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Abstract:

This deliverable presents the Greek IPv6 pilot and how the IPv6 technology takes on the role of a "green" enabler for the school communities. The developed smart metering infrastructure is being described along with related results.

Keywords:

IPv6, Governments, IPv6-enabled services, energy awareness, energy smart metering, Greek School Network (GSN), public sector, roadshow in schools, IPv6 enabled weather station, IPv6 enabled environmental sensors

Revision History

The following table describes the main changes done in this document since its creation.

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Disclaimer

Executive Summary

The goal of the Greek IPv6 pilot is to make students and educators aware of the energy characteristics of their school buildings and the energy consumption consequences of their behaviours, utilizing the benefits of the IPv6 protocol. Energy related information from participating schools is recorded using smart meters, it is transferred through IPv6-enabled networks, it is stored and processed using scalable cloud computing system and it is disseminated to the users through a web portal.

To achieve these goals, the Greek IPv6 pilot has exploited and augmented the existing IPv6 infrastructure of the Greek School Network (GSN), extended the IPv4-only infrastructure of the application domain (smart meters and cloud-based application) so that it becomes IPv6-enabled, and integrated the two through a pilot deployment of smart meters in 50 schools. The meters measure and record in real time the energy consumption of the participating schools. The measurements are analysed and displayed to the students through a portal and are used in order to raise energy-awareness and motivate behavioural changes in the education community, as well as to reduce the actual carbon footprint and the electricity cost of the participating schools.

Together with the smart metering infrastructure, the Greek pilot is extended with a number of meteorological stations and energy sensors, utilizing the IPv6 enabled networks. These stations and sensors are installed in schools in order to measure environmental conditions such as wind speed, direction, temperature, barometric pressure, humidity, temperature, light intensity and correlate them with the energy consumption of the schools. These devices have become IPv6-enabled for the Greek pilot's needs. In this way the energy consumption in the particular school is correlated with the outdoor weather conditions.

Notation, Abbreviations and Acronyms

6LoWPAN	IPv6 over Low Power Wireless Personal Area Networks
AMI	Advanced Metering Infrastructure
AMR	Advanced Metering Reading
CMD	Consumption Metering Device
CT	Current Transformer
EIS	Energy Information System
EUI	Energy Utilization Index
GSN	Greek School Network
HAN	Home Area Network
HES	Head End Sustem
ICT	Information & Communication Technology
IDE	Intercompany Data Exchange
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
KPI	Key Performance Indicator
MDM	Meter Data Management
NAN	Neighborhood Area Network
NAT	Network Address Translation
p2p	Point to point
QoS	Quality of Service
WAN	Wide Area Network

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1. INTRODUCTION

Reducing energy consumption and CO2 emissions in order to address climate changes requires behavioral changes by the citizens, who will have to adopt more environmentally friendly and energy-saving practices (Figure 1). As buildings account for about 40% of total energy consumption and emissions, improving the energy behavior of their occupants is a key factor for achieving the desired climate and energy objectives. A first, but necessary and important, step in this direction is raising the energy awareness of the buildings' occupants by providing them immediate feedback on the energy implications of their actions (e.g., when turning on the lights or some equipment), in the same way that the speed measurement equipment present in a car gives the driver immediate feedback on the implications of his actions while driving (e.g., when stepping on the gas pedal).

Figure 1: Energy Efficiency.

Energy awareness is even more important when it refers to pupils, as behavioral changes in them are more long lasting, easier to accomplish, and have larger cumulative impact. It is evident that energy monitoring systems are important for energy awareness. Studies have shown that by simply monitoring one's energy consumption, the savings on the electric bills can be 5 to 15 percent.

Today, the many recent advances in energy metering technology and the design of more energy efficient equipment have only partially been adopted in public and residential buildings. One of the reasons limiting their adoption is that their internetworking is often difficult to implement due to the lack of public IPv4 addresses (and the use of NAT technologies, which complicate things) and the difficulties encountered in configuring the network of devices. IPv6 [4] is a technology that promises to meet the needs of the huge Internet growth (and the "internet of things" vision), eliminating some of the restrictions caused by IPv4 technology. Thus, the IPv6 technology takes the role of a "green" enabler, and introduces various additional benefits such as security, effective access control, reduced management and maintenance effort.

Figure 2: GEN6 Greek pilot "Energy Efficiency in School Networks with IPv6".

"Energy Efficiency in School Networks with IPv6" is the Greek pilot (Figure 2) implemented in the GEN6 project. Through the implementation of the Greek IPv6 pilot, the deployed infrastructure is extended and many problems that are related with the use of IPv4 for access to the smart energy meters are outreached. This extension provides a signal to European stakeholders that IPv6 technology can indeed be a "green" enabler.

In particular, the pilot has to do with the development, the installation and operation of a system for gathering energy consumption data from Greek schools over an IPv6 network. The system consists of a set of IPv6 enabled smart meters, an energy information system, a web platform with social engagement tools for the pupils of the schools, and an IPv6 enabled network that interconnects them (Figure 3). Currently, 50 Greek schools energy consumption is monitored in real-time over the IPv6-enabled network. In parallel, a number of dissemination actions are being kicked off aiming at increasing energy awareness and motivating students to change their behavior towards an energy-efficient and environmentally-friendly direction. IPv6 awareness will be also increased based on the proper dissemination actions (targeting mainly the information technology teachers and the research community), presenting the selected technologies for the implementation of the pilot.

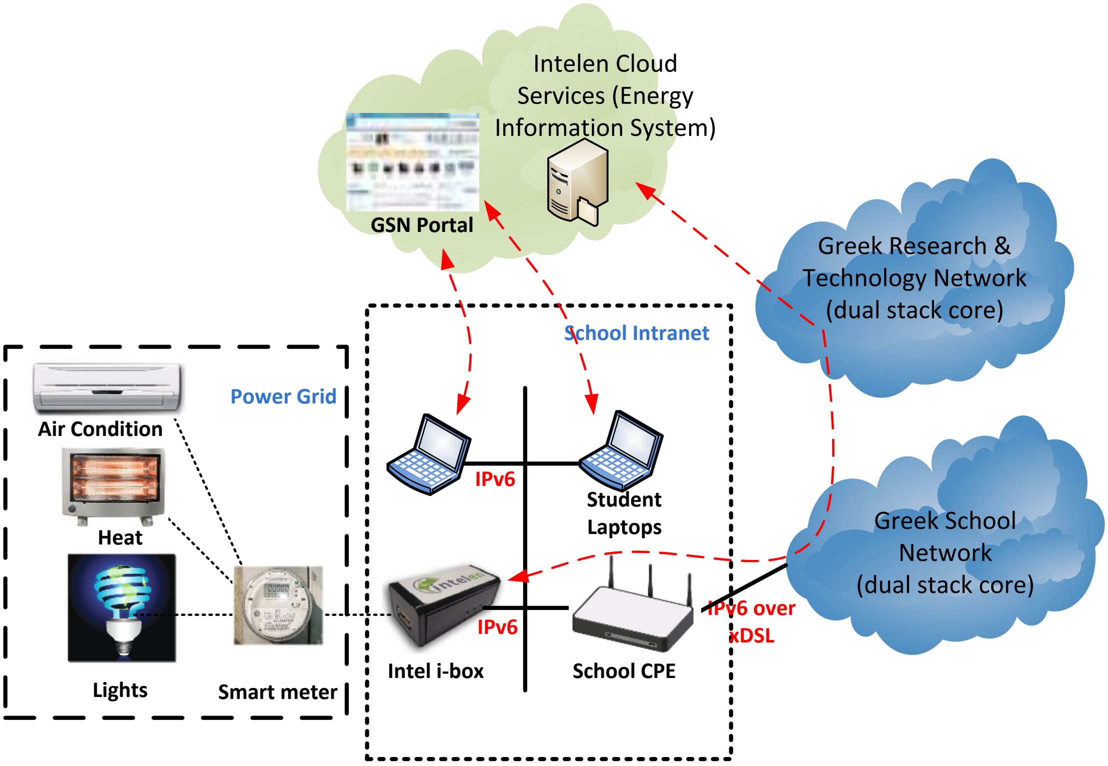


Figure 3: GEN6 Greek pilot system.

The rest of this deliverable is organized as follows. In Section 2 we discuss on the installation of energy monitoring and analysis systems in public education buildings. In Section 3 we present Greek pilot's smart metering infrastructure. The characteristics of the IPv6 networks configured and utilized for the pilot are presented in Section 4. Section 5 describes the web portal that presents real-time energy data from the Greek pilot's schools. In Section 6 we discuss how the pilot's results are presented to the students. The collected data analysis is presented in Section 7. Finally, in Section 8 we conclude the paper.

2. PUBLIC EDUCATION BUILDING

One of the reasons we focused our efforts on public educational buildings as opposed to general public building, is that in the former case the buildings' architecture and topology are more suitable for running energy efficiency case studies. Usually educational buildings are more complex and have a more distributed architecture with many individual facilities inside the campus (classroom space, library/resource space, indoor and external sports facilities), so that the energy consumed is much more than that of common public building. Moreover, the occupants of the educational buildings are students, whose energy consumption behavior is easier to be modified when compared to that of adults. Indeed, the goal of education is behavioral change, and the use of ICT in the formulation of effective teaching methods that tap into the mechanisms of behavioral change can be very efficient. In fact, some of the behavioral change theories, like the Social Learning Theory and Theory of Planned Behavior, were developed as attempts to improve behavior through education in schools.

In numbers, today there are around 3.600 secondary education units and 12.000 primary education units, hosting more than 800.000 students and 100.000 teachers [5] Public education buildings in Greece are distributed over the whole country, with varying student population sizes per building, varying floor area, and varying weather conditions. The mere energy consumption of a building is not a good measure of energy efficiency, as it has to be adjusted to account for these factors. One of the most objective KPI used to quantify energy efficiency in schools is the "Energy Utilization Index (EUI)" of a school which is measured in kwh/student. Using objective and easy to compare KPIs is important in our pilot for initiating an energy efficiency improvements "competition" among pupils of different schools, and the competition of course have to be fair to all participants.

