of the trials in T4.4. It presents the principles that have to be taken into account in WP4 in order to ensure that GAIA will:

a) measure reliably all its target KPIs,
b) maximize its impact on energy efficiency and green awareness.

GAIA project has already defined (in the first sections of chapter 8) a first list of scenarios that can be implemented in real life in GAIA schools. At the beginning of task 4.1 lifetime, we will

- Select the scenarios that will be executed in each school.
- Prepare a time schedule per school.

For the selection of the scenarios that will be executed per school, we will take the following steps:

- Identify the KPIs evaluated through each scenario
- Classify the schools in categories: we can distinguish GAIA -involved schools according to the
    - level of automation installed in the school, we will consider
        - Schools with fully automated Energy Management Systems (EA and the school at Soderhamn)
        - Schools with sensing equipment
        - Schools with limited sensing equipment
    - Climate conditions: for the GAIA project, a limited set of climates will be considered (e.g. 5). For example, the school at Soderhamn is not suitable for testing scenarios relevant to cooling.
- Define which scenarios are applicable to each school (based on the above school classification)
- Define the scenarios that will be executed in each school. This assignment will ensure that:
    1. Each KPI is measured in more than one schools
    2. Each school will run at least three scenarios while the maximum depends on the manager of each trial site
    3. We will try to execute similar scenarios to as many as possible trial sites to improve the reliability of the measurements
    4.

Once this assignment has been agreed, we will schedule the trials per site taking into account

- The proposed duration per scenario decided to run on each trial site to ensure the meaningful measurements will be collected
- The duration of the school years and the availability of staff
- The possibility to run additional phases to fine-tune the scenarios and re-assess the GAIA impact.

It is worth stressing that GAIA consortium has enriched the equipment available in the GAIA trial sites already during its first 10 months of lifetime ensuring that the number of school that each KPI can be assessed is adequately large to ensure reliable measurements. The available equipment and the additional installation are described in separate chapters of this deliverable.

10. System Requirements

From the use cases and scenarios described in chapter 5, we derive the following requirements which are prioritized as: H means high priority, L stands for low priority.

It is worth stressing that:

- Before the design and development of the GAIA applications, the following requirement list will be elaborated based on the decisions regarding the scenarios that will be tested in real-life. These scenarios will drive the definition of more concrete requirements that suit the buildings and cultures of the school communities.
- Irrespective of the scenarios that will be finally selected to be tested in real-life, the design of the GAIA applications will be as flexible and expandable as possible so that the implementation of additional features immediately after the project lifetime is efficiently supported (e.g. by the database design and scalable responsive designs).

Req. ID	Requirement description	Scen. that generated the req.	Priority
1	The serious game educates the faculty and student about the importance of the lightning in energy consumption (percentage it represents, major causes of waste, the equivalent in CO2, and/or trees and/or other environmental indices).	L1	H
2	The reading of motion sensors can be viewed by the building manager and the teachers at least to 30min granularity.	L1	H
3	The reading of energy consumption of the classrooms can be viewed by the building manager and the teachers at least to 30min granularity.	L1	H
4	The students, faculty and building managers can enter information about room occupancy.	L1	H
5	The GAIA mobile app should communicate the achievements/activities of the community members with the serious game (through the GAIA cloud platform).	L1	H
6	Reward for lights turn-off actions are granted to communities (teacher and students).	L1	H
7	The serious game educates the faculty and student about the ideal luminosity levels for studying.	L2	H
8	The GAIA mobile app should allow the user enter luminosity levels manually.	L2	H
9	The GAIA mobile app should allow the user enter luminosity levels automatically (i.e. exploiting the luminosity sensor of the mobile device).	L2	L
10	The building manager should be capable to viewing the luminosity data per day on the school floorplan	L2	H
11	The building manager should be capable to viewing the luminosity data per hour on the school floorplan.	L2	L
12	The GAIA mobile app should allow the building managers enter the type of lamps per area and get reminders for maintenance.	L3	H

