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2014-2020

ESMARTCITY

Enabling Smarter City in the MED Area through Networking

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Priority Axis 1. Promoting Mediterranean innovation capacities to develop smart and sustainable growth

Specific Objective 1.1 To increase transnational activity of innovative clusters and networks of key sectors of the MED area

WP3 – Testing

Activity 3.3 – Pilot Testing

Deliverable 3.3.1 – Pilot deployment – Partner PP5

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Dissemination Level		
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Contents

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Within the framework of the European project Esmartcity (Enabling SMARTer City in the MED area through NET working - ESMARTCITY) implemented under the Interreg MED Mediterranean Program 2014-2020 and co-funded by the European Regional Development Fund (ERDF), the Region of Western Greece (RWG) participates as a partner.

1. Introduction

The current document aims at describing the procedure that has been followed up to now for the installation of the smart meters to the pre-defined RWG buildings in the frame of WP3-Pilot Testing, as well as defining the basic components of the data management plan that will be followed towards applying energy efficiency solutions to these buildings.

First of all, we describe the general framework that is proposed in order to establish a data collection process and perform the corresponding analytics steps that will lead to reduced energy consumption. Then the structure of the document is as follows:

- A description of the existing submetering techniques for energy savings potential is provided, along with the corresponding references.
- Meazon's submetering solutions and products are demonstrated, to justify the company's superiority against existing products.
- The smart meters' installation is fully described accompanied with pictures from the on-site installation
- A first screening of the data acquired up to now is presented, to better understand the buildings' behavior during the weekdays and hours of the day.
- Comparative analysis cases are demonstrated for a subset of buildings, to explore the differences within different time spaces for the same building each time.

2. Vision of RWG-Energy efficiency framework

The main purpose of energy monitoring of RWG buildings is the development of a complete energy saving solution by exploiting the measurements acquired from the smart meters and extracting the corresponding energy profile of the buildings.

Real-time energy consumption monitoring after the smart meters' placement is feasible through the platform that has been developed my Meazon for the purpose of collecting and managing energy data. Energy consumption is measured with one-minute report interval, thus providing high quality measurements and robust data analysis.

In order to develop an energy efficiency plan, the following actions should take place:

- Installation of smart meters to buildings of interest
- Energy data acquisition
- Statistical characteristics extraction from measurements
- Change of equipment/change of users' habits scenarios investigation
- Energy saving potential calculation in case of applying the aforementioned scenarios

The very first step towards implementing the aforementioned framework requires having selected the appropriate equipment that is able to measure energy consumption with high-frequency.

3. Submetering technologies towards energy efficiency in buildings

By the term "submetering" we are referring to electrical submetering involves the installation power meters (also called power monitors, electrical meters, or energy monitors) that can measure energy usage after it reaches the primary utility meter. Submetering offers the ability to monitor energy usage for individual tenants, departments, pieces of equipment or other loads to account for their actual energy usage [1].

3.1 Submetering Market Analysis

According to Navigant Research [2], the submetering market is relatively mature in terms of technology, but still it has a long way to go in terms of actual deployments. In terms of size, the Western European market has the lead, followed closely by the North American one.

In terms of forecasting, the global market for submetering technology and services will grow to $1.58 billion in 2020 at a CAGR of 9.4%, while the services associated with submetering represent the industry's major revenue-generating sources. Finally, market and regulatory issues will increase the penetration of submetering into commercial, industrial, and multi-unit residential facilities around the world.

In the same report, the market analysis and forecasting for the submetering technology and related-services for the time frame of 2012-2020 was also presented for the global market, as well as for the markets of North America, Western Europe, and Asia Pacific. In this analysis the following categories were considered:

- Basic submeter hardware;
- Advanced submeter hardware;
- Submeter energy management software;
- Other hardware costs;
- Installation costs;
- Customer training services; and
- Other submeter services.

The results of the Navigant research report are presented in the following figures.

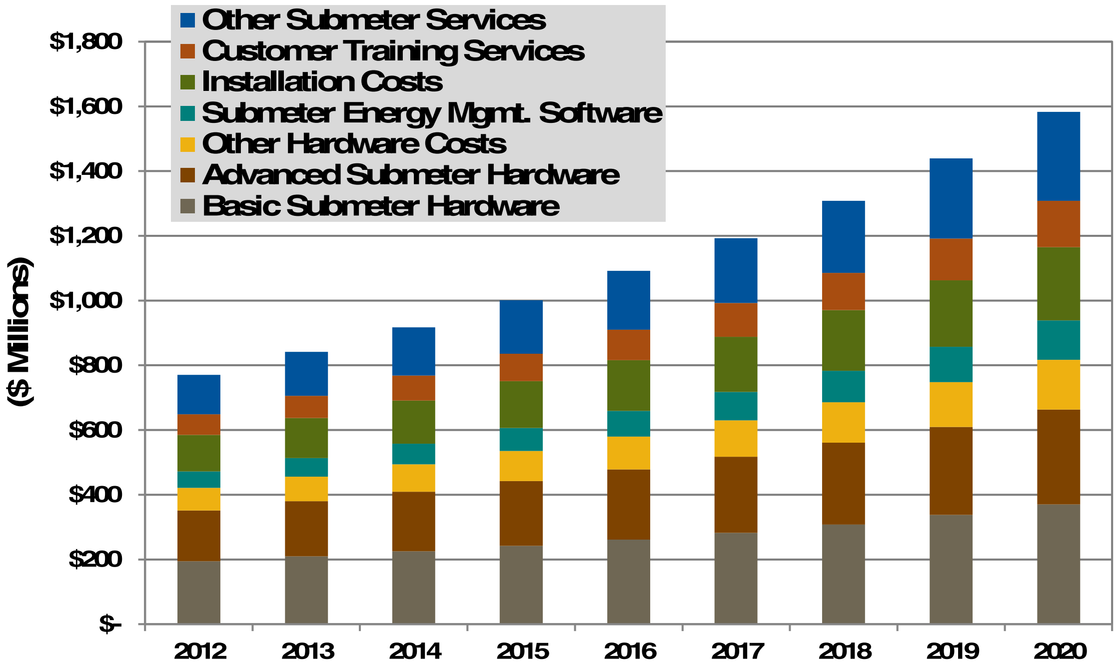


Figure 1: Submetering technology and services market by category in world markets 2012-2020 [2]

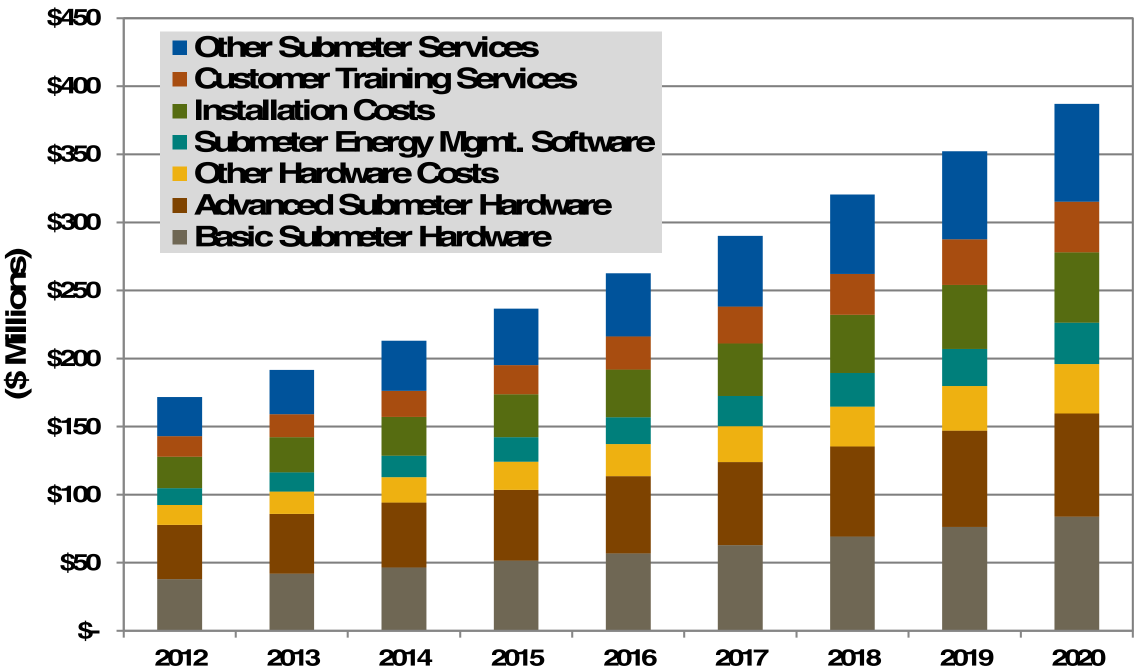


Figure 2: Submetering technology and services market by category in North America 2012-2020 [2]