Developing and deploying an energy monitoring and analysis system in all public education buildings is a huge task, considering the number of buildings and responsible personnel, the possible electrical and network peculiarities of each educational unit, and the huge amount of information that needs to be collected and analyzed. The advantages obtained by accomplishing this task are however also important, with the most obvious one be the energy savings and corresponding environmental benefits that are obtained, and the elimination of great costs that are spent annually to meet the schools' energy needs. The money savings can also be translated into the ability to invest in additional intervention actions for additional high performance facilities, hiring more teachers, and purchasing more textbooks and computers. Beyond these bottom line benefits, schools also can realize better overall student health and better serve as centers of community life.

3. SMART METERING INFRASTRUCTURE

3.1 Smart Energy Meters

3.1.1 Smart Energy Metering System Infrastructure

The energy measurements (in KWh) that are used in the Greek pilot are being acquired through an **Advanced Metering Infrastructure (AMI)**. An AMI system is a system that measures, collects and analyses energy usage, and communicates with metering devices such as electricity meters either on request or on a schedule. These systems include hardware, software, communications, consumer energy displays, controllers and Meter Data Management (MDM) Systems. AMI differs from traditional Automatic Meter Reading (AMR) in that it enables two-way communication with the meters. The following figure depicts the evolution of an AMI system through the years.

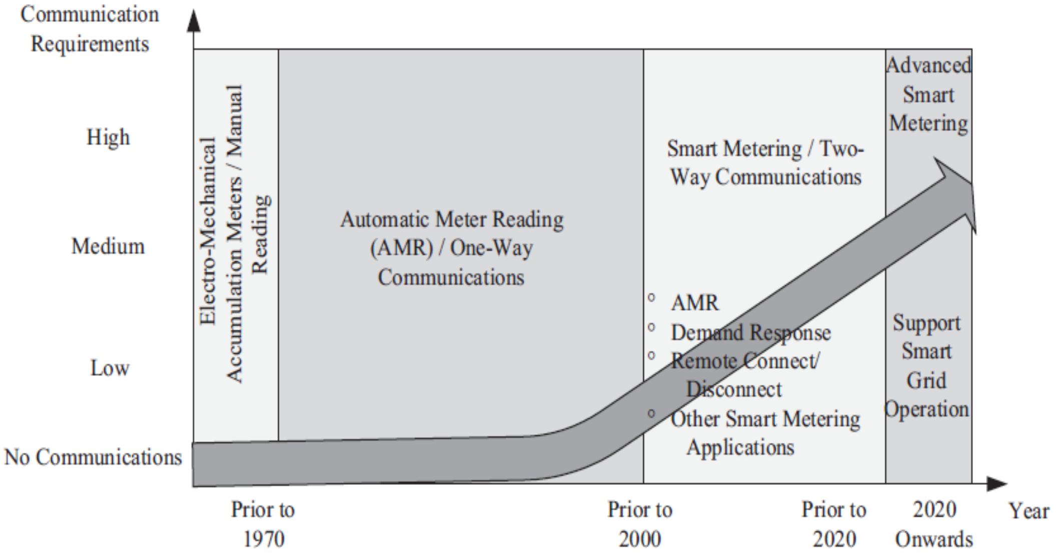


Figure 4: Evolution of an AMI system.

Key components in modern AMI architecture are the smart energy meters. The smart meters of an AMI system can send the measurements through various Sub Networks (HAN, NAN, WAN) and communication technologies (Ethernet, Wireless Ethernet, PLC,etc).

The smart meters, installed to each building's general switch, measure and push the energy consumption data through the network to an aggregation system, which analyzes the collected information and presents it in a user friendly manner, usually through a web interface. The proposed system utilizes Intelen's smart metering infrastructure consisting of a consumption metering device (abbreviated CMD) along with its CT's (current transformer), a transmitter and the so-called iBox (Figure 5). The iBox is a smart network device that acts as a data bridge between the power meter and the local building router. Both iBox and the GSN/GRNET local router can have IPv6 global address using stateless auto configuration method (prefix delegation).

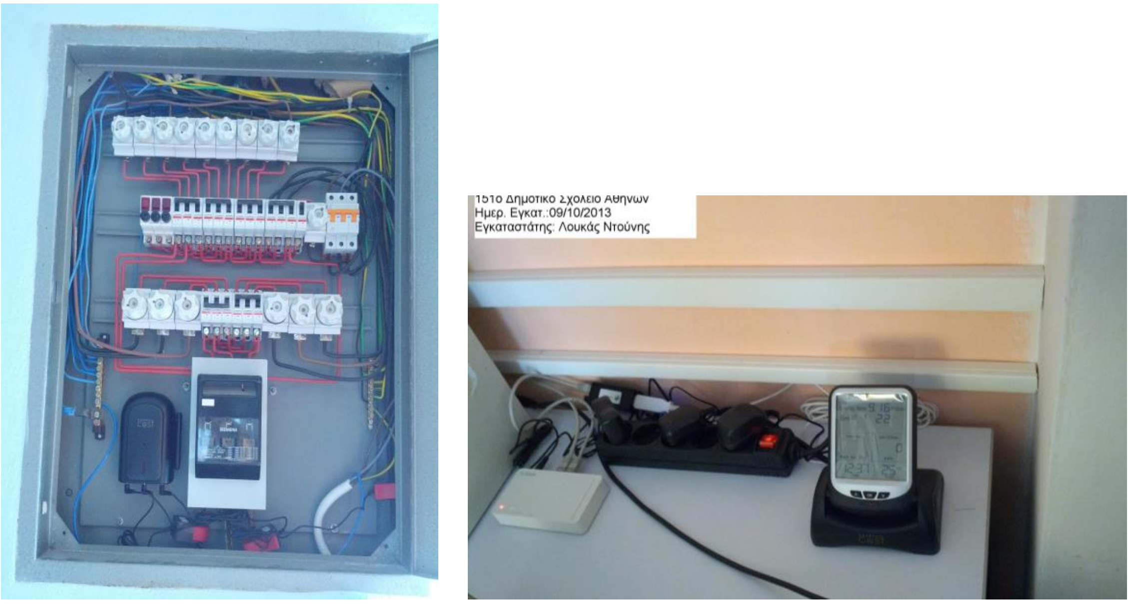


Figure 5: A school's installation: the consumption metering device installed in an electric panel and the iBox.

The installed power meters collect energy consumption data that are sent over the GSN/GRNET network aggregated to Intelen's Head-End System (HES) and then to Intelen's Meter Data Management (MDM). The MDM is responsible for data acquisition, storage and exposure to other applications through RESTful APIs. Furthermore, it is capable for a series of services, including energy analysis, and demand response (signal notification, manual and automated response, response analysis and quantification), and, also importantly, the remote management by authorized partners. Finally, the MDM feeds the interactive IPv6 web platform with distributed energy data management and stream analytics through the Intercompany Data Exchange (IDE) system, which exposes data through RESTful APIs. Intelen's MDM systems were extended in order to meet the envisioned system's requirements and is used from the project website in order to retrieve data from electrical energy meters. Energy consumption data from energy meters are being collected through the iBox with a sampling period of ~6 seconds.

They are sent every 15 minutes at Intelen's MDM System where further aggregation/analysis takes place in 24 hour intervals for infrastructure fault detection, application performance, storage and speed optimization. An overview of the data flow from a smart meter to Intelen's Intercompany Data Exchange System is summarized in the following figure:

Figure 6: Overview of the data flow of a smart meter to Intelen's IDE system.

The Meter Data Management - MDM - system comprises of:

- Specific middleware for data acquisition, data aggregation, data structuring and transformation, so as to feed all Functionalities and Services in a generic way.
- Functionalities and services for data validation, integration / storage, consolidation and access. Functionalities are internal modules to be accessed by higher layers and services. Services are web services offered to/accessible by client application either internal or external to the system. It is a matter of specific design according to the available computing infrastructure (centralized/grid based) how and where to embed these functionalities and services. Some of these will be hosted into dedicated servers; others (more fundamental ones) will be delivered as attachments to the middleware.
- Generic applications that can be realized in a modular way through the invocation/combination/ orchestration of functionalities and/or services. These applications are still generic but form the basis for those offered to clients, either through parameterization or through client specific instantiation.

The smart metering infrastructure is capable of offering a series of services, including the following:

- real-time or near real-time registration of electricity use,
- local and remote access to the meter (on demand),
- it performs basic calculations in order to translate the raw data that are collected by the specific consumption metering device (abbreviated CMD) to information that can be handled by centralized (cloud) infrastructure,
- it acts as memory storage (buffer) so that data are not lost in case of a network or other error, but are stored for transmission when network connectivity is re-established,
- it extracts the appropriate key performance indicators (KPIs) from the raw

data received by the CMD,

- it performs error handling concerning the CMD, the connectivity of the system,
- it receives instructions for extra KPIs from Intelen's Energy Information System (EIS), named Meter Data Management (MDM).