13	The mobile app informs the building manager for more efficient lamp types that can be used and the associated return on investment.	L3	H
14	The building manager can register the change of lamp types and get rewards (e.g. eco points).	L3	H
15	All the members of the school community (building manager and/or faculty and/or students) can enter information on devices found on stand-by mode through the GAIA mobile app.	EL1	H
16	The students are educated to turn-off the PCs when they finish using them.	EL1	H
17	The building manager should be reminded by the GAIA mobile about holidays so that he/she inspects all appliances before leaving the school and registers the appliances found on standby.	EL2	H
18	The building manager should be able to register in the GAIA platform the temperature and the time the heating system was turned on.	H1	H
19	The building manager should be able to register the consumption of energy resources in the GAIA platform.	H1	H
20	The building manager is notified to turn off the heating based on the input from the temperature sensors.	H1	H
21	The school communities are educated to understand the resource savings per 1oC difference in the desired temperature.	H2	H
22	The school community can be notified by the GAIA platform about the weather conditions of the next day.	H2	H
23	The school community can vote about the desired temperature (If the legislation allows so).	H2	H
24	The building manager is notified by the GAIA platform about the result of the vote procedure and adapts the thermostat settings.	H2	H
25	The GAIA platform can calculate eco-points for the energy saving achieved through the voting.	H2	L
26	The GAIA optimization components is capable of advising the building manager on his actions to achieve specific temperatures after long weekends and vacations.	H3	H
27	The GAIA game should be capable of rewarding actions relevant to the ceiling fan (e.g. change in the direction)	H4	L
28	Requirements 21 to 25 should be met to support efficient operation of the cooling/air-conditioning system.	C1	H
29	Some type of marketplace should be activated and delivered to the school community to facilitate resource sharing.	R1	L
30	The school community should be educated about asset re-use.	R1	H
31	The school community should be educated about appropriate recycling.	R2	H
32	GAIA social networking fosters the attitude to waste separation and recycling.	R2	H
33	The GAIA platform should register information regarding the volumes of waste recycled to enable competition.	R2	H
34	The GAIA platform should allow the user enter a water leakage event.	ES1	H
35	The GAIA platform should allow the user validate a water leakage event.	ES2	L
36	The GAIA educational game educates the school community on the differences in environmental burden brought by different car types.	T1	H
37	The GAIA platform allows for evaluation of the environmental impact for transportations using alternative car types.	T1	L

38	The GAIA educational game should raise awareness on carpooling potential benefits on environment and potential financial savings.	T2	H
39	The GAIA social networking app should foster the use of specific carpooling apps.	T2	L
40	The GAIA platform should allow the school community member enter information about the embracement of carpooling activities.	T2	H

11. Conclusions

In this document, we have presented a first approach on GAIA's design. We have discussed in detail the principles behind our approach, along with summaries regarding the participating school trial sites. We tried to give better insights on the factors affecting the design, by also presenting the current situation at the trial sites, along with the progress achieved by the project thus far.

An analytic presentation of the metering technologies involved in the implementation of the project is also provided in this document. We presented the consortium partners' technologies utilized thus far in GAIA's IoT infrastructures, along with third party technology providers that are compatible with the current design approach of GAIA. This presentation is complemented by the introduction of the API design with respect to data services provided by GAIA.

We have attempted also to define a coherent and analytic set of KPIs complementing the ones initially referenced in GAIA's DoW document. This set of KPIs explains in greater detail the crucial aspects of the project and allows to have a more holistic view on its future contributions.

Aspects like the Educational Lab Kit and open source policies are being further introduced and discussed, showcasing some of the more unique aspects of GAIA. We plan to develop further these concepts in the coming months, in order to integrate them into the project's core.

Moreover, we have discussed several use-cases, showcasing how GAIA's design will materialize in the following phases of the project, while also outlining some of the fundamental directions with respect to the trials design and organization. An initial list of system requirements is also introduced to the discussion, providing additional information regarding the overall design.

Finally, although this is mainly a design document, we have simultaneously attempted to provide an overview of the current state of the project with respect to its implementation. In the coming months several additional steps will further enhance the current status of the project.