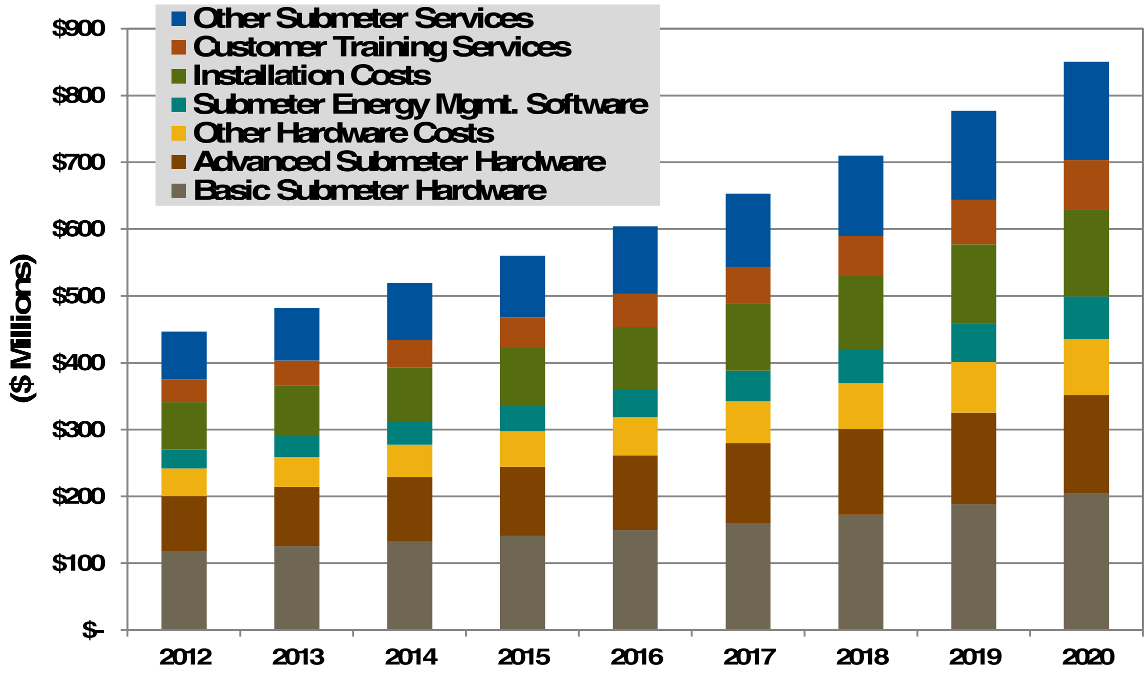


Figure 3: Submetering technology and services market by category in Western Europe 2012-2020 [2]

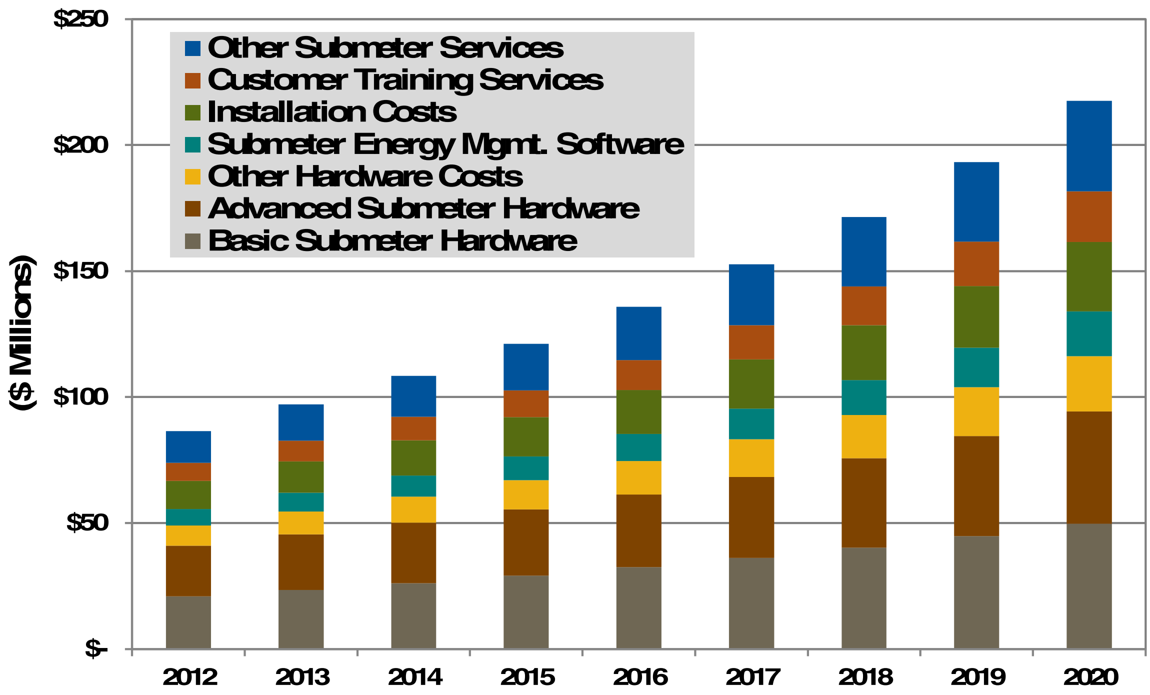


Figure 4: Submetering technology and services market by category in Asia Pacific 2012-2020 [2]

3.2 Energy Submetering Use Cases

According to [1] ,some of the advantages that stem out of the use of submeters, are listed below:

- Accurate energy monitoring, real-time energy consumption;
- Granular in-depth review of facility energy data;
- Better informed to make decisions that can help optimize energy performance;
- Ability to record actual energy usage (no estimates);
- Comparison of usage across similar facilities over time;
- Ability to identify and eliminate wasted energy; and
- Early access to maintenance issues for repair before critical equipment fails.

Some of the most commonly used use cases of submeters are discussed below.

3.2.1 Peak Demand Management

One of the easiest ways to lose control of electricity costs is by what utilities refer to as "peak demand" charges. In this situation, a utility provider will charge a greater cost per kWh when demand is greater in order to prevent all consumers from maximum consumption during these peak times. The utility company argues that the grid must be able to support each customer's max consumption, therefore the grid must be built in order to support each customer getting charged based on their max kW rate.

By increasing the cost per kWh, consumers will shift their usage to off-peak and reduce the chance that the grid reaches dangerous capacity levels. Submeters allow the end-user to receive detailed consumption information, which allows the customer to avoid cost increases with time-of-usage billing and to take advantage of off-peak rates.

3.2.2 Tenant Submetering

In non-submetered commercial and residential buildings, tenants are typically billed on square footage of rented space. In this scenario, the landlord receives an electrical bill for the entire facility and bills each tenant based on the amount of space they rent. The problem here is that tenants are not billed based on consumption behavior, but rather they are billed based on the total consumption of the rest of the tenants.

Tenant submetering allows each tenant to be billed only for the energy consumed within the rented space. Revenue-grade power meters are accurate enough to be used for billing purposes and can be installed at each tenant location. By holding tenants responsible for their personal consumption, they will be more likely to reduce their electricity usage habits and lower the buildings overall electricity consumption.

3.2.3 Energy Cost Allocation

When rising energy costs and a greater emphasis on energy efficiency, all types of facilities are looking to better understand their consumption and what is driving increased electrical bills. Submetering gives the user the ability to monitor individual pieces of equipment so that energy costs can be allocated to different departments and processes. By using this data, building managers has a better understanding of the who is using the most energy and where it's being used so corrective actions may take place.

3.2.4 Energy Consumption Optimization

In addition to the direct energy savings provided by a traditional energy management system based on energy measurements through the traditional energy meter, the use of equipment-level submetering, big data analytics, and cloud computing, allows for the emerge of the following seven hidden benefits to energy efficiency according to [3]:

- Optimized Equipment Performance;
- Smarter Alarms;
- Integrated Sustainability;
- Dynamic Control;
- Financial Verification;
- Proactive Demand Response and Peak Shaping; and
- Intelligent Building Design.

3.3 Communication Technologies for Submeters

Among the various communication technologies, wireless communication technologies are the preferred type of communication that dominates the submeter market. Additionally, among the wireless communication technologies the wireless low-power networks have the lead.

The packets transmission wireless networks technology begun developing in the 1970-1980s decade, though its main development coincided with the spread of microcomputers during the period 1980-1990. Due to the special characteristics of the transmission means, wireless networks use dedicated protocols for the Medium Access Control sub-layer and the Data Link Layer and often for the upper levels (i.e. packets routing). Wireless networks include mobile telephony networks, satellite communications, wide area wireless networks (WWANs), wireless metropolitan networks (WMANs), wireless local networks (WLANs) and wireless private networks (WPANs).

There is an incredible range of connectivity options for information engineers and application programmers working on products and systems related to Internet of Things (IoT) [4],[5]. Depending on the application, factors such as range, data requirements, security requirements, battery energy and lifespan define the selection of a technology or a combination of technologies.

Figure 5: Categorization of LPWA/LPWAN communication technologies [6]

Below follow some of the major telecommunication technologies deemed ideal for IoT applications.

Bluetooth

Bluetooth [7] is an important small range communications technology which has become particularly important for informatics and numerous consumer-products markets. It is expected to be the key for various products dedicated for connection with IoT, usually using a smartphone.

ZigBee

ZigBee [8], same as Bluetooth, avails a large installed operation base, though it was traditionally used mainly for industrial applications. ZigBee is based on 802.15.4 IEEE protocol.

Z-Wave

Z-Wave [9] is a low-power Radio Frequency (RF) communications technology designed mainly for the automation of functions in household environment, that is, for products such as fixture controllers and sensors, among others. It is optimized for reliable and low delay communication of small data packets at data rates up to 100 Kbit/s and operates under the 1GHz band that is impermeable to other wireless technologies which operate in the 2.4 GHz band.

6LowPAN

A technology based on IP protocol is 6LowPan [10]. Instead of being an application protocol of IoT, such as Bluetooth and ZigBee, 6LowPAN is a network protocol that defines the header encapsulation and compression mechanisms. It provides the ability of free selection of frequency band and physical layer and can be used on multiple communication platforms including Ethernet, 802.11 and 802.15.4.