3.1.2 Smart Energy Metering System and IPv6

Intelen's smart meters are fully IPv6 enabled and can be assigned a global IPv6 address for their connection to the GSN/GRNET network. IPv6 is as a necessary technology for the reliable, efficient and scalable implementation of the proposed energy metering system. Even if the major force for the transition to IPv6 is related with the absence of public addresses in IPv4, there are several IPv6 protocol characteristics that facilitate the deployment of advanced networking services, especially in the sensor networking world, and were found to be particularly useful in our proposed system. In particular, the IPv6 technology takes the role of a "green" enabler, and raises various benefits such as:

- Reduced management and maintenance effort due to end-to-end communication and management of the smart sensors. End-to-end communication scheme facilitates the proper management/configuration of the devices, the installation of software updates and the monitoring of the infrastructure.
- Better policy schemes over heterogeneous networks are made possible; for example, nodes of various on-site communications systems can be provided with unique public IPv6 addresses to avoid conflicting use of private IPv4 addressing; centralized communication initiation and management can be provided and services can be directly connected as all nodes across different on-site networks can have globally unique public IP addresses.
- Advanced security features to the schools intranets are enabled; for example, transparent end-to-end security without complex NAT traversal mechanisms, fine-grained security policies and filtering rules can be applied based on unique end system addressing scheme.
- Advanced auto-configuration features (e.g., IPv6 stateless auto-configuration, bootstraping of the infrastructure) and ad-hoc routing are made possible.
- Quality of Service (QoS) can be supported in local and global network environment.
- Multicast transmission features are enabled.

Facilities are provided to deploy new services without NAT-related limitations and requirements for application gateway implementation (e.g., exchange of sensor data, services for situation monitoring, etc.).

3.1.3 Configuration and Updates

In case of a communication problem between the smart meters and Intelen's MDM (e.g. network malfunction at installation site, MDM malfunction, physical disaster etc) smart-meters store the measurements in their internal memory and send them to Intelen's MDM whenever they re-establish a connection with the MDM.

Exposing energy data through web services

Data is being exposed to the Greek pilot's web platform through Intelen's Intercompany Data Exchange (IDE) API. In particular, two RESTful API methods were implemented to expose electric energy and smart meter related data to the Greek pilot's web platform. The "energy_data" method exposes the measurements of a smart meter for a given time frame and interval, while the "meters" method exposes all installed meters and their measurements for a given date. API security is based on an HMAC encryption algorithm.

3.2 Environmental sensors

3.2.1 Environmental Sensors type

Except for the installation of the 50 smart energy meters, in 50 schools the Greek pilot's installation is extended with nine (9) sensors and one (1) meteorological station in order to provide the ability to measure –over IPv6- environmental conditions such as wind speed, direction, temperature, barometric pressure, humidity, temperature, light intensity and correlate them with the energy consumption of the schools.

3.2.2 Environmental Sensors & Cross boarder scenario

The configuration and commission of the nine environmental sensors is performed in collaboration with University of Murcia that hosts IPv6 enabled environmental sensors. Overall the main objectives of the Greek pilot extension are:

- the interconnection of IPv6 enabled sensors in different countries and the establishment of communication upon an IPv6 network,
- the extension of the Greek pilot with 6LowPAN sensors for measuring environmental parameters,
- the remote management of sensors in a cross border scenario from a centralized management point,

- the integration of other type of sensors in the existing infrastructure in the Greek pilot implementation and
- the exchange of knowledge and experience among the cooperating partners.

Towards this direction, IPv6 end-to-end connectivity will be established based on IPv6 enabled cross border networks and specifically the GEANT pan-European network, GRNET and RedIRIS national research and academic networks for Greece and Spain accordingly, the Greek School Network (GSN) and the network within the University of Murcia. End-to-end communication with the sensors can be realized since they are based on 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks) that allows IPv6 packets to be sent to and received from over IEEE 802.15.4 based networks.

The interconnection with the sensors and the access to the existing services provided from University of Murcia (e.g. remote monitoring and management services) constitutes the basement for the installation of similar sensors in Greek schools and the provision of unified services based on the collection of data in a centralized computing infrastructure. This setup constitutes a pilot for the realization of larger cross border scenarios in the future, with the installation of IPv6 enabled smart meters as well as environmental sensors in several schools across Europe.

University of Murcia's implementation is based on two components, a mote-sensor and an ethbridge gateway, which is responsible for converting 6LoWPAN packets to IPv6 packets. The motes communicate with the gateway over 6LoWPAN. University of Murcia's implementation provides two main data provisioning services that will both be integrated in the Greek pilot. "Request data sender" service is responsible to send aggregated sensor data to a specific server periodically. This service will be used to collect data from sensors over IPv6 in the centralized Greek pilot infrastructure. "Web Server" service provides an interface for direct data acquisition. This service will be integrated in Greek pilot's UI, enabling the user to connect directly to a sensor over IPv6 and view data in real time.

3.2.3 Configuration and Updates

Intelen's Head End System (H.E.S) was enhanced by implementing a RESTful API that enables data provision from 6LoWPAN sensors, while Intelen's MDM was upgraded to handle, store, and expose these measurements to other Intelen applications including Intelen IDE.

In order to establish a direct communication and be able to retrieve data from the Univercity of Murcia's 6LoWPAN sensor Intelen updated the internal LAN of relevant systems and internal services to work over IPv6.

4. IPv6 Network

In the following paragraphs the IPv6 implementation in the Greek School Network (GSN) is analysed pointing out some of the current issues regarding the mass deployment of IPv6 for the services that GSN is offering to its users. The backbone network of GSN is fully IPv6 enabled including IPv6 support on all the point to point (p2p) links of the primary and secondary nodes of GSN, while the peering with GSN's ISP (GRNET) is also IPv6 enabled. OSPFv3 has been also enabled as a routing protocol for IPv6 within the GSN. Thus, the backbone network of GSN is dual stack i.e. supports both IPv4 and IPv6. On the access network, IPv6 has been enabled also for the ADSL users (95% of the users of GSN). This has been achieved by enabling IPv6 on the LNS and on the radius profiles of each ADSL router connected to GSN. Regarding Security issues, GSN has been running as a network infrastructure for over a decade using IPv4 and thus has established strict security rules for the aforementioned traffic. Those rules have been expanded to also cover IPv6 traffic after it has been enabled in GSN.

4.1 Addressing

Since 2003, GSN has been delegated a /47 and one /48 IPv6 address spaces from GRNET, the LIR for the research networking infrastructures in the country. The current address space is not adequate to fulfill the future needs of the school networks and, thus, it will be fully revised in the near future.

The current IPv6 addressing schema has been provided by the GSN's NOC, as follows:

- 2001:db8::1300/47 assigned to access network
- 2001:db8::1302/48 assigned to backbone network

The first IPv6 segment has been split in two equal parts (/48) and the following assignment has been made:

IPv6 Block 2001:db8:1300::/47	Assigned Network	Start IP (prefix /128)	End IP (prefix /128)	/64 Subnets
Kindergartens	2001:db8::1300::/51	2001:db8::1300:0000::	2001:db8::1300:1FFF: FFFF:FFFF:FFFF:FFFF	8.192
Primary Schools	2001:db8::1300:2000::/51	2001:db8::1300:0000::	2001:db8::1300:3FFF: :FFFF:FFFF:FFFF:FFFF	8.192
Secondary Schools	2001:db8::1300:4000::/51	2001:db8::1300:4000::	2001:db8::1300:5FFF: :FFFF:FFFF:FFFF:FFFF	8.192
High Schools	2001:db8::1300:6000::/51	2001:db8::1300:6000::	2001:db8::1300:7FFF: :FFFF:FFFF:FFFF:FFFF	8.192
Technical Schools	2001:db8::1300:8000::/51	2001:db8::1300:8000::	2001:db8::1300:9FFF: :FFFF:FFFF:FFFF:FFFF	8.192
Directorates	2001:db8::1300:A000::/51	2001:db8::1300:8000::	2001:db8::1300:BFFF: :FFFF:FFFF:FFFF:FFFF	8.192
Various entities	2001:db8::1300:C000::/51	2001:db8:1300:C000::	2001:db8::1300:DFFF ::FFFF:FFFF:FFFF:FFFF	8.192
Unassigned	2001:db8:1300:E000::/51	2001:db8:1300:E000::	2001:db8:1300:FFFF: :FFFF:FFFF:FFFF:FFFF	8.192
Unassigned	2001: db8:1301:::/48	2001:db8:1301::	2001:db8:1301:FFFF: :FFFF:FFFF:FFFF:FFFF	65.536

Table 1: Addressing Plan.

According to the previous table, different address blocks are allocated to different school categories, e.g. primary schools, secondary schools, etc. Every school connected to the GSN is provided a /64 subnet to be used for its own internal LAN. By the time the address space was allocated to each school, this address space was considered adequate for future expansion. However, for management purposes, e.g. the support of multiple LANs per site, this address space has to be extended in the future. Note that address block 2001:db8:1301::/48 remains unassigned for future use.

4.2 Architecture / Topology

The logical architecture of the GSN, operated by CTI, is shown in Figure 7.