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[hw5] www.sparkfun.com/datasheets/Sensors/Weather/Weather%20Sensor%20Assembly.pdf

[hw6] Iboard: https://www.itead.cc/iboard.html

Annex I: List of available data sources for Greek public schools

54th Elementary School, Patras

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh	30 sec samples are taken and then added to send in 5 min periods	11/2014
Current	Ampere	30 sec samples are averaged to 5 min sampling periods	11/2014
CO2 emissions	G	Produced indirectly by energy consumption through a standard formula	11/2014
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	
Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Start of trials
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Start of trials
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Start of trials

Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	03/2015
Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	03/2015
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	03/2015
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	03/2015
Wind speed outdoor	m/sec	30 sec samples are averaged to 5 min sampling periods	11/2014
Wind direction outdoor	Direction	30 sec samples are averaged to 5 min sampling periods	11/2014
Rain gauge outdoor	Mm	30 sec samples are averaged to 5 min sampling periods	11/2014
Radiation outdoor	μSv/h	30 sec samples are averaged to 5 min sampling periods	03/2015

8th Gymnasium, Patras

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh	30 sec samples are taken and then added to send in 5 min periods	09/2014
Current	Ampere	30 sec samples are averaged to 5 min sampling periods	09/2014
CO2 emissions	G	Produced indirectly by energy consumption through a standard formula	09/2014
Heating energy consumption	Joule, kWh, petrol litres, …	Currently we have manual records of energy bills. This will	

	(depending on the infrastructure installed)	probably change in the near future – we need to work out the way to do that	
Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Start of trials
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Start of trials
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Start of trials
Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Not Installed
Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	Not Installed
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Not Installed
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	10/2014
Wind speed outdoor	m/sec	30 sec samples are averaged to 5 min sampling periods	10/2014
Wind direction outdoor	Direction	30 sec samples are averaged to 5 min sampling periods	10/2014

Rain gauge outdoor	Mm	30 sec samples are averaged to 5 min sampling periods	10/2014
Radiation outdoor	μSv/h	30 sec samples are averaged to 5 min sampling periods	Not Installed

Experimental Gymnasium, Patras

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh		04/2016
Current Meazon	Ampere		04/2016
CO2 emissions	G		04/2016
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	
Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Start of trials
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Start of trials
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Start of trials
Various gases - concentrations	Ppm	30 sec samples are averaged to 5 min sampling periods	02/2015

outdoor			
Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	02/2015
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	02/2015
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	02/2015
Wind speed outdoor	m/sec	30 sec samples are averaged to 5 min sampling periods	10/2014
Wind direction outdoor	Direction	30 sec samples are averaged to 5 min sampling periods	10/2014
Rain gauge outdoor	Mm	30 sec samples are averaged to 5 min sampling periods	10/2014
Radiation outdoor	μSv/h	30 sec samples are averaged to 5 min sampling periods	02/2015

Pentavrysso Gymnasium, Kastoria

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh	30 sec samples are taken and then added to send in 5 min periods	12/2014
Current	Ampere	30 sec samples are averaged to 5 min sampling periods	12/2014
CO2 emissions	G	Produced indirectly by energy consumption through a standard formula	12/2014
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	

Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Start of trials
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Start of trials
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Start of trials
Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	02/2015
Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	02/2015
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	02/2015
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	02/2015
Wind speed	m/sec	30 sec samples are averaged to 5 min sampling periods	12/2014
Wind direction	Direction	30 sec samples are averaged to 5 min sampling periods	12/2014
Rain gauge	Mm	30 sec samples are averaged to 5 min sampling periods	12/2014
Radiation	μSv/h	30 sec samples are averaged to 5 min sampling periods	02/2015

2nd Technical High School, Larissa

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh	30 sec samples are taken and then added to send in 5 min periods	Not Installed
Current	Ampere	30 sec samples are averaged to 5 min sampling periods	Not Installed
CO2 emissions	G	Produced indirectly by energy consumption through a standard formula	Not Installed
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	
Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Start of trials
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Start of trials
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Start of trials
Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	04/2015

Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	04/2015
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	04/2015
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	04/2015
Wind speed	m/sec	30 sec samples are averaged to 5 min sampling periods	04/2015
Wind direction	Direction	30 sec samples are averaged to 5 min sampling periods	04/2015
Rain gauge	Mm	30 sec samples are averaged to 5 min sampling periods	04/2015
Radiation	μSv/h	30 sec samples are averaged to 5 min sampling periods	Not Installed

Primary School, Ligia, Lefkada

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh	30 sec samples are taken and then added to send in 5 min periods	06/2015
Current	Ampere	30 sec samples are averaged to 5 min sampling periods	06/2015
CO2 emissions	G	Produced indirectly by energy consumption through a standard formula	06/2015
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	

Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Start of trials
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Start of trials
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Start of trials
Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	11/2014
Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	11/2014
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	11/2014
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	11/2014
Wind speed	m/sec	30 sec samples are averaged to 5 min sampling periods	11/2014
Wind direction	Direction	30 sec samples are averaged to 5 min sampling periods	11/2014
Rain gauge	Mm	30 sec samples are averaged to 5 min sampling periods	11/2014
Radiation	μSv/h	30 sec samples are averaged to 5 min sampling periods	11/2014

Primary School, Megisti, Kastelorizo

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh	30 sec samples are taken and then added to send in 5 min periods	08/2015
Current	Ampere	30 sec samples are averaged to 5 min sampling periods	08/2015
CO2 emissions	G	Produced indirectly by energy consumption through a standard formula	08/2015
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	
Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Start of trials
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Start of trials
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Start of trials
Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	12/2014

Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	12/2014
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	12/2014
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	12/2014
Wind speed	m/sec	30 sec samples are averaged to 5 min sampling periods	12/2014
Wind direction	Direction	30 sec samples are averaged to 5 min sampling periods	12/2014
Rain gauge	Mm	30 sec samples are averaged to 5 min sampling periods	12/2014
Radiation	μSv/h	30 sec samples are averaged to 5 min sampling periods	12/2014

55 th Primary School Athens

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh	30 sec samples are taken and then added to send in 5 min periods	03/2015
Current	Ampere	30 sec samples are averaged to 5 min sampling periods	03/2015
CO2 emissions	G	Produced indirectly by energy consumption through a standard formula	03/2015
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	

Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Start of trials
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Start of trials
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Start of trials
Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Not Installed
Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	Not Installed
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Not Installed
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Not Installed
Wind speed	m/sec	30 sec samples are averaged to 5 min sampling periods	03/2015
Wind direction	Direction	30 sec samples are averaged to 5 min sampling periods	03/2015
Rain gauge	Mm	30 sec samples are averaged to 5 min sampling periods	03/2015
Radiation	μSv/h	30 sec samples are averaged to 5 min sampling periods	Not Installed

1 st Gymnasium, Nea Philadelphia, Attica

Input Name	Type of value	Sampling rate	Availability from
Power consumption (1 floor measure)	kWh	30 sec samples are taken and then added to send in 5 min periods	12/2014
Current (1 floor measure)	Ampere	30 sec samples are averaged to 5 min sampling periods	12/2014
CO2 emissions (1 floor measure)	G	Produced indirectly by energy consumption through a standard formula	12/2014
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	
Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Start of trials
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Start of trials
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Start of trials
Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	02/2015

Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	02/2015
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	02/2015
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	02/2015
Wind speed	m/sec	30 sec samples are averaged to 5 min sampling periods	12/2014
Wind direction	Direction	30 sec samples are averaged to 5 min sampling periods	12/2014
Rain gauge	Mm	30 sec samples are averaged to 5 min sampling periods	12/2014
Radiation	μSv/h	30 sec samples are averaged to 5 min sampling periods	02/2015

1st Gymnasium, Rafina, Attica

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh	30 sec samples are taken and then added to send in 5 min periods	Not Installed
Current	Ampere	30 sec samples are averaged to 5 min sampling periods	Not Installed
CO2 emissions	G	Produced indirectly by energy consumption through a standard formula	Not Installed
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	

Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Not Installed
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Not Installed
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Not Installed
Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	02/2015
Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	2/2015
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	02/2015
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	02/2015
Wind speed	m/sec	30 sec samples are averaged to 5 min sampling periods	Not Installed
Wind direction	Direction	30 sec samples are averaged to 5 min sampling periods	Not Installed
Rain gauge	Mm	30 sec samples are averaged to 5 min sampling periods	Not Installed
Radiation	μSv/h	30 sec samples are averaged to 5 min sampling periods	02/2015