Thread

This is a new networking protocol based on Internet Protocol version 6 (IPv 6), which aims at the automation of domestic environment. It is based on 6LowPAN and, same as the previous one, it is not an application protocol of IoT. However, application-wise, it is mainly designed as a supplement of IEEE 802.11, as it acknowledges that 802.11 is good for many consumer devices with use limitations for the automation of domestic environment.

NFC

Near-Field Communication (NFC) [11] is a technology allowing easy and secure two-way interaction between electronic devices and specifically smartphones, allowing consumers to perform contactless payment, access digital content and connect electronic devices between them.

Sigfox

An alternative, broad-scale technology is Sigfox [12], which in terms of range is ranked between 802.11 and cellular communications. It uses the Industrial, Scientific and Medical (ISM) frequency bands, which are free to use without licensing requirements.

Neul

Neul [13] has similar philosophy with Sigfox and operates under the 1GHz frequency band. Neul exploits particularly small sections of the TV range to provide high scaling, high coverage, low consumption and low-cost wireless networks.

LoRa

LoRa [14] is a low power wide area network with features supporting low-cost mobiles phones, so as to ensure two-way communication for the Internet of Things (IoT), machine-to-machine (M2M), smart city and industrial applications. LoRaWAN constitutes the precursor of the development of these technologies and has numerous different categories of devices to address the various needs over a broad range of applications. It is similar, in some points, to Sigfox and Neul, and aims at WAN applications providing low-consumption WAN networks with features particularly required for the secure, two-way and low-cost mobile communication over IoT, Machine-to-Machine (M2M), industrial and smart city applications.

LoRa technology was developed by Semtech Company and constitutes a new wireless protocol designed for long-range, low power communication. LoRa network allows devices to connect to the Internet even when there is no Wi-Fi, using a system operating complementary to the mobile telephony network. An additional small antenna added to the base-stations of mobile telephony stations allows the transmission and reception of low-power but long-range radio signals.

NB-IoT

NB-IoT is a Narrow Band IoT technology specified in Release 13 of the 3GPP in June 2016. NB-IoT can coexist with GSM (global system for mobile communications) and LTE under licensed frequency bands (e.g., 700 MHz, 800 MHz, and 900 MHz). NB-IoT occupies a frequency band width of 200 kHz, which corresponds to one resource block in GSM and LTE transmission. With this frequency band selection, the following operation modes are possible:

- Stand-alone operation: a possible scenario is the utilization of GSM frequencies bands currently used.
- Guard-band operation: utilizing the unused resource blocks within an LTE carrier's guard band.
- In-band operation: utilizing resource blocks within an LTE carrier.

An overview of the architecture of an NB-IoT can be seen in the illustration below.

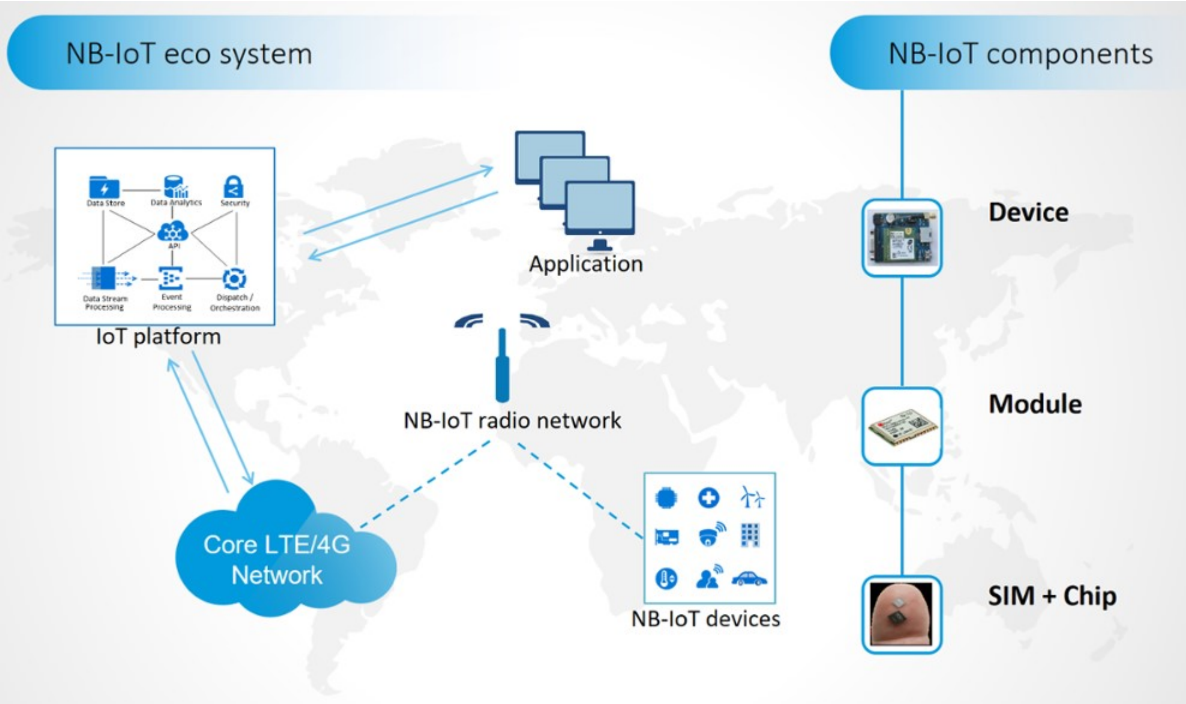


Figure 6: NB-IoT network architecture overview [15]

The NB-IoT communication protocol is based on the LTE protocol. In fact, NB-IoT reduces LTE protocol functionalities to the minimum and enhances them as required for IoT applications. For example, the LTE backend system is used to broadcast information that is valid for all end devices within a cell. As the broadcasting backend system obtains resources and consumes battery power from each end device, it is kept to a minimum, in size as well as in its occurrence. It was optimized to small and infrequent data messages and avoids the features not required for the IoT purpose, e.g., measurements to monitor the channel quality, carrier aggregation, and dual connectivity. Therefore, the end devices require only a small amount of battery, thus making it cost-efficient [16].

Consequently, NB-IoT technology can be regarded as a new air interface from the protocol stack point of view, while being built on the well-established LTE infrastructure. NB-IoT allows connectivity of up to 100 K end devices per cell with the potential for scaling up the capacity by adding more NB-IoT carriers. NB-IoT uses the single-carrier frequency division multiple access (FDMA) in the uplink and orthogonal FDMA (OFDMA) in the downlink and employs the quadrature phase-shift keying modulation (QPSK). The data rate is limited to 200 kbps for the downlink and to 20 kbps for the uplink. The maximum payload size for each message is 1600 bytes. NB-IoT technology can achieve 10 years of battery lifetime when transmitting 200 bytes per day on average.

The improvement of NB-IoT continues with Release 15 of the 3GPP. According to the 3GPP's current plan, the NB-IoT will be extended to include localization methods, multicast services (e.g., end-devices software update and messages concerning a whole group of end devices), mobility, as well as further technical details to enhance the applications of the NB-IoT technology.

3.3.1 Advantages of NB-IoT for Energy Submeters

According to ABI Research [6], the forecast of LTE-M and NB-IoT connections globally, will exceed the 691 million connections by 2022.

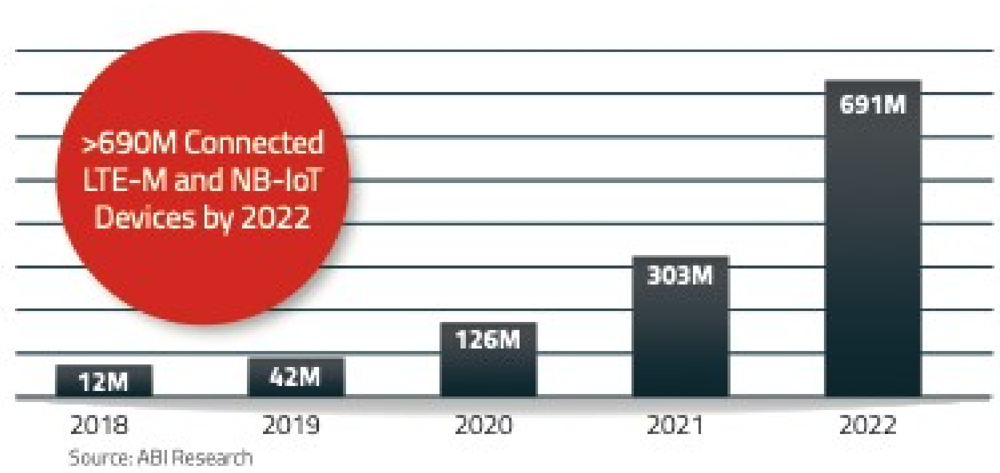


Figure 7: Forecast of LTE-M and NB-IoT connections globally [6]

According to the same report, the two leading LPWA technologies are the NB-IoT and the LTE-M communication technologies. With regards to the latency introduced by the LTE-M and NB-IoT technologies, the LPWA applications can be arranged as shown in the following illustration [6].