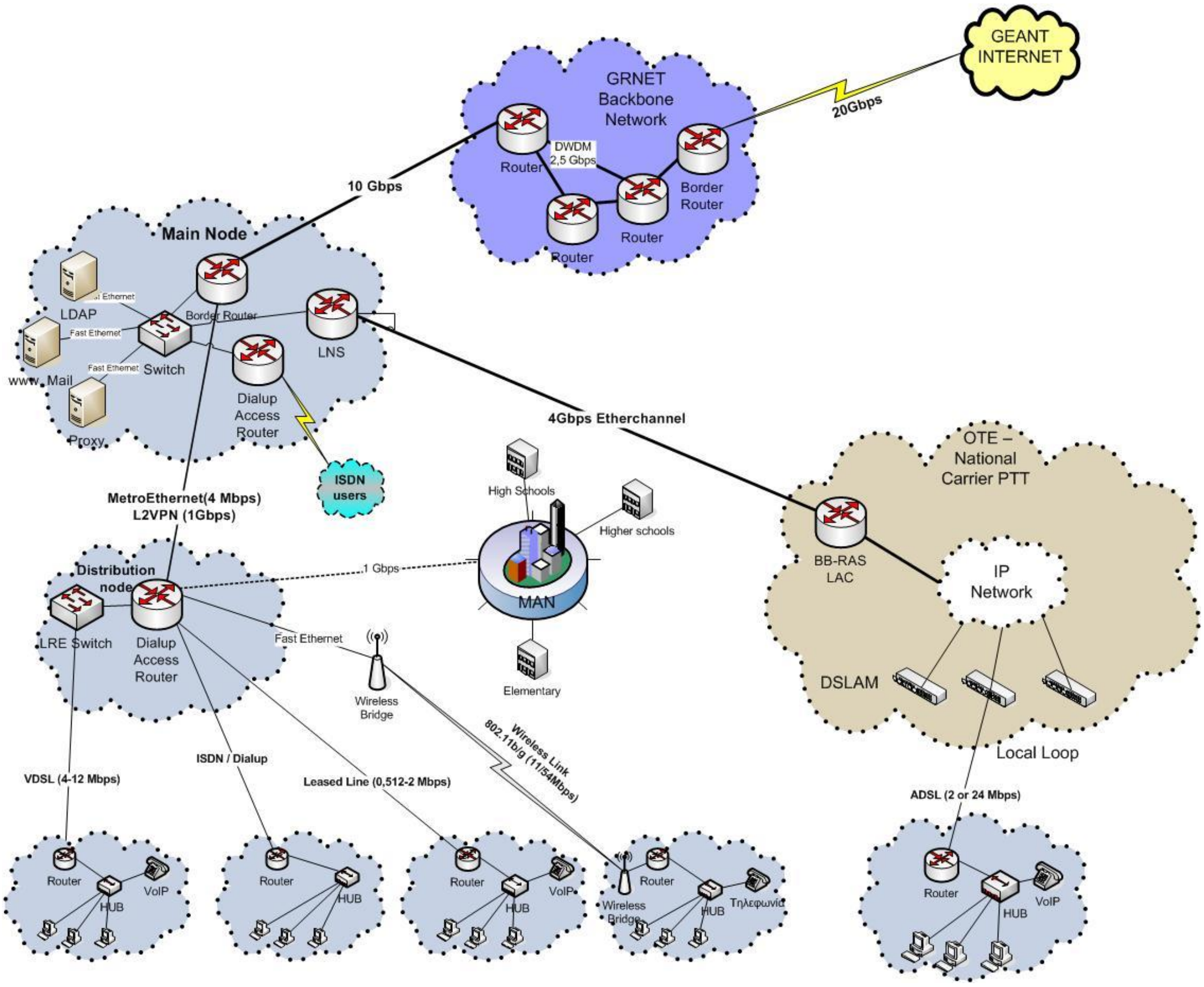


Figure 7: GSN Architecture.

The figure depicts the six different technologies that are used in order to interconnect schools into the GSN and, thus, to the Internet. Aggregation of traffic is done either to a prefectural node, called distribution node, or to the central LNS[1] farm using the national carrier IP infrastructure. The prefectural node forwards the traffic to the main node where also most of the core services of the network are hosted. Finally, GSN has a single 10Gbps connection to the Internet through GRNET backbone network. As already stated, for the cross-border services, end-to-end IPv6 connectivity is realised based on GRNET network's interconnection with the GEANT network that supports dual stack IPv4/IPv6 connectivity.

4.3 Equipment

The networking, computational and sensor networking equipment used in the pilot supports dual stack IPv4/IPv6. The equipment includes GSN and GRNET IPv6 enabled

[1] *L2TP Network Server*

routing and switching infrastructure, smart meters and meteorological stations with IPv6 and 6LoWPAN support as well as centralized IPv6 enabled servers for storage and processing purposes. A set of autoconfiguration and remote management IPv6 characteristics are exploited at the various sites of the infrastructure for reducing the overall complexity as well as the administration overhead.

4.4 IPv6 and the Greek Pilot

Since the networks supporting the Greek Pilot (GSN and GRNET) are IPv6 enabled by default, as a result no major related problems appeared during the Pilot's installation, configuration and operation. Additional permissions where given in order for Intelen's Meter Data Management (MDM) system to have direct network access to the energy meters (that have an IPv6 address), mainly for configuration and software updating purposes. Also, because the GSN and GRNET networks are used every day by thousands of students, teachers, professors and administrative personnel, care has been taken so as not to disrupt in any anyway their operation. Also, the software entities in the iBox and the MDM where extended in order to support IPv6.

5. Web Portal

An interactive IPv6 web platform: http://gen6.sch.gr (Figure 8) is in charge of monitoring the processed energy consumption data coming from Meter Data Management (MDM). Via a real-time intuitive interface, the school community is taught the correlation between the actions they undertake and the energy consumption/CO2 emissions of their schools, providing in this way significant motivation for behavioral changes. Moreover, the IPv6 web-based platform can become an educational and social engagement tool for teachers and students, stimulating discussions and enabling actions within schools in order to better understand complex energy consumption data, through their interactive display using animations, graphical statistics, historical data, comparative schools' energy data, average factor, best performing school competition, etc.

Figure 8: GEN6 Greek pilot's portal: gen6.sch.gr

The portal is based on joomla open-source content management system, while custom joomla modules have also been developed.

Of course gen6.sch.gr site is IPv6 ready:

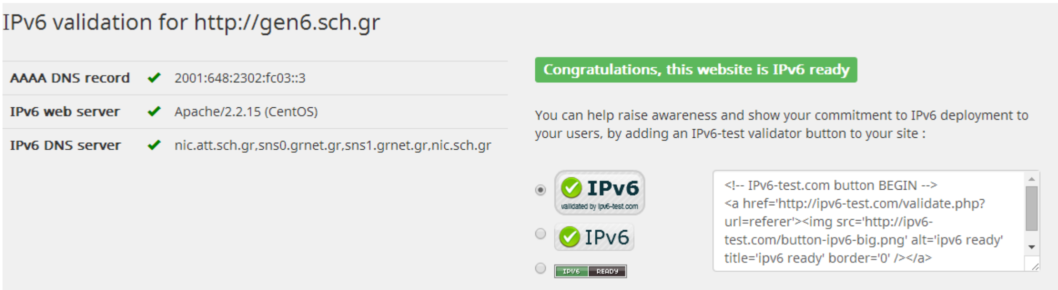


Figure 9: gen6.sch.gr site is IPv6 ready.

5.1 Structure

The map of the site is presented in Figure 10. The site includes education material in relation to energy and IPv6, news and information regarding the pilot and the project, along with the interactive pages with the real-time energy consumption data.

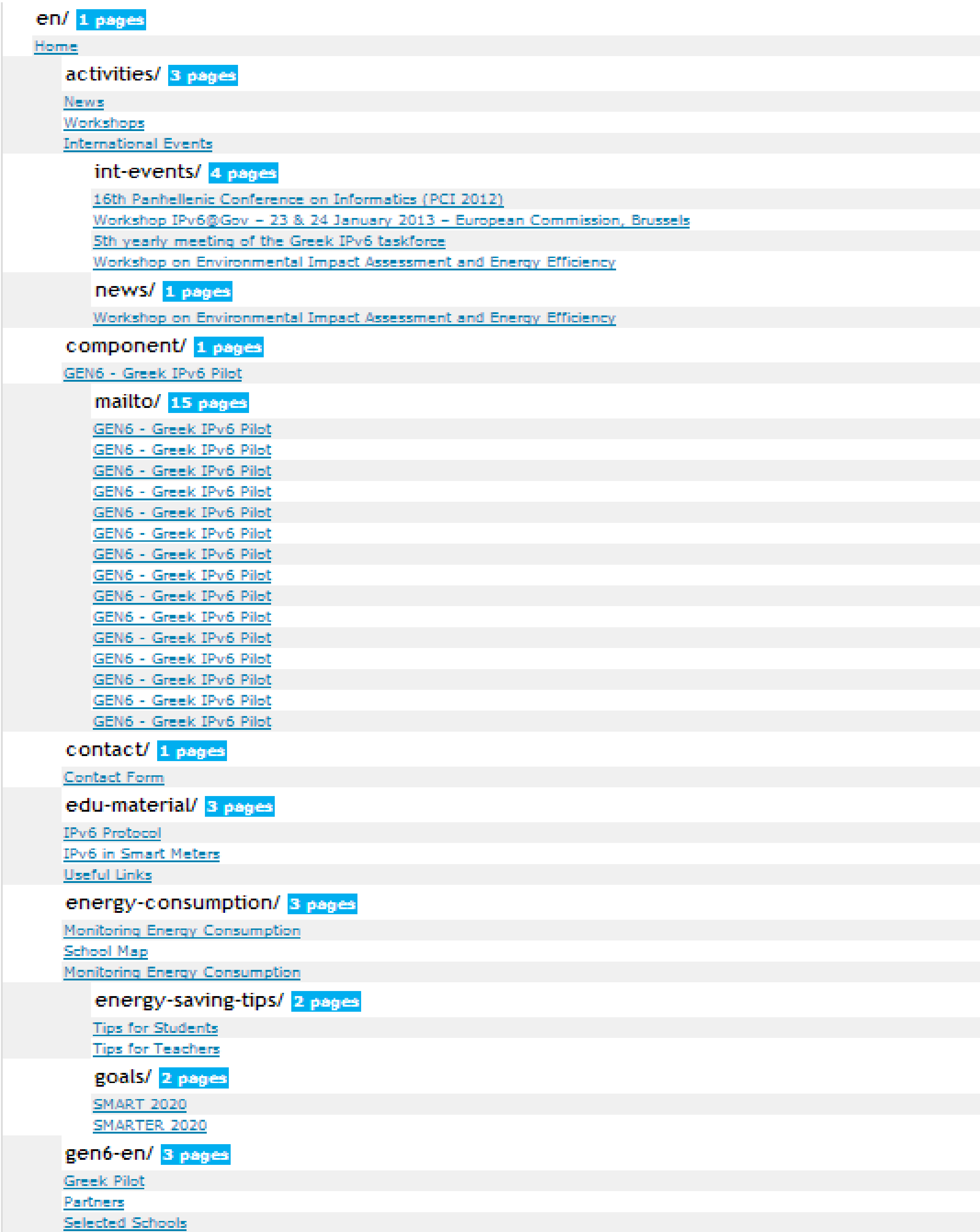


Figure 10: gen6.sch.gr site map.