27th Primary School, Piraeus

Input Name	Type of value	Sampling rate	Availability from
Power consumption	kWh	30 sec samples are taken and then added to send in 5 min periods	Not Installed
Current	Ampere	30 sec samples are averaged to 5 min sampling periods	Not Installed
CO2 emissions	G	Produced indirectly by energy consumption through a standard formula	Not Installed
Heating energy consumption	Joule, kWh, petrol litres, … (depending on the infrastructure installed)	Currently we have manual records of energy bills. This will probably change in the near future – we need to work out the way to do that	
Temperature indoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	Start of trials
Humidity indoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	Start of trials
Motion indoor	Level of motion	30 sec or whenever an event is detected	Start of trials
Noise indoor	dB	30 sec samples are averaged to 5 min sampling periods	Not Installed
Light indoor	Lux	30 sec samples are averaged to 5 min sampling periods	Not Installed
Methane and CO - detection indoor	Ppm	30 sec samples are averaged to 5 min sampling periods	Not Installed
Various gases - concentrations outdoor	Ppm	30 sec samples are averaged to 5 min sampling periods	12/2014

Atmospheric pressure outdoor	kPa	30 sec samples are averaged to 5 min sampling periods	12/2014
Temperature outdoor	Degrees Celsius	30 sec samples are averaged to 5 min sampling periods	12/2014
Humidity outdoor	% of humidity	30 sec samples are averaged to 5 min sampling periods	12/2014
Wind speed	m/sec	30 sec samples are averaged to 5 min sampling periods	Not Installed
Wind direction	Direction	30 sec samples are averaged to 5 min sampling periods	Not Installed
Rain gauge	Mm	30 sec samples are averaged to 5 min sampling periods	Not Installed
Radiation	μSv/h	30 sec samples are averaged to 5 min sampling periods	12/2014

Annex II: Overview of the Greek Educational System and details about schools participating in GAIA

The education in Greece is obligatory for all children from 6 up to 15 years old. It includes the Primary and (Basic) Secondary education. The duration of study in Primary education is 6 years (starting from 6 years old child). In parallel with the common primary schools, there are All-Day schools which have expanded working hours and enriched curriculum. The basic secondary education has 3 years duration and the post-obligatory secondary education is divided in two types of schools (General High Schools, Vocational High Schools). The duration of attendance in both types is 3 years. Moreover, there are many subcategories of these schools both in Primary and Secondary education depending on the students (e.g. students with special needs, minorities, etc.) or the school expertise (e.g., musical schools, etc.).

Primary Education

The primary education is provided in the Primary Schools (public and private). The attendance and the books are free. Primary schools belong in the obligatory education and intent to the versatile, harmonic and balanced intellectual and physical students' development. The duration of studies in primary school is 6 years as mentioned above from the age of 6 up to 12. There are many categories of primary schools too. Students who graduate from primary continue their mandatory studies in junior high school (obligatory secondary education).

In GAIA project the 5 out of 11 schools are primary schools. See below the list of the GAIA primary schools:

1. 27th Primary School of Piraeus.
2. 54th Primary School of Patras.
3. 55th Primary School of Athens.
4. Primary School of Lygias Leukada.
5. Primary School of Megisti Kastelorizo.

According to the data for the school year 2015-2016:

27th Primary School of Piraeus			
Class	Classroom	Number of student	Number of students per class
A	A1	22	44
	A2	22	
B	B1	21	41
	B2	20	
C	C1	20	41
	C2	21	

D	D1	14	31
	D2	17	
E	E1	19	38
	E2	19	
ST	ST1	21	43
	ST2	22	
TOTAL	12	238	238

54th Primary School of Patras			
Class	Classroom	Number of student	Number of students per class
A	A1	14	27
	A2	13	
B	B1	21	43
	B2	22	
C	C1	22	22
D	D1	14	28
	D2	14	
E	E1	12	25
	E2	13	
ST	ST1	20	20
TOTAL	10	165	165

55th Primary School of Athens			
Class	Classroom	Number of student	Number of students per class
A	A1	20	20
B	B1	16	30
	B2	14	
C	C1	18	18
D	D1	20	20
E	E1	21	21
ST	ST1	14	28
	ST2	14	
TOTAL	8	137	137

Primary School of Lygia (Leukada)			
Class	Classroom	Number of student	Number of students per class
A	A1	24	24
B	B1	20	20
C	C1	15	15
D	D1	23	23
E	E1	14	14
ST	ST1	21	21
TOTAL	6	117	117