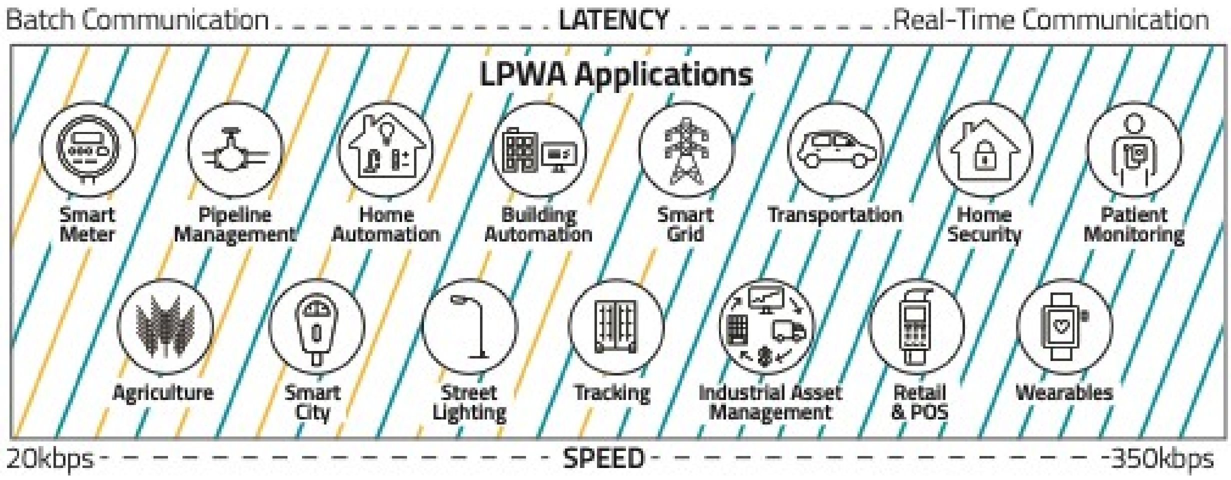


Figure 8: LPWA applications according to introduced latency [6]

A comparison between the technical characteristics of the aforementioned technologies is shown in the following figure.

	NB-IoT	LTE-M
	REL 13	REL 13
Power Consumption	75X or 10 Years	
Network Coverage	20dB or 164 dB MCL	
Deployment	In-band, Guard-band, Stand alone	In-band
Worldwide SKU	Yes	
Bandwidth	180kHz	1.08MHz
Data Rate (DL/UL)	27/65kbps	300/375kbps
Resource Allocation	pre-allocated	dynamic
Mobility	no	yes
Real Time	no	yes
Voice	no	yes
Network Requirements	mostly software upgrade	software upgrade

Figure 9: Specification comparison between the LTE-M and NB-IoT communication technologies [6]

The main advantages of NB-IoT and LTE-M technologies when compared with LoRa and Sigfox are graphically presented in the following graphic.

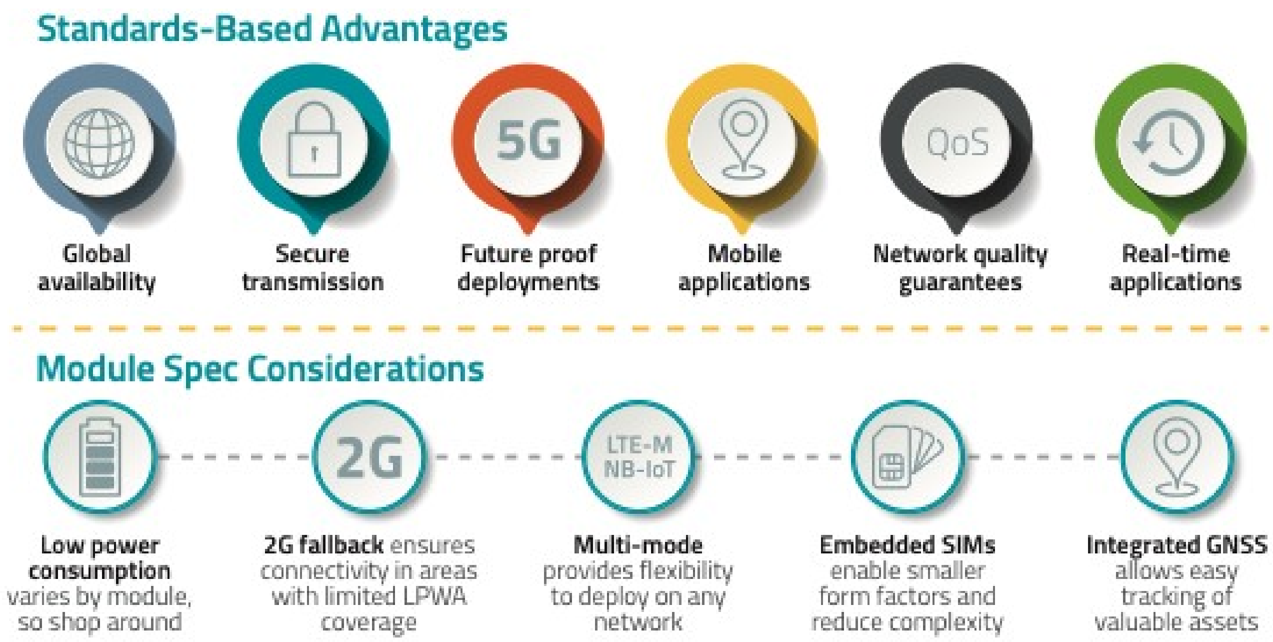


Figure 10: Standards and specification of LTE-M and NB-IoT communication technologies [6]

One may observe that when it comes to standards-based advantages, global availability and network quality guarantees, as well as future proof deployment are the advantages that drive the fast market penetration of the said technologies compared with LoRa and Sigfox networks, mainly due to the fact that the mobile operators are the ones driving both NB-IoT and LTE-M.

Moreover, when considering the module specifications, embedded SIMs and 2G fallback are the specifications that make these technologies highly attractive.

3.3.2 Communication Technology Comparison

A comparative study of LPWAN technologies for large-scale IoT deployments has been carried out in [16]. According to this study by 2020, more than 50 billion devices will be connected through radio communications. In conjunction with the rapid growth of the IoT market, LPWAN have become a popular low-rate long-range radio communication technology. Sigfox, LoRa, and NB-IoT are the three leading LPWAN technologies that compete for large-scale IoT deployment. This paper provides a comprehensive and comparative study of these technologies, which serve as efficient solutions to connect smart, autonomous, and heterogeneous devices. We show that Sigfox and LoRa are advantageous in terms of battery lifetime, capacity, and cost. Meanwhile, NB-IoT offers benefits in terms of latency and quality of service. In addition, we analyze the IoT success factors of these LPWAN technologies, and we consider application scenarios and explain which technology is the best fit for each of these scenarios.

According to a report from Lux Research [17] NB-IoT will likely win the battle for the LPWAN market as telecom companies and new entrants race to build an optimized network to connect billions of devices in IoT. LPWANs are key to IoT's bid to connect far-flung sensors and other devices. They optimize battery life by decreasing power consumption, while networking standards ensure reliable connections at low speeds to support low levels of data use.

By 2022, NB-IoT will likely capture over 90% of the LPWAN connections globally, thus winning the race against the rival standards Sigfox and LoRaWAN on the strength of its wider coverage and reliability. Also the report states that LoRaWAN is likely to complement NB-IoT in niche cases, and 5G is unlikely to disrupt the LPWAN space until at least 2028.

Lux Research evaluated diverse LPWAN technologies on four key criteria:

- power consumption;
- cost
- data reliability;
- and geographical coverage.

Some of the important findings of the Lux Research study [17] are listed below.

- **LoRaWAN has niche use cases.** The LoRaWAN standard has an edge in niche cases. It is the only system with built-in GPS-like technology and can be used to build shared community networks. Mobile network operators are deploying it or considering dual deployment along with NB-IoT.
- **Sigfox's early lead is fragile.** Sigfox's only advantage is its lead in network deployments, mainly in Europe, and these existing uses are the main reason why solution providers choose it today. However, as LPWAN competition like NB-IoT grows, Sigfox's advantage will begin to erode.
- **5G will be hit by delays and costs.** Fifth-generation mobile technology, or 5G, won't disrupt the LPWAN space any time soon. LTE and LTE-A wide scale coverage began only two years to three years after standardizations were set,

and it is likely that 5G will face the same fate or even longer, with standardized and full stack deployments beginning in 2022. High costs are another deterrent.

The key drivers according to [6] that drive change in the LPWA space are graphically illustrated in the figure below.

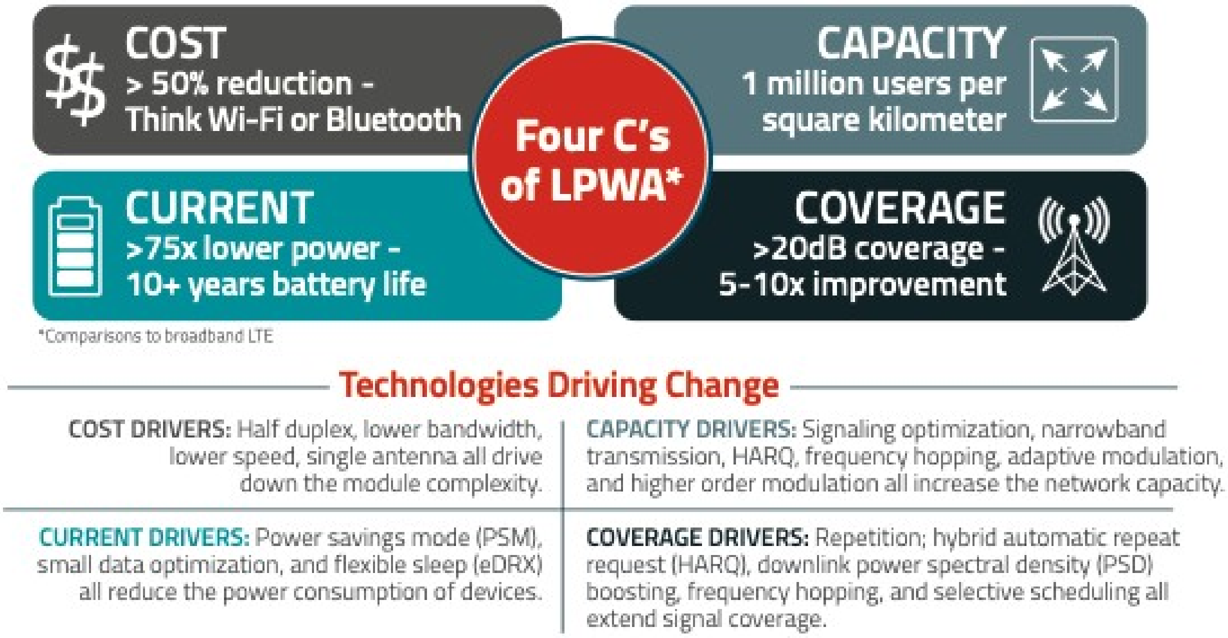


Figure 11: Technologies driving change [6]

4. Summary of Pilot Deployment

4.1 Meazon's Submetering Solutions

About Meazon

Meazon [18]is a technology company that brings the power of the IoT to real life. The company designs and develops microelectronic systems and software that allow the smart, simple and effective management of appliances and facilities of a company or a house remotely, through the user's smart device or computer. Meazon also provides customized solutions to satisfy the special needs in every market segment.