5.2 Functionalities

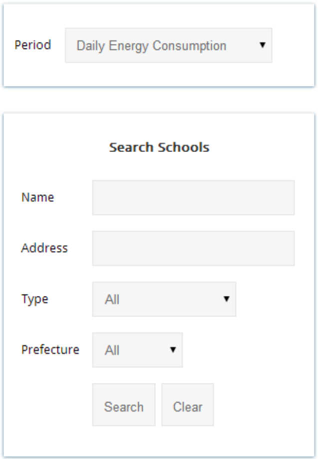
5.2.1 Key Performance Indicators – Schools Comparison

Through the portal the students can view key performance indicators of the energy efficiency of their school in comparison to other schools (Figure 11): energy consumption, energy saving, energy consumption accounting for the number of students of each school.

Figure 11: The real time energy consumption of schools.

5.2.2 Summary table and search

A summary of schools energy status is also available, while it is possible to search for particular schools based on their location and type (Figure 12).



Summary Table For Daily Energy Consumption

School Name	Number of Students	Energy Consumption/Student	Comparison to Previous Date Interval %	CO_2 Emissions
[GEN6] 24ο Γυμνάσιο Αθηνών	221	0	100.000	4.486
[GEN6] 7ο Δημοτικό Σχολείο Αιγάλεω	251	0	0.000	0.000
[GEN6] 14ο Δημοτικό Σχολείο Αχαρνών	252	0	0.000	0.000
[GEN6] 1ο Δημοτικό Σχολείο Βάρκιζας	216	0	0.000	0.000
[GEN6] 152ο Δημοτικό Σχολείο Αθηνών	191	0	2.028	200.452
[GEN6] 16ο Γυμνάσιο Αθήνας	212	0	100.000	36.742
[GEN6] 7ο Γυμνάσιο Περιστερίου	254	0	0.000	0.000
[GEN6] 7ο Δημοτικό Σχολείο Μεταμόρφωσης	322	0	-2.831	123.555
[GEN6] 2ο Γυμνάσιο Καισαριανής	340	0	0.000	0.000
[GEN6] 6ο Δημοτικό Σχολείο Άνω	364	0	0.000	0.000

1 - 10 από 48 στοιχεία 10 | 25 | Όλα 1 2 3 4 5

Figure 12: Summary table and search.

5.2.3 School History

Historical data regarding the energy consumption of schools are also available (Figure 13), which can be combined with weather information (temperature, wind, humidity) collected through online web-services or on the spot weather stations.

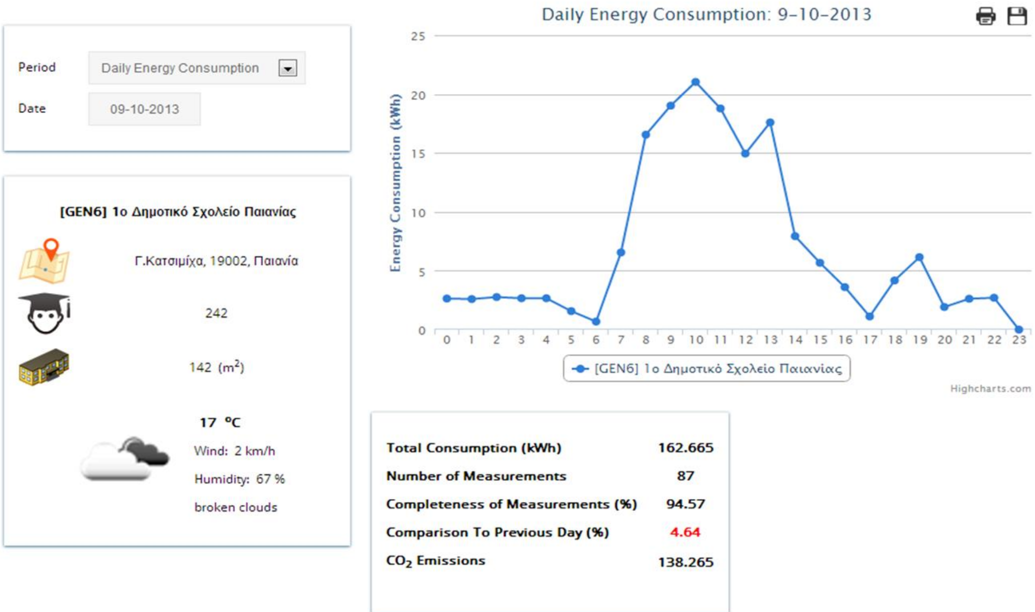


Figure 13: Historical energy data for a school.

5.2.4 Geo-location

gen6.sch.gr also associates geo-information with schools energy profile (Figure 14).

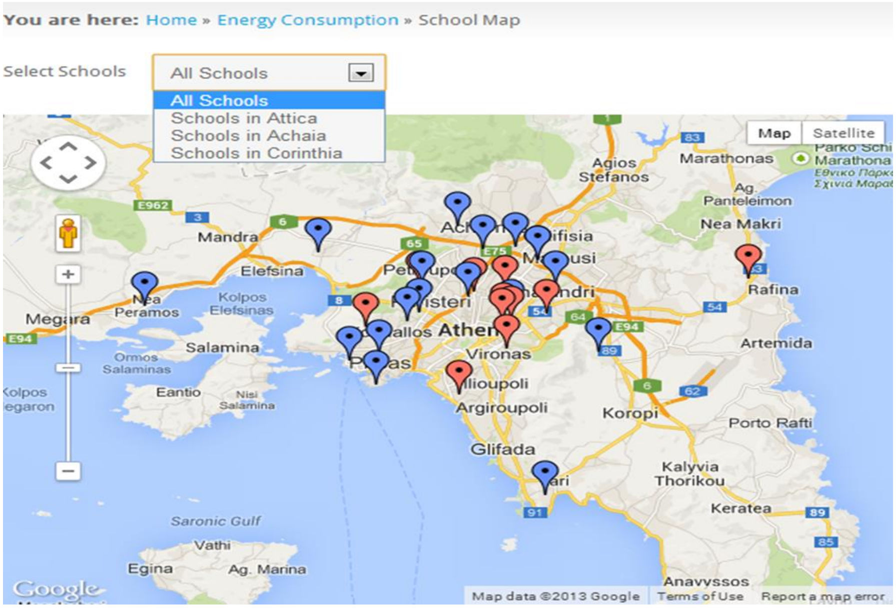


Figure 14: The location of schools participating in the GEN6 Greek pilot.

6. Communication with School Communities

The Greek pilot has as goal to increase IPv6 awareness along with the energy awareness of the school communities based on the proper dissemination activities and the provision of direct access to the students for viewing real time energy consumption from the installed smart meters.

Energy awareness is even more important when it refers to pupils, as behavioral changes in them are more long lasting, easier to accomplish, and have larger cumulative impact. The application of behavioral change theories in the field of energy consumption supports criticism of a too narrow focus on individual behavior and the need to broadening to include social interaction [1]. So, intervention programs aimed at the change of energy consumption patterns need to take into account that behavioral change is best achieved and maintained if supported by tailored information and changes in context, for example through supportive social networks.

6.1 Energy awareness through energy monitoring displays

It is evident that energy monitoring systems are important for energy awareness. Studies have shown that by simply monitoring one's energy consumption, the savings on the electric bills can be 5 to 15 percent. However, Van Dam et al [2] found that the introduction of energy monitors in buildings results in a distinct decrease in the level of energy savings originally made by occupants, after a period of only a few months. This is attributed to a lack of habit formation as well as poor design with overly complex interfaces. The authors showed that where people adopt a regular habit of looking at energy monitors on a daily basis, they exhibit larger savings over time compared with others. An implication is to question the notion of mass-produced 'one-size fits- all' home energy monitors and whether solely technological solutions (such as energy monitors) actually achieve the desired results. It also suggests that a deeper understanding of the relationship between the user and these systems is needed. Darby [3] also discusses the level of 'affordance' that smart meters offer, i.e. their usability and effectiveness and points out that: "Taking control away from the customer cannot be relied upon to improve the situation: it may actually entrench and legitimize high-demand practices, disengaging customers from any need to consider and question them". Darby argues that effective forms of interface, feedback, narrative, and support need to be developed to reach more diverse populations and to reduce actual consumption. The challenge is for the smart meter to prove itself in terms of developing a useful relationship with the user, through new forms of user engagement (understanding, expectation and behavior) enabled by new design and media approaches.

In the Greek pilot, this phenomenon was noticed in school communities when the installation of each smart energy meter was completed. When it was ensured that the energy meter was sending properly measurements both in energy monitoring display but also to the web-platform as well, students were informed by the specialized energy awareness team that they can see in real time the energy measurements of their school. A difference of about 6% in the behavior of the students was noticed only by installing the energy monitoring display in their school. Students were calling continuously to Greek partners reporting them about the reduction of energy consumption as it was recorder only by the display.

6.2 Energy awareness through web-portal

As described in Section 5, within the framework of the Greek pilot, we have developed an interactive web platform that is in charge of presenting the processed energy consumption data coming from the Meter Data Management (MDM) system. In order to achieve this and enable the students' community better understand complex energy data, the display of the data in the students' portal has been enriched with animations, graphical statistics, historical data, comparative school energy data, average factor, information on the best performing school, etc.