Primary School of Megisti (Kastelorizo)			
Class	Classroom	Number of student	Number of students per class
A	A1	4	4
B	B1	1	1
C	C1	3	3
D	D1	4	4
E	E1	1	1
ST	ST1	5	5
TOTAL	6	18	18

The courses per class are the following:

Courses in Primary Education					
A	B	C	D	E	ST
Language	Language	Language	Language	Language	Language
Art	Art	Art	Art	Art	Art
Flexible Zone: Experiential Actions	Flexible Zone: Experiential Actions	Flexible Zone: Experiential Actions	Flexible Zone: Experiential Actions	Flexible Zone: Experiential Actions	Flexible Zone: Experiential Actions
Flexible Zone: Health Education	Flexible Zone: Eating Habits	Flexible Zone: Traffic Education	Flexible Zone: Environmental Education	Social and Political Education	Social and Political Education
Theater Education	Theater Education	Theater Education	Theater Education	Theater Education	Theater Education
Math	Math	Math	Math	Math	Math
Environmental Studies	Environmental Studies	Environmental Studies	Environmental Studies	Physics	Physics
Informatics and ICT	Informatics and ICT	Informatics and ICT	Informatics and ICT	Informatics and ICT	Informatics and ICT
Reading	Reading	Reading	Reading	Reading	Reading
Physical Education	Physical Education	Physical Education	Physical Education	Physical Education	Physical Education
Dance	Dance	Dance	Dance	Geography	Geography
	Music	Music	Music	Music	Music
		History	History	History	History
		Religious	Religious	Religious	Religious

Secondary Education

The Secondary Education in Greece is provided in two stages: the obligatory secondary education and the post-obligatory (upper) secondary education.

The obligatory Secondary Education is provided through the junior high schools. Its duration is 3 years and covers the ages between 12 up to 15. The provided education aims at the promotion of the students' versatile development based on their available skills and the demands that they will face in their life. The assessment in the Junior High School is a combination of the daily students' participation in the classroom and the results of the tasks/ mini exams/ final exams at the end of the school year. The graduated students are able to continue their studies on High School (upper Secondary Education).

Obligatory Secondary Education

In GAIA project 5 out of 12 schools are junior high schools. See below the list of the GAIA junior high schools:

1. 1st Junior High School of N. Philadelphia
2. 1st Junior High School of Rafina
3. 8th Junior High School of Patras
4. Junior High School of Pentavrissos
5. Model Experimental Junior High School of Patras

According to the data for the school year 2015-2016:

1st Junior High School of N. Philadelphia			
Class	Classroom	Number of student	Number of students per class
A	A1	24	73
	A2	24	
	A3	25	
B	B1	20	88
	B2	22	
	B3	24	
	B4	22	
C	C1	22	90
	C2	22	
	C3	23	
	C4	23	
TOTAL	11	251	251

1st Junior High School of Rafina			
Class	Classroom	Number of student	Number of students per class
A	A1	26	130
	A2	26	
	A3	26	
	A4	26	
	A5	26	

	A1 project	19	
	A2 project	18	
	A3 project	19	
	A4 project	18	
	A5 project	18	
	A6 project	19	
	A7 project	19	
B	B1	26	137
	B2	28	
	B3	27	
	B4	27	
	B5	29	
	B1 project	20	
	B2 project	20	
	B3 project	20	
	B4 project	21	
	B5 project	19	
	B6 project	18	
	B7 project	19	
C	C1	23	109
	C2	22	
	C3	21	
	C4	22	
	C5	21	
	C1 project	18	
	C1 project	18	
	C1 project	18	
	C1 project	18	
	C1 project	19	
	C1 project	18	
TOTAL	15	376 (without highlighted)	376

8th Junior High School of Patras			
Class	Classroom	Number of student	Number of students per class
A	A1/project	20/20	85/70
	A2/project	20/16	
	A3/project	21/18	
	A4/project	24/16	
B	B1/project	20/15	58/58
	B2/project	20/16	
	B3/project	18/14	
	projectB4	/13	
C	C1/project	17/17	56/56
	C2/project	19/19	