Based on the Meazon's breadth of products and services, the company is capable of supporting residential, as well as Commercial and Industrial (C&I) customers to control and reduce energy costs and their environmental footprint.

4.2 Meazon's Ecosystem

The ecosystem of Meazon's products and service is graphically illustrated in Figure 12.

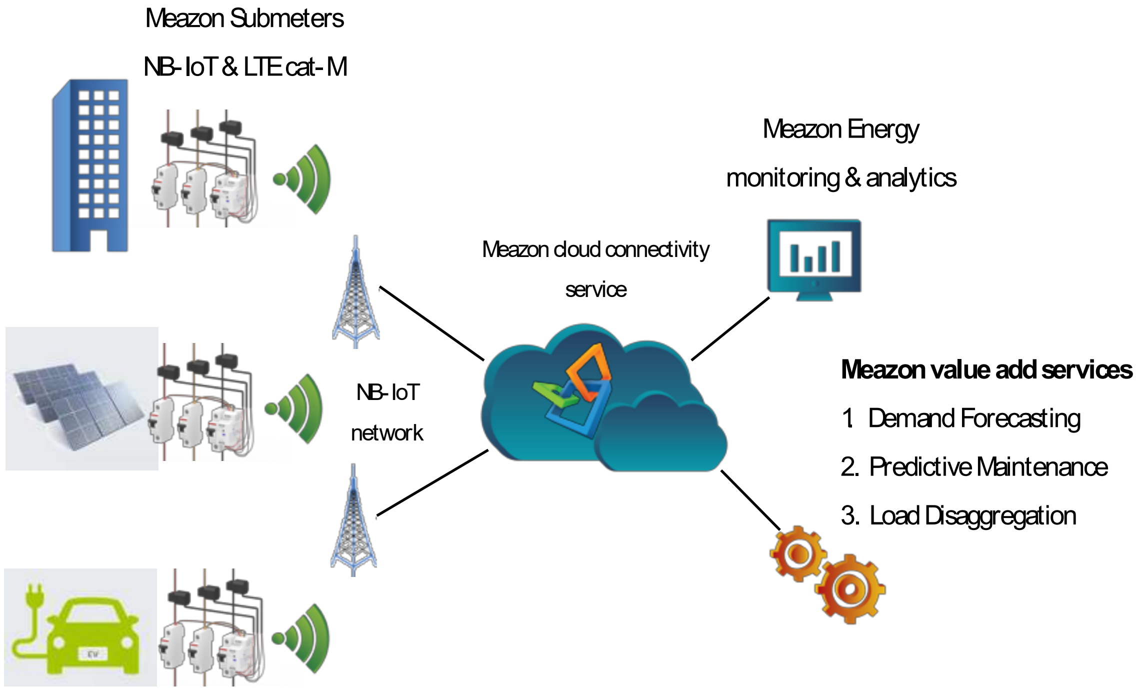


Figure 12: Meazon's ecosystem of products and services

The ecosystem consists of hardware devices and software services that are discussed below.

4.3 Hardware Devices

Meazon DinRail 3-phase Advanced NB-IoT submeter is a wireless web-enabled three-phase energy circuit-level meter. It belongs to the Meazon DinRail energy submeters family and is Meazon's most advanced energy submeter. The Meazon DinRail 3-phase Advanced NB-IoT submeter is capable of measuring the following parameters:

- Current;
- Voltage;
- Frequency;
- Active power;
- Reactive power; and
- Active energy.

Therefore, it is ideal for monitoring and controlling up to three phases electrical power feeds or three electrical lines in an electrical board in businesses or homes. The device is shown in the following figure.

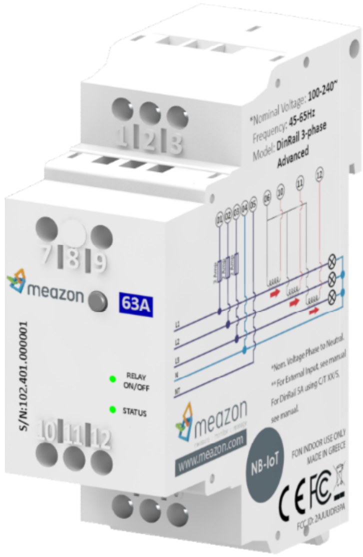


Figure 13: Meazon DinRail 3-phase Advanced NB-IoT submeter

Meazon DinRail 3-Phase Advanced comes with three (or four) split-core Current Transformers (CTs), which can measure up to 600 Amperes per phase using CTs. Ideal for real time monitoring, equipped with build-in data logger. Report interval down to 1 second over ZigBee and interface with different cloud platforms (Azure, AWS, etc.). It can also drive a cold junction where a relay could potentially be connected and control (on/off) the power supply to a load. The control logic could be driven by external or internal events. Weekly scheduling available on the meter level.It comes with a general-purpose AC input indication contact that can be used as an extra information input to your system (e.g. night tariff activation info).

The main characteristics and specifications of the Meazon DinRail 3-phase Advanced NB-IoT submeter are listed in the tables provided below.

Table 1: Communication specifications

Architecture	NB-IoT, LTE Cat M1 ZigBee Mesh Network
Frequency band	Zigbee Band: 2.4 GHz NB-IOT Bands: 20, 8, 3 M1 Bands: 13, 12, 5, 4, 2
System	Single-Phase 3-Ph. 4-wire
Minimum Data communication interval	1 second (default 5 minutes)
Data storage—measurement device	Yes
Security mechanism	Yes. AES encryption 128 bits.

Table 2: Operating specifications

Operating Voltage / Frequency	100 to 285 Vac / 45 to 65 Hz
Power loss response	Automatic resumption of operation after power loss

Table 3: Metrological unit specifications

Electric parameters measured	Irms, Vrms, Active Power & Energy, Reactive Power & Energy, Harmonics (optional)
Ranges of measured parameters **-model depended(*)**	Voltage: 0 to 285 Vac phase-to-neutral, 45 to 65 Hz 80% to 120% of normal line voltage Current: up to 600 Amperes(*)
Accuracy of measurements	<1% of reading measurement error (metering device)
Data log record	Depends on the report interval

Table 4: Digital outputs

Extra features / functionalities	• External relay control • External relay scheduling • Neutral Detection indication contact

Table 5: Dimensions and environmental specifications

Coverage	ZigBee mesh topology or NB-IoT coverage
Dimensions	25 x 80 x 69.6 (WxHxD) in mm
Operating environment	Temperature: -20°C to 50°C Relative Humidity: 10% to 90% (RH), non-condensing

Apart from the Meazon DinRail 3-phase Advanced NB-IoT submeter described above, Meazon's hardware device portfolio extends also to other products that enable the realization of the concept of the Smart Cities. Some of the products belonging to Meazon's portfolio are listed below.

- **Meazon Janus Gateway**: Meazon Janus is a Linux-based, small form factor powerful State-of-the-Art hub for provisioning, aggregating and backhauling ZigBee or W-Mbus sensor data from Meazon metering and sensor devices to online analytics services (Meazon or 3rd party). Thanks to the user-friendly provisioning web UI (MicroBizy), minimal configuration effort is required even for large scale deployments. Supports various messaging and OSS protocols including Meazon ZigPy for troubleshooting ZigBee networks. Supports SIA protocol for security systems connection and open ADR 2.0, for implementing DR strategies.

Figure 14: Meazon Janus gateway

Meazon Janus supports Meazon MicroBizy, an HTTP User Interface commissioning tool for real time monitoring. Full control of the ZigBee network is also possible including adding, removing and configuring devices plus capability of configuring Janus's network parameters. The gateway, also supports Node-RED a virtual tool for wiring the IoT.

- **Sensors**: Meazon's family of wireless sensors supports sensors for:
  - water;
  - motion;
  - door alarm;

   - temperature; and
   - humidity.

- **Smart Plugs**: Meazon smart plug is used for controlling the power feed on electrical appliances. It connects wirelessly an appliance to the Home Area Network (HAN). It’s an ideal device to plug in appliances such as pc monitors, printers, lighting, coffee makers, water heaters, chargers, air conditions or any other electrical appliance that could be controlled by switching it on and off. Meazon offers smart plugs for Type F, Type N, Type G, Type B, and Type L.