For example, students can see through the web-portal their energy consumption in real time and according the interval that they have chosen (daily, weekly, monthly, yearly). This can be seen in the figure below:

Select Consumption Period: Daily Energy Consumption

Daily Energy Consumption
Weekly Energy Consumption
Monthly Energy Consumption
Yearly Energy Consumption

Energy Consumption (kWh)

	School Name	Consumption (kWh)
1	[GEN6] 152ο Δημοτικό Σχολείο Αθηνών	156.308
2	[GEN6] 5ο Δημοτικό Σχολείο Πειραιά	119.965
3	[GEN6] 7ο Δημοτικό Σχολείο Μεταμόρφωσης	114.061
4	[GEN6] 3ο Δημοτικό Πεύκης	66.193
5	[GEN6] 14ο Δημοτικό Σχολείο Αιγάλεω	54.659

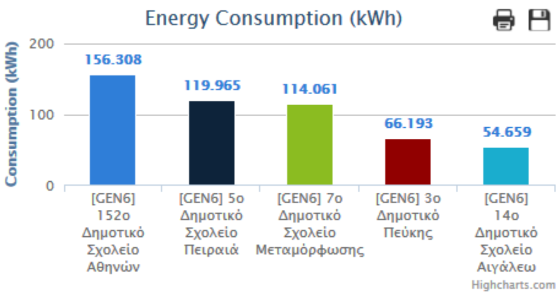


Figure 15: Real time energy consumption of each school.

Through the monitoring of the real time energy consumption, students have a daily overall view of their schools energy consumption and this automatically helps them in saving energy.

Each school's energy consumption information is made more directly comparable by accounting the number of students and the area of the school. Due to many difficulties that we had in finding each schools exact area, the KPI for the comparison of the most efficient school was kWh/student.

Energy Consumption/Student (kWh/Student)

	School Name	kWh/Student
1	[GEN6] 14ο Δημοτικό Σχολείο Αχαρνών	0.006
2	[GEN6] 2ο Γυμνάσιο Πεύκης	0.019
3	[GEN6] 3ο Δημοτικό Πεύκης	0.243
4	[GEN6] 7ο Δημοτικό Σχολείο Μεταμόρφωσης	0.354
5	[GEN6] 14ο Δημοτικό Σχολείο Αιγάλεω	0.448

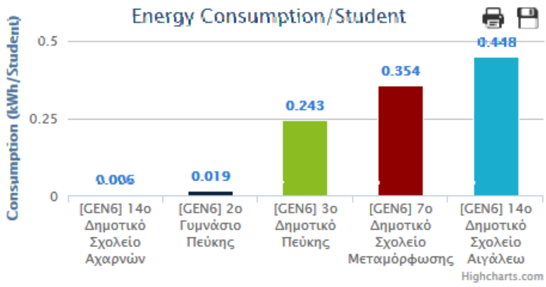


Figure 16: Comparison between schools.

Except for the real time monitoring of the energy consumption of each school which is a powerful tool, students can find in the web portal energy savings tips that can help them reduce their energy consumption.

6.3 Energy awareness through green dissemination activities

The students were also give the opportunity to participate in a series of interactive workshops designed to develop their knowledge on environmental and energy issues, encouraging them to take actions in the direction of sustainable living, energy consumption minimization and climate change, and motivating them to adopt a long-term environmentally friendly behavior, inside and outside the school.

6.3.1 The concept of the green activities

The green dissemination activities took place in 6 schools in close collaboration with SciCo company and another EU project called "The Green Agents Mission". The "Green Agents Mission" is a Programme of Education for Sustainability (Environmental Educational Programme) addressed to students between 11 and 16 years old, first presented as a Commitment for Action at Clinton Global Initiative University in April 2013 and supported by the Angelopoulos Fellowship 2013.

A roadshow was organized and applied by SciCo in collaboration with Intelen, Educational Radiotelevision, the Greek Ministry of Education and the British Council in Greece, to a number of schools in Athens during the school period 2013 -2014. During the roadshow the students learn the "real science" related to the energy/environmental issues and get challenged to become "Green Agents", secret spies who will help reduce electricity use in their schools with the help of the Greek Pilot's energy meters and web portal and will spread the word in their family and the community.

The main directions of the green actions were:

1. To encourage students to come up with ideas and reduce their energy footprint.

2. To challenge them to spread the word and engage their family and community into adapting environmentally friendly habits.

3. To create knowledge to the teachers for an education with energy sustainable tips and awareness.

The energy awareness in schools was made under the four following concepts:

A. Knowledge
- ✓ Flow of energy: from photosynthesis to electricity
- ✓ Energy sources: Renewable and non – renewable
- ✓ The Green House Effect and Climatic Change
- ✓ Energy consumption

B. Affect
- ✓ Attitudes
- ✓ Awareness of environmental consequences of everyday activities
- ✓ Environmental Sensitivity
- ✓ Willingness to act
- ✓ Motivation to act

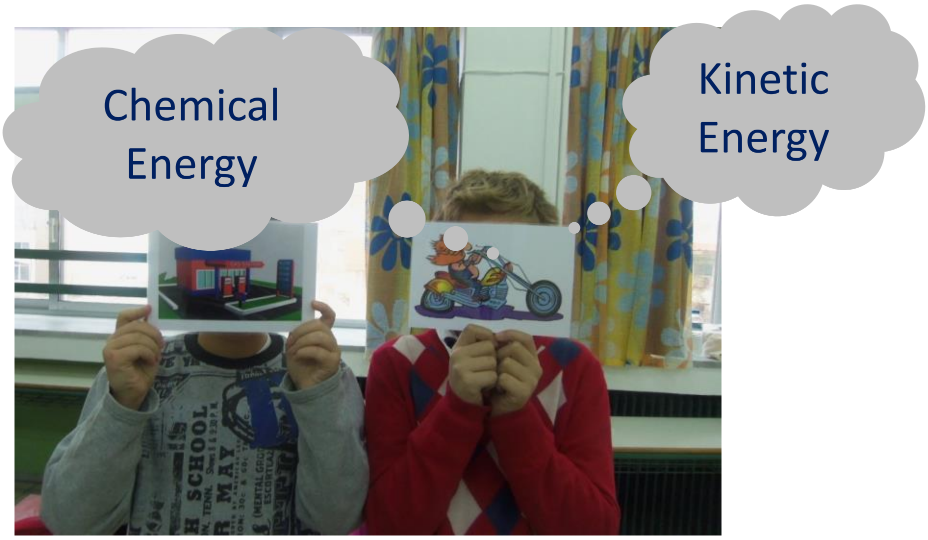
C. Behavior
- ✓ Active Participation (Save Energy at school, Save energy at home)
- ✓ Personal Responsibility
- ✓ Individual and Public Persuasion

D. Skills
- ✓ Action Strategies
- ✓ System thinking

6.3.2 Dissemination activities execution

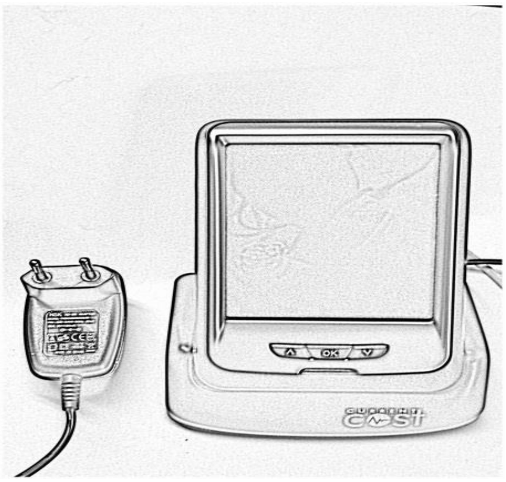
In order the aforementioned concepts to be communicated to students, 5 rounds of visits were organized and took place in schools:

Visit 1: The different faces of energy



Visit 2: Energy Flow

Visit 3: The energy meter



Visit 4: Collecting ideas of energy saving

When we leave classroom, we remember to switch off the lights.

Visit 5: Engaging our Community

6.3.3 Final event with the participating schools

At the end of the school visits a special event was organized where all the schools that participated in the green dissemination activities were gathered. In that event, students presented paintings with main object the energy efficiency and the ways to succeed energy savings. Alternative energy resources were also presented in students paintings like Renewable Energy Resources.

6.3.4 Video

A shooting of a special video took place where all the people that organized and participated in the green dissemination activities has a specific role and explained the usefulness of the energy awareness in schools. Greek pilot members described the role of the smart meter and the value of IPv6 Technology.

7. Report on Collected Data

7.1 Pilot Setup

An important initial decision that had to be made and would influence the success and the impact of the Greek pilot was the selection of the participating schools. The selection was based on the location of the schools and their detailed characteristics:

- **Location of the schools**: we decided that the selected schools will be located across three adjacent prefectures (namely, Achaia, Korinthia and Attiki) within the Greek territory. The selected prefectures present sufficiently diverse geological and climate conditions. Variations in energy consumption can be monitored without, however, affecting the impact on the achieved energy savings in the pilot, which will be based on a percentage basis.
- **Detailed school characteristics**: GSN-CTI organized a survey to take place among the schools. The survey that was completed at the end of March 2012, collected information regarding the characteristics of the schools and the school buildings, the students' and teachers' populations, and their degree of interest in environmental issues, including existing or past activities on energy efficiency and related issues. Some important parameters of interest are the following: 1) the willingness of the school to participate in the pilot, 2) the existence or lack of broadband connectivity, 3) type of school (primary or secondary education), and the specific grades it includes; students at the last grades of primary education and the first grades of secondary education would be preferable as participants in the pilot's activities, 4) the number of students in the school (we prefer schools with a relatively high student population), 5) the availability or lack of local technical support staff, 6) any student activities related to environmental and energy efficiency issues, 7) the total area of the school, 8) the daily electricity load, 9) the ease of accessibility of the electrical panel, 10) the proximity of the electrical panel to the school computer room, 11) the number of high consumption (over 500W) energy devices or appliances that operate at the school, 12) whether single phase or three phase power supply is available at the school,13) the existence or not of a person responsible for environmental activities in the school, 14) the availability of sufficient contact information for the schools, and 15) the nominal Amperes of the building's general switch.