	C3/project	20/20	
TOTAL	10/11	199/184	199/184

Junior High School of Pentavrissos			
Class	Classroom	Number of student	Number of students per class
A	A1/project	11/11	11/11
B	B1/project	15/15	15/15
C	C1/project	18/18	18/18
TOTAL	3	44/44	44/44

Model Experimental Junior High School of Patras			
Class	Classroom	Number of student	Number of students per class
A	A1	30	60
	A2	30	
B	B1	30	60
	B2	30	
C	C1	30	60
	C2	30	
TOTAL	6	180	180

The courses per class are the following:

Courses in Obligatory Secondary Education		
A	B	C
Ancient Greek (translation)	Ancient Greek (translation)	Ancient Greek (translation)
Ancient Greek Language	Ancient Greek Language	Ancient Greek Language
Biology	Biology	Biology
Geography	Geography	Social Political Education
Language Teaching	Language Teaching	Language Teaching
Religious	Religious	Religious
History	History	History
Art	Art	Art
Math	Math	Math
Music	Music	Music
Literature	Literature	Literature
Household economy	Household economy	Chemistry
Informatics	Informatics	Informatics
Technology	Technology	Technology
Physics	Physics	Physics
Physical Education / Working out	Physical Education/ Working out	Physical Education/ Working out
Experiential Actions – Complex Creative Works - Project	Experiential Actions – Complex Creative Works - Project	Experiential Actions – Complex Creative Works - Project

	Chemistry	

Upper Secondary Education

The upper Secondary Education in Greece lasts 3 years and the students are from 16-18 years old. There are two types of high school in Greece: General High School and Vocational School.
In GAIA, 1 Vocational High School participates, 2nd EPAL in Larissa. According to the data for the school year 2015-2016:

2nd EPAL of Larissa			
Class	Classroom	Number of student	Number of students per class
A	A1	18	57
	A2	20	
	A3	19	
	A1 TECH APP[24]	18	
	A2 TECH APP	20	
	A3 TECH APP	19	
	A1 Project	18	
	A2 Project	20	
	A3 Project	19	
B	B1	21	86
	B2	24	
	B3	21	
	B4	20	
	B1 ELECT. SYSTEMS[25]	15	
	B2 ELECT. SYSTEMS	13	
C	C1	17	69
	C2	16	
	C3	18	
	C4	18	
	C1 ELECT.SYSTEMS	12	
	C2 ELECT. SYSTEMS	12	
TOTAL	21	212 (without highlighted)	212

The courses per class are the following:

Courses in Upper Secondary Education (Vocational School)		
A	B	C
Research Project	Algebra	Algebra
Algebra	Geometry	Geometry
Geometry	Introduction in the Computer Science	Introduction in the Computer Science

[24] Technological Applications
[25] Technician Electrical Systems, Installations and Networks

Religious	Religious	Chemistry
History	Recent Greek Language	Recent Greek Language
Recent Greek Language	Recent Greek Literature	Recent Greek Literature
Recent Greek Literature	Physics	Physics
Policy Education (Economics, Political Institutions & Authorities Law and Sociology)	Physical Education/ Working out	Physical Education/ Working out
Physics	Chemistry	Automation Programmable Logic
Physical Education/ Working out	Electromechanical Automation Technology	Electrotechnics and Electrical Machines Laboratory
Chemistry	Electrical Installations I	Electrical Installations II
Electronics and Electrical Engineering Principles	Direct Current Circuits - Electromagnetism	
Engineering principles	Design of Electrical Installations	
IT Applications		
School Vocational Guidance Work-Environment-Safety and Health		
Technical Design		

Projects/Interventions

The selected schools have already participated in a project of smaller scale aiming at the

- reduction of energy consumption,
- sustainability,
- change of students' attitude towards environment

However, some of the participating schools have been involved in more projects/interventions (see the table below):

School	Title of Intervention	Year	Comments
55th Primary School of Athens	"Tales with garbage"	2011-2012	
	Approaching the topic of diversity through the tale "Trigonopsaroulis"	2011-2012	
	Manage waste of-school adopted the proper recycling behavior	2011-2012	
	Athens, our city	2012-2013	
	Young journalists for the environment	2012-2013	
	Routes in old and and new Athens	2012-2013	
	Sea	2012-2013	
	Animals our friends	2012-2013	