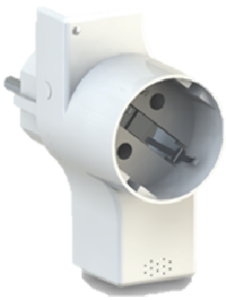


Figure 15: Meazon's smart plug

- **Smart Clamps**: Meazon Zi-Clamp 3ph is a revolutionary self-charging induction meter that combines the benefits of Bizy DinRail wireless networking with plug and play convenience to enable deployment in space- or access-constrained environments. Ideal for large scale deployments where cost of installation and provisioning in-cabinet solutions becomes prohibitive.

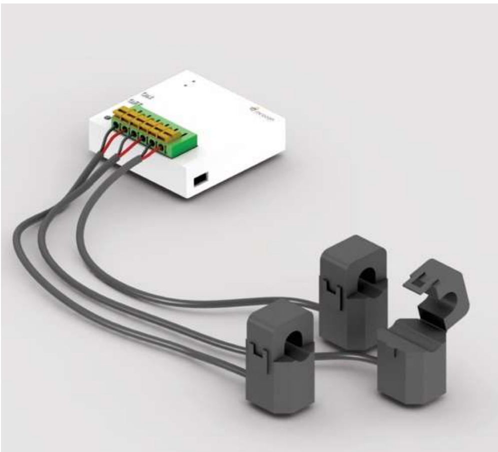


Figure 16: Meazon Zi-Clamp 3ph

Zi-Clamp 3ph is a ground-breaking product for the energy management market due to its very easy installation. It allows a very quick deployment of many devices in order to get a quick audit on cloud or locally, of a building in order to characterize the loads without interrupting the power supply. As there is no need to cut power supply there is no risk for a damage on the DB of the building. Due to its small size it can fit everywhere,while the wireless interface simplifies things further. The energy harvesting from the power line that is measured allows long monitoring periods without the need of maintenance for battery change. Removing the devices is also very easy, fast and simple.

- **Light Controller**: The Light Controller is a device that is going to be developed within the scope of the project. This device will be able to dim and control one or more LED lights inside the building acting (with the energy meters) as the backbone mesh network to connect different types of sensors to measure luminosity, temperature, humidity and anything else that might be needed.
  A high accuracy ambient light digital 16-bit resolution sensor for ambient light detection from 0 lx to about 167 klx will be included in the device.

4.4 Software Services and Energy Analytics

Meazon’s energy analytics platform deploys the latest Information and Communication Technologies (ICT) to offer a robust, secure and expandable tool for operational energy data management. The platform is capable of receiving and exporting multi-structured data sets and sensibly represent this data over a web browser. Meazon utilizes Microsoft Azure [19] to ensure maximum reliability and availability of service. Meazon’s platform is fast, dynamic and secure. Users can manually upload their energy data keeping the same analysis capabilities. Moreover, both iOS and Android applications enable mobile users to access it from anywhere they might be.

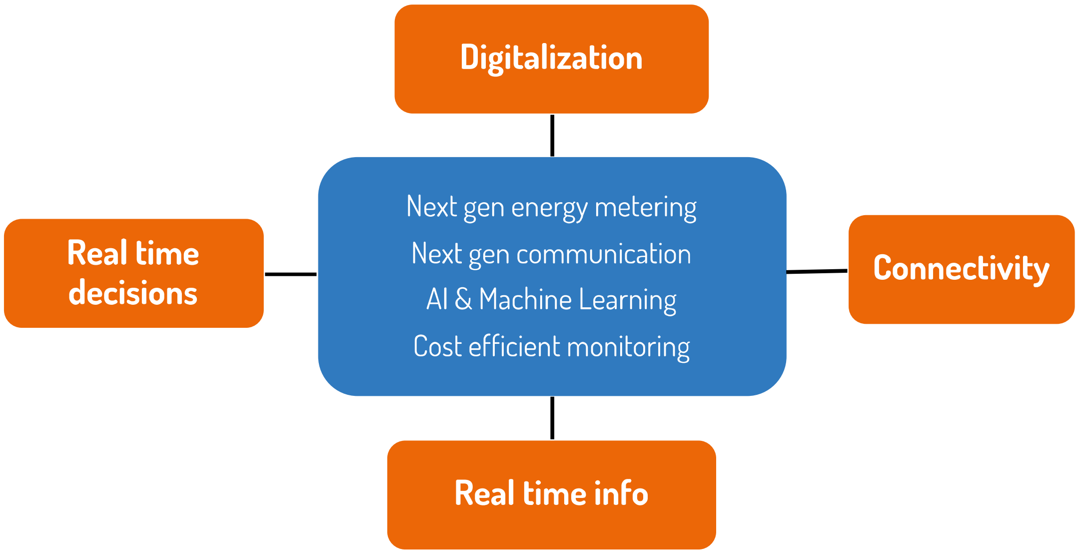


Figure 17: Meazon's cloud platform philosophy

Real time energy management on both user and load level becomes critical for load balancing and energy efficiency reasons. Every energy user and load should potentially be connected and controlled by the grid in real time, providing information of energy consumption, production and control. IoT is the technology that enables real time data to be communicated in real time to and from the loads to central decision points, where energy service providers such as utilities, aggregators and Energy Service COmpanies (ESCOs) process them and provide relevant energy management and efficiency services.

Using Meazon Bizy Analytics SaaS platform, companies and buildings get real-time, meaningful information about the consumption and generation of electrical energy and sensor data. The information is analyzed per appliance, line, phase, site or geographic area. Data can easily be exported for off-line processing in Excel or Business Intelligence systems.

Some of the key feature of Meazon's energy analytics platform are listed below.

- Real time monitoring of consumption/generation/sensor data per location, phase, line and appliance.
- Comparison and aggregation of time series data across metrics, devices, phases, and locations.
- Customizable notifications and alarms by SMS or email when thresholds are exceeded.
- Advanced "intelligent" reporting with regression modelling, auditing, data heat maps, load profiling.

- Model baselines and PV net metering.
- Available on web, iOS, and Android.

5. Pilot Implementation

5.1 Installation of smart meters in RWG's buildings

With the completion of the 1st phase the following were determined: the installation locations of the 28 3-phase meters to electrical panels, the 11 bizy plugs and 15 Janus Gateways, as well as the necessary materials for the corresponding installation and interconnection.

In the 2nd phase of the project, a pilot installation of smart energy consumption meters was performed by Meazon S.A., at buildings of RWG. More specifically, the buildings that were selected are involved in the Prefecture of Achaia, Ileia and Aitoloakarnania.

Detailed tables are listed for each of the selected buildings in the Appendix at the end of the document. The tables contain the following information: the number, type, serial number and MAC address of smart devices, as well as the required side materials needed for connecting the meters to the existing network, plugs, or network ports nearby.

5.2 Energy profile extraction in RWG buildings

After the smart meters' installation, energy measurements are gathered in real-time. A first screening of the data from different buildings is followingly performed in order to identify the energy profile of each building.

In detail, for each smart meter of type *DinRail* we extract the following three kinds of figures:

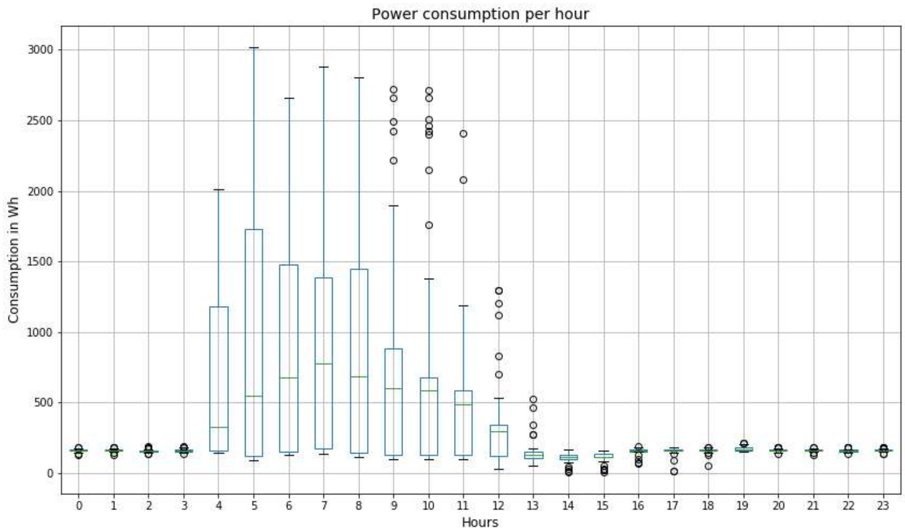
i. A box plot of the hourly consumption, indicating the range of the consumed energy across all days for each hour of the day
ii. The hourly consumption from the day we started monitoring each building up to now.
iii. A histogram of the mean daily consumption per weekday