The previous factors are actually soft requirements that have been used for the selection, and some of the schools that finally participated may not have all the desired characteristics. The final selection of the schools in the pilot has been done based on the analysis of the questionnaire's responses, interviews with interested teachers, and on-site visits that were also performed.

7.2 Installations' problems resolved

During the installations of the smart energy meters in the 50 schools, many problems and difficulties came up. The problems that the Greek partners dealt with, were divided in 3 main categories: difficulties in finding schools, installations' difficulties, failure of hardware.

Difficulties in finding schools

The problems that are connected to this category, had to do with the difficulties that the Greek partners were dealing with finding schools that were willing to participate in the Greek GEN6 pilot. The candidate schools' main hesitations were concerning the benefits that they would have by participating in this program and whether this was free or not. Extra efforts from the Greek partners were given in order to persuade them that the installation was cost free and it was not going to take more than 20 minutes to be completed. Finally an important and determinant role in the selection of schools played the questionnaire that was sent to them during the pilot set up. Special resources were spent there in order to collect all the questionnaires filled.

Installations' Difficulties

Some of the major issues that were faced during the installation were mainly the ones related with the available room inside the electricity board to place the CT jaws. This is more often when

i. the electricity boards are shallow,
ii. when there are plenty of separate lines in the electricity board (which is in general desirable) and/or the electrician had not left spare space (below 30% according to the Greek Regulations),
iii. in 3 phase installations where 3 CTs should be installed inside the cabling and at the same time the electricity board should seem in the same way as before.

Another issue is the number of plugs required. The Smart metering system requires 2 plugs, one for the monitor and one for the iBox. Since the iBox is usually installed near the router and perhaps other office loads the space for additional plugs is extremely limited. Finally, another important difficulty that the installers met, was the big distance between the transmitter and the display. Due to this problem, the communication of the display and the transmitter was bad and occasionally some measurements were being lost during the day.

Failure of Hardware

When the installations in the 50 schools were completed, a hardware failure in Intelen's iBox came up which resulted in their replacement. To this end, extra effort and resources were used.

7.3 Pilot results on the collected data

Energy Consumption

Below it can be seen a random weekday of a school. Its curve it is more or less similar for all schools during weekdays:

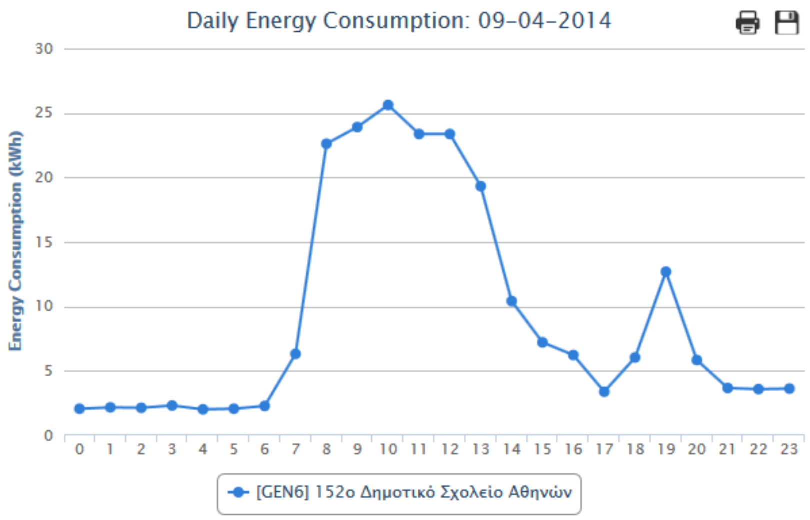


Figure 17: Energy consumption of a school during a week day.

On the other hand the consumption curve of a school during weekend can be seen below:

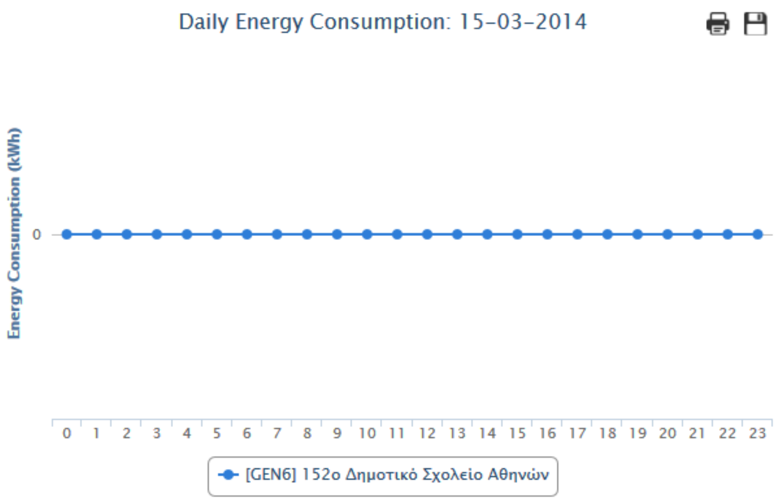


Figure 18: Energy Consumption of a school during weekend.

As it was expected during weekends the energy consumption of the schools is minimal and it tends to zero.

Figure 19 shows the energy consumption of a school during year 2013. We observe that the school's energy consumption increases when school opens and as entering in the winter, while it is reduced in the spring and in the summer when the school is almost closed.

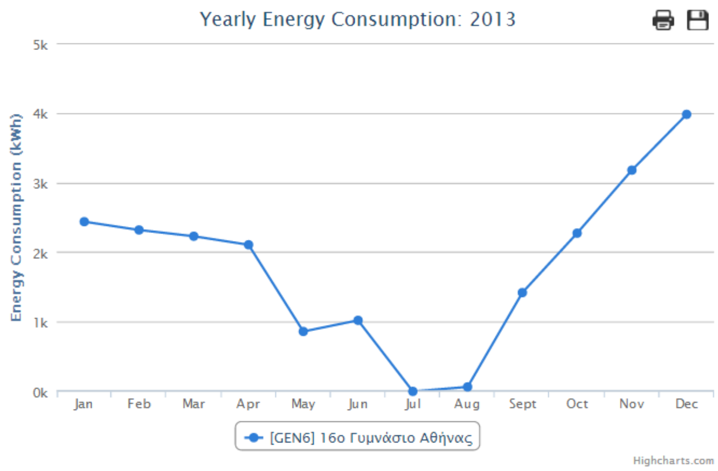


Figure 19: A school's yearly (2013) energy consumption.

Typical Energy Consumption of a week

A typical day/week/month is a day of a previous similar time interval (same season etc.) which works as reference day/week/month. In the diagram below you it can be seen a typical week of a school:

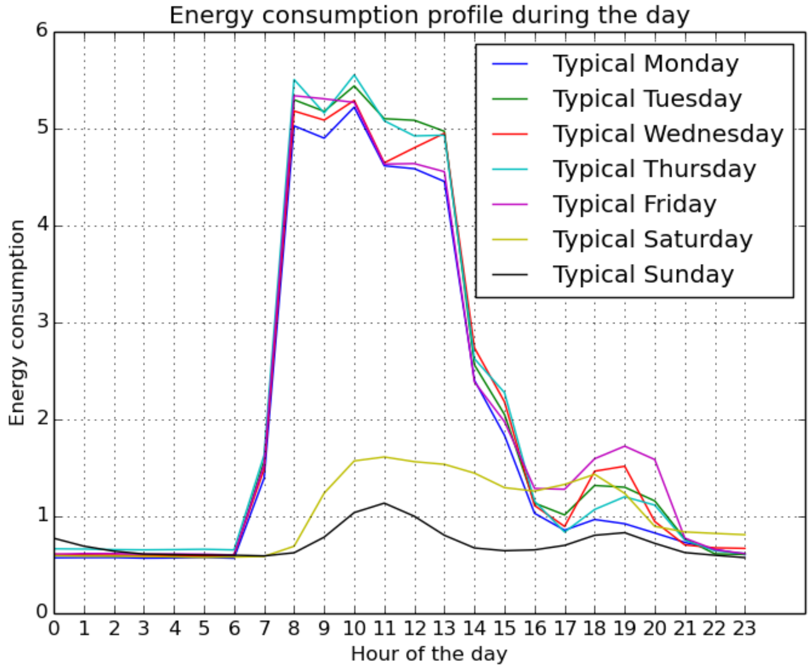


Figure 20: A typical week of the schools.

Energy Consumption correlated to temperature

The smart energy meter except for the energy consumption in real time is capable also of providing the temperature of the place that the energy meter is installed. In the diagram below, a correlation of the energy data to the external temperature is presented for a period of one normal week:

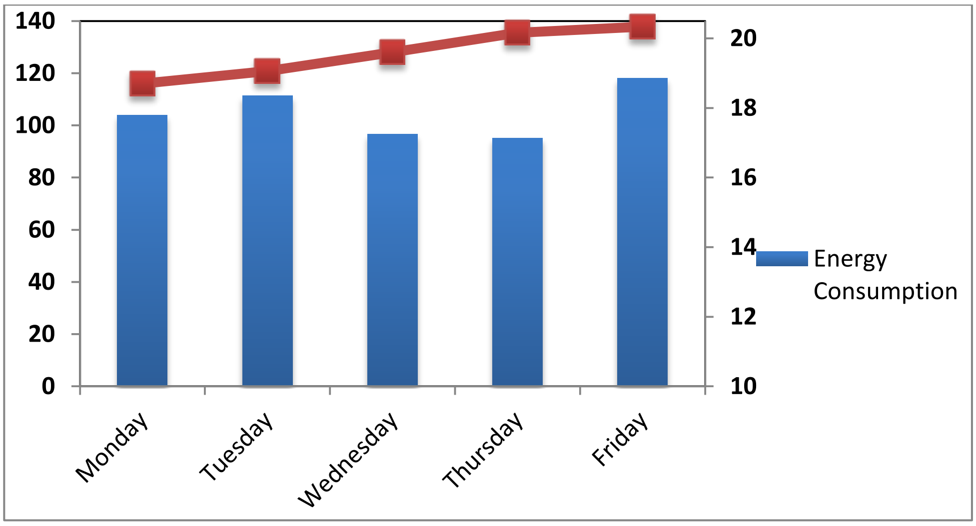


Figure 21: Energy Consumption in correlation with temperature.