	We and Plants	2012-2013	
	Endangered species (wolf-bear-turtle-marine mammals)	2012-2013	
	Landmarks of our region	2012-2013	
	Exploring the environmental issues	2012-2013	
	Games in the city and in the country	2012-2013	
	Working for a school of respect diversity and human rights	2012-2013	
	Feelings	2013-2013	
	Neighborhood	2013-2014	
	Mythology-Animals	2013-2014	
	Cultural Routes - our school – Panagiotis Kiriakos	2013-2014	
	Traditional music and songs	2013-2014	
	Traditional games in the yard	2013-2014	
	Diet	2013-2014	
	Exploring the word playing	2013-2014	
	Green Mindset	2013-2014	• Use of sensors • Application of educational scenarios
	All equal, all different	2014-2015	
	We and our diet	2014-2015	
	Healthy diet and environment	2014-2015	
	The dietary habits of Greeks in sites, municipalities. Health and exercise	2015-2016	
	Animals	2015-2016	
	Waste management. Become active citizen	2015-2016	
	Sea: become active citizens for rescue of it	2015-2016	
	The sea in poetry-literature-music	2015-2016	
Model Experimental	CRITON	2012-2014	• http://www.criton.eu/

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Junior High School of Patras			• LLP/KA3 • Piloting the Criton Platform
	GreenMindset	2013-2014	• http://greenmindset.cti.gr/ • use of sensors in the school building • Application of educational scenarios • Publication in conference
	E-STEP	2013-2015	• http://estep-project.eu/ • LLP/Comenius • Action plans and activities for parental engagement • Use of ICT • Publication in conference
	Learners' and Personnel's mobility	2014-2016	• Erasmus+/KA1 • 2014-1-EL01-KA101-000542
Junior High School of Pentavrissos	GreenMindset	2013-2014	• http://greenmindset.cti.gr/ • use of sensors in the school building • Application of educational scenarios
54^{th} Primary School of Patras	GreenMindset	2013-2014	• http://greenmindset.cti.gr/ • use of sensors in the school building • Application of educational scenarios • Participation in one day workshop
Primary School of Megistis (Kastellorizo)	GreenMindset	2013-2014	• http://greenmindset.cti.gr/ • use of sensors in the school building

Annex III – Letter from Province of Prato

PROVINCIA DI PRATO
Are Ambiente e Infrastrutture
Servizio Edilizia Pubblica
Via B. Cairoli, 25 - 59100 Prato
Tel. 0574 5341 Fax 0574 534281

Alla cortese attenzione di

Dott.ssa Federica Paganelli, PhD
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Research Unit at the University of Florence
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Oggetto: nota su funzionamento impianto di riscaldamento dell'Ist. Gramsci.

L'impianto di riscaldamento dell'Istituto Gramsci è costituito da un circuito del tipo a vaso chiuso con le seguenti caratteristiche:
Centrale termica composta da tre caldaie aventi la seguente potenza:
_ GC1: Pot. al focolare: 516kW – Potenza termica utile: 465kW
_ GC2: Pot. al focolare: 516kW – Potenza termica utile: 465kW
_ GC3: Pot. al focolare: 568kW – Potenza termica utile: 470kW

Le caldaie sono poste in parallelo e vengono inserite in cascata con tre valvole a farfalla ON/OFF poste sulle tubazioni di mandata. Su ogni caldaia sono inserite pompe singole anticondensa.

Nell'adiacente sottocentrale:
Tre circuiti con pompe gemellari e tre con doppia pompa che spingono nei circuiti e da qui nelle caldaie. I circuiti alimentati sono i seguenti:
_ Circuito aule
_ Circuito uffici
_ Circuito laboratori
_ Circuito aerotermi palestra
_ Circuito radiatori palestra
_ Circuito boiler
Quattro dei suddetti circuiti sono termoregolati con valvole a tre vie, gli altri in presa diretta dal circuito primario.

Nei locali della scuola non sono presenti sistemi di termoregolazione interna pertanto il personale non può impostare la temperatura degli ambienti. Come si evince dalle caratteristiche sopra riportate la temperatura dell'acqua può essere regolata solo in centrale e quindi da personale autorizzato.

Il funzionario tecnico
Arch. Francesca Toci

PROVINCIA DI PRATO

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