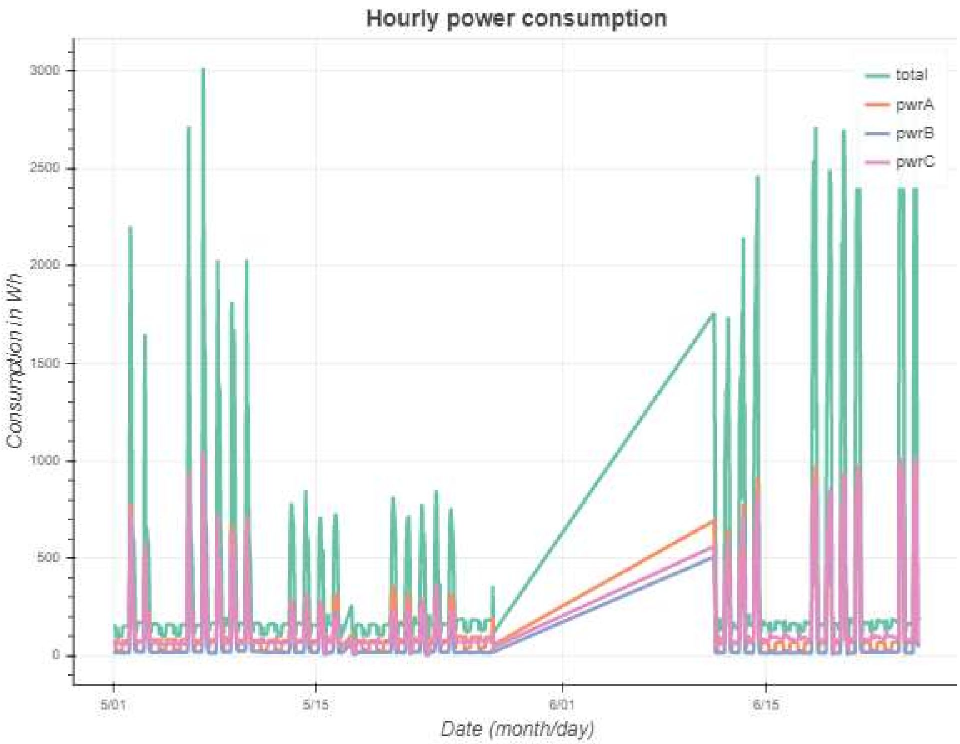
It should be noted here that there are cases where the meters might stop measuring for a certain amount of time (e.g. for some hours) due to technical issues, thus there are empty measurements in the corresponding dates.

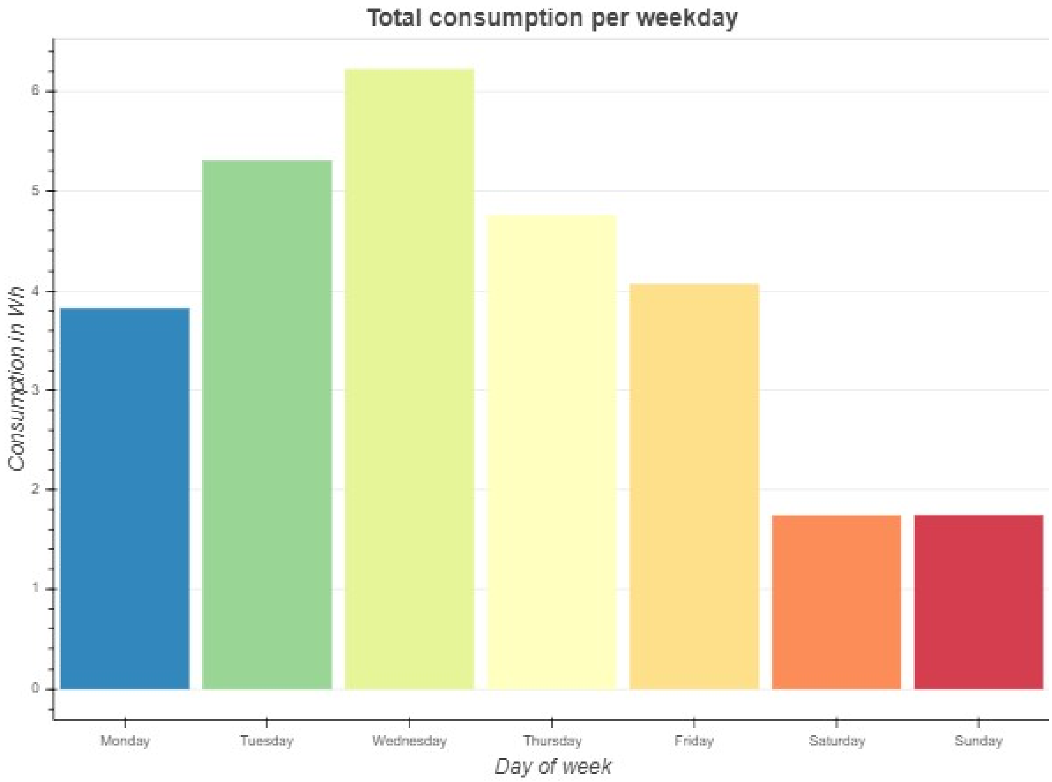
We first present the above figures for all buildings for which we have acquired data, then we discuss the summarized results from the screening to get a sense of the buildings' profile.

The corresponding figures for each building are depicted below:

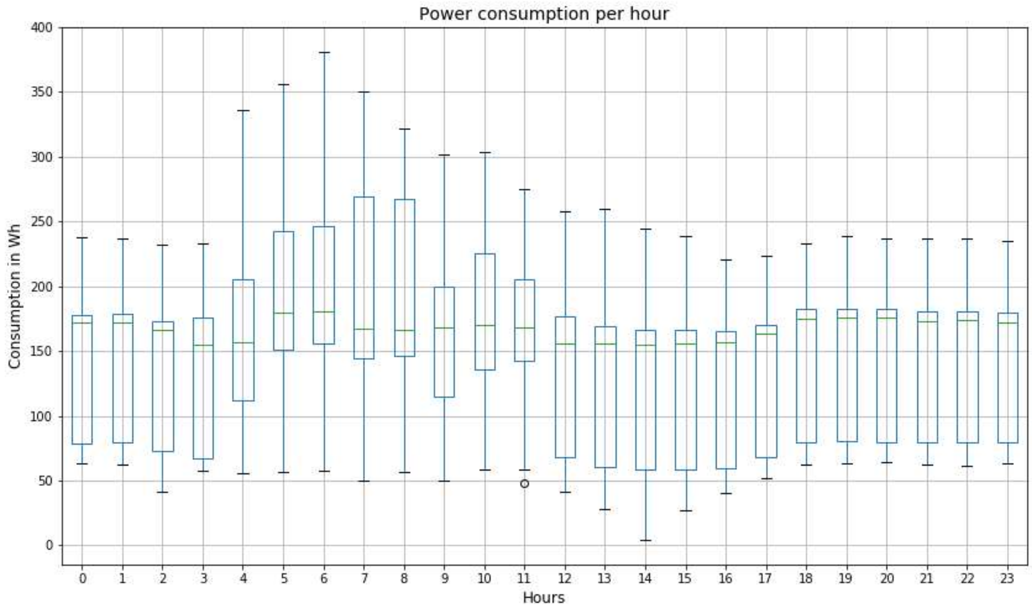
1. *Directorate of Agricultural Economy and Veterinary Medicine*