As we can see in the diagram above, as it was expected, the energy consumption is reduced when the temperature is increased.

In the diagram below a comparison of two months is presented. The two months are March and November. The remarkable point here is that while in March the temperature is higher than November, the energy consumption remains also higher.

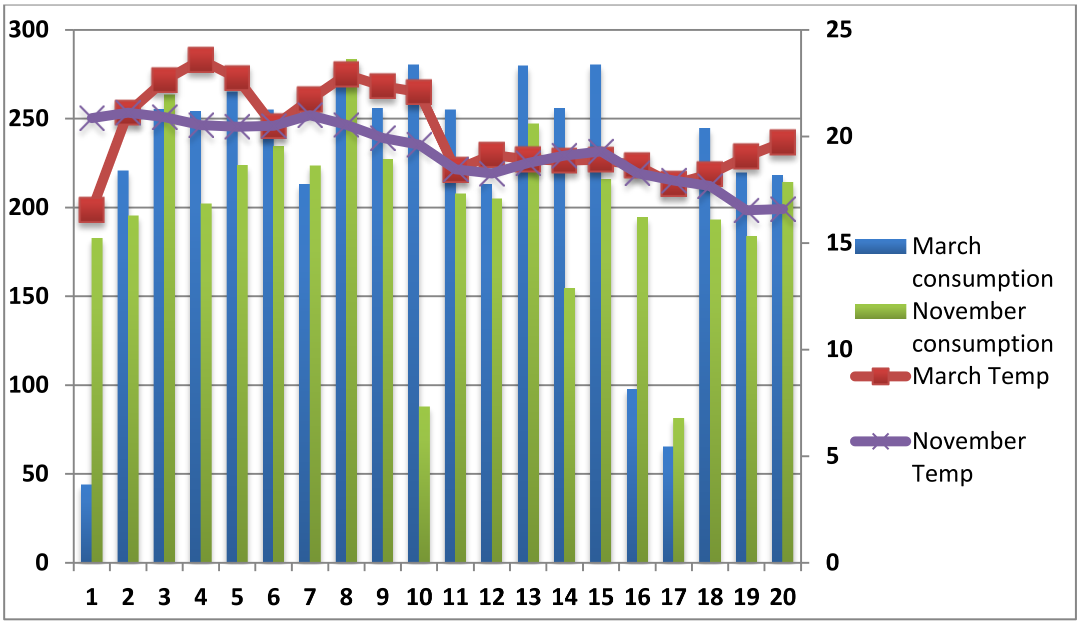


Figure 22: Comparison between 2 months and correlation with temperature.

Energy Savings after the green actions

As we described in the previous chapter, the students in the 6 schools that the actions took place, were educated on the ways that could save energy through energy saving tips, commitments and engagement actions. In the diagrams below it can be seen the difference in energy consumption between two weeks of the same month in two different years.

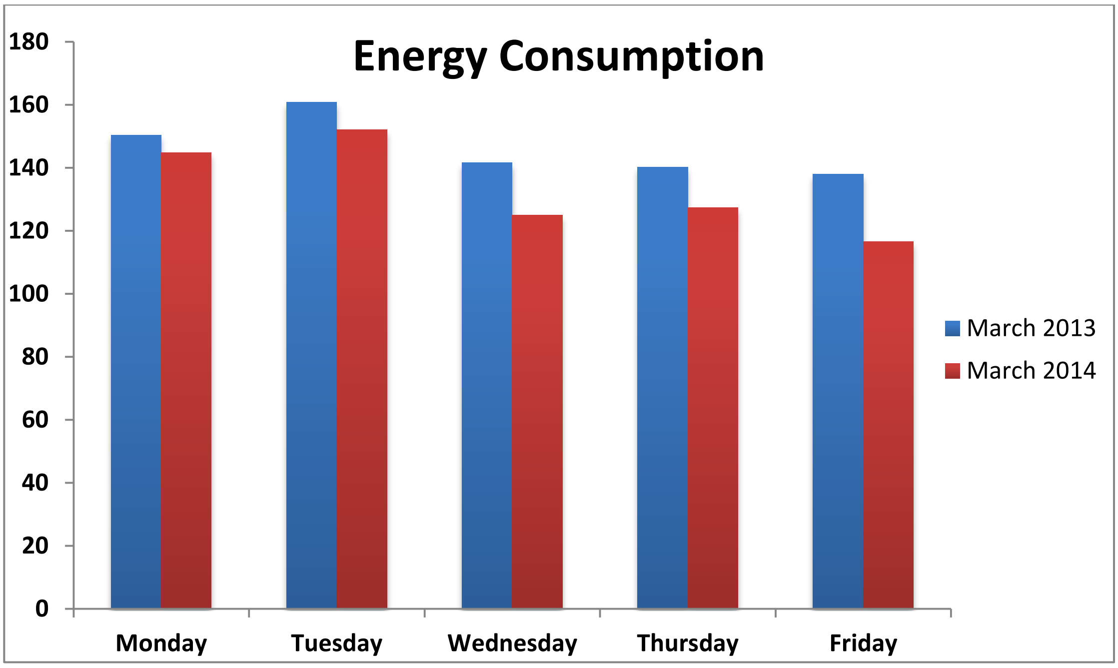


Figure 23: 7th primary school of Metamorfosis.

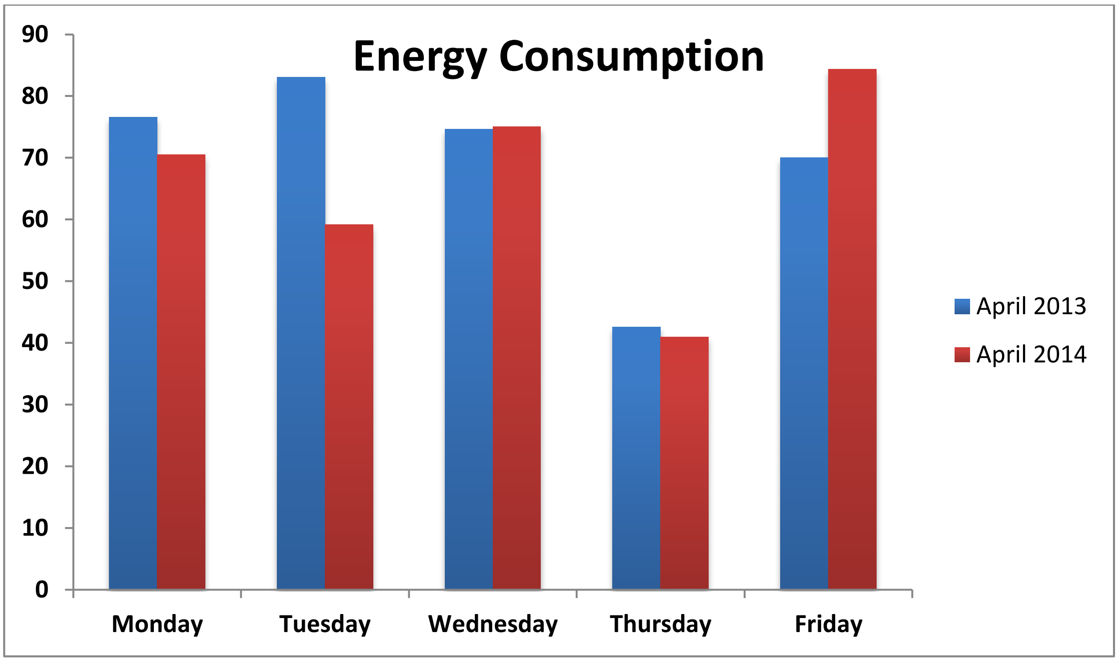


Figure 24: 14th Primary school of Aigalew.

As we can see in the diagrams above, there is a significant difference between the energy consumption before and after the green dissemination actions in schools.

In the table below the results of 6 schools and the energy savings that they accomplish are presented.

School Name	Energy Savings
7th Primary school Metamorfosis	9%
5th Primary school Piraeus	5%
9th Primary school Xalandri	12%
14th Primary school Axarnai	11%
14th Primary school Aigalew	7%
152th Primary school Athinwn	15%

Table 2: Energy savings in percentage.

8. CONCLUSIONS

The GEN6's Greek pilot target was to utilize IPv6 technology and develop a system for monitoring, analyzing and reporting energy consumption in Greek schools. The last three years the Greek pilot's partners (CTI, GRNET, Intelen) succeed to develop, install and operate successfully the system in 50 schools, while more schools are requesting to participate. Considering the fact that the student population of these schools is around 11000, we see a great opportunity in influencing positively these students and many more in the future, towards environmental friendly practices.

Additionally, as a result of the work performed, we published one article in the 16th Panhellenic Conference on Informatics (2012): "Eco-labeling Greek Schools for Energy Efficiency over IPv6", and another in the 18 Panhellenic Conference on Informatics (2014): "GEN6 EU-project – Greek Pilot: "IPv6 upgrade of Energy Efficiency in School Networks", while we have also submitted one journal summarizing the Greek pilot's results.

9. References

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