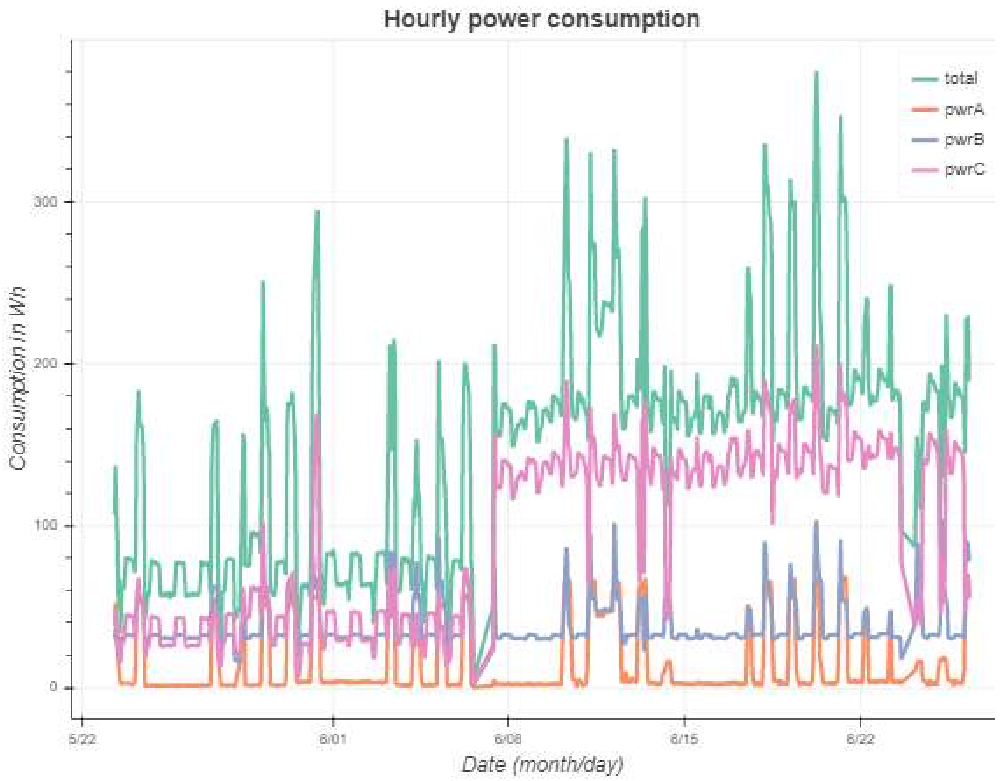


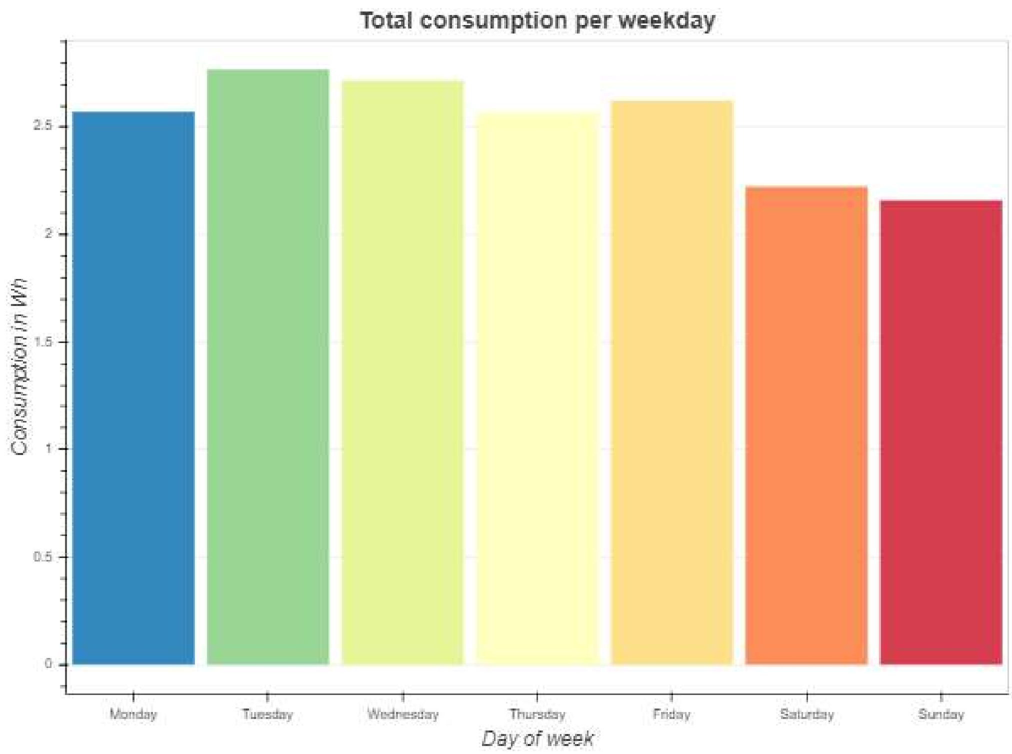




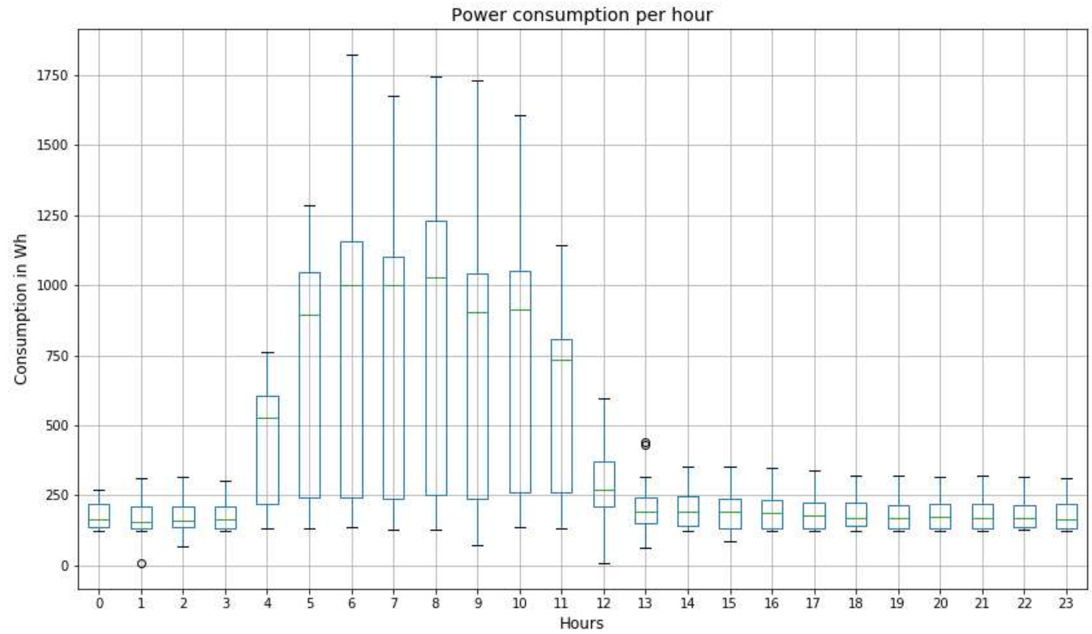
2. Directorate of Transport, Shipping & Communications of Ileia Prefecture

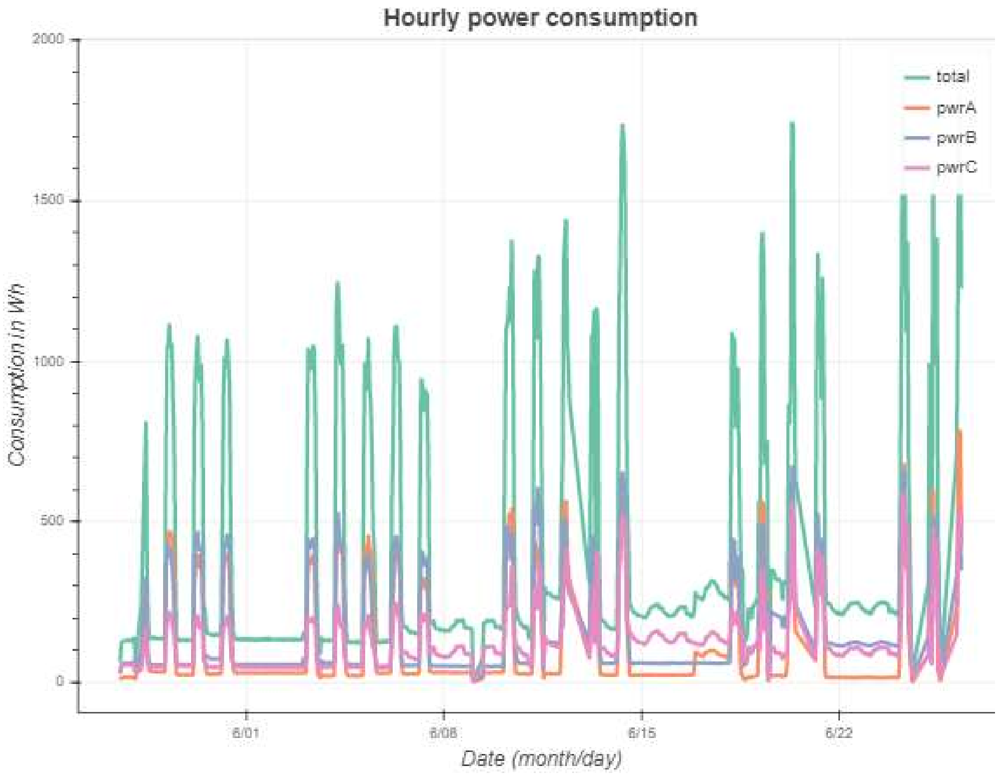


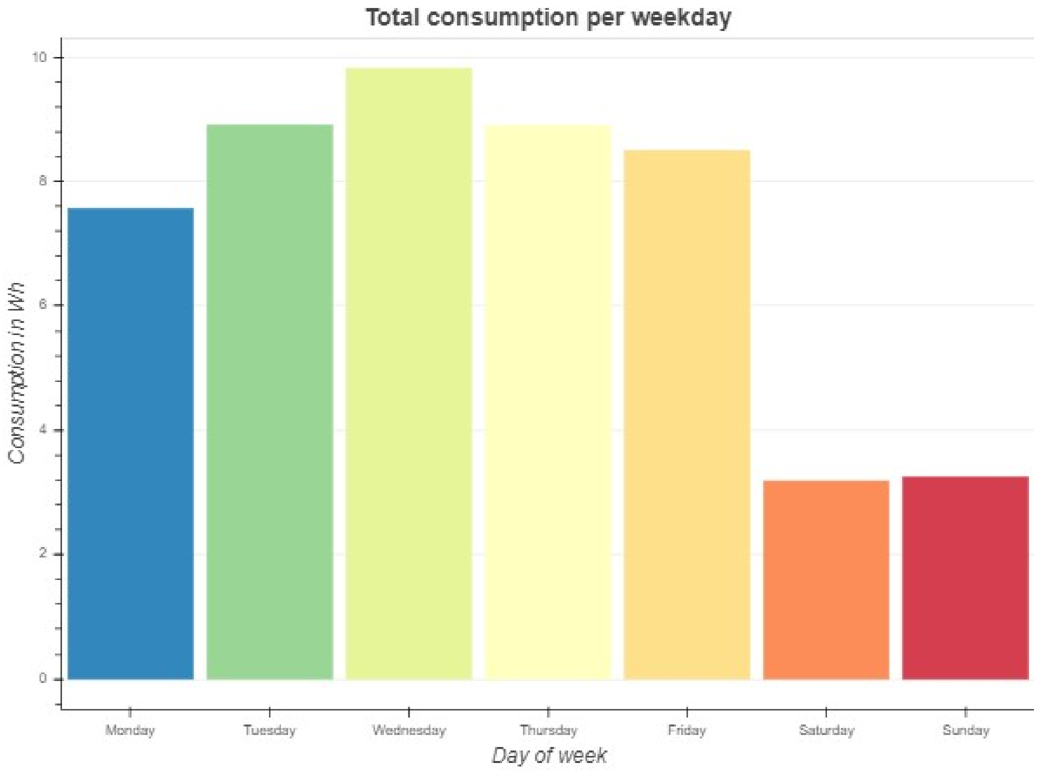

Hourly power consumption
Consumption in Wh
Date (month/day)
total
pwrA
pwrB
pwrC
0
100
200
300
5/22
6/01
6/08
6/15
6/22


Total consumption per weekday
Consumption in Wh
Day of week
0
0.5
1
1.5
2
2.5
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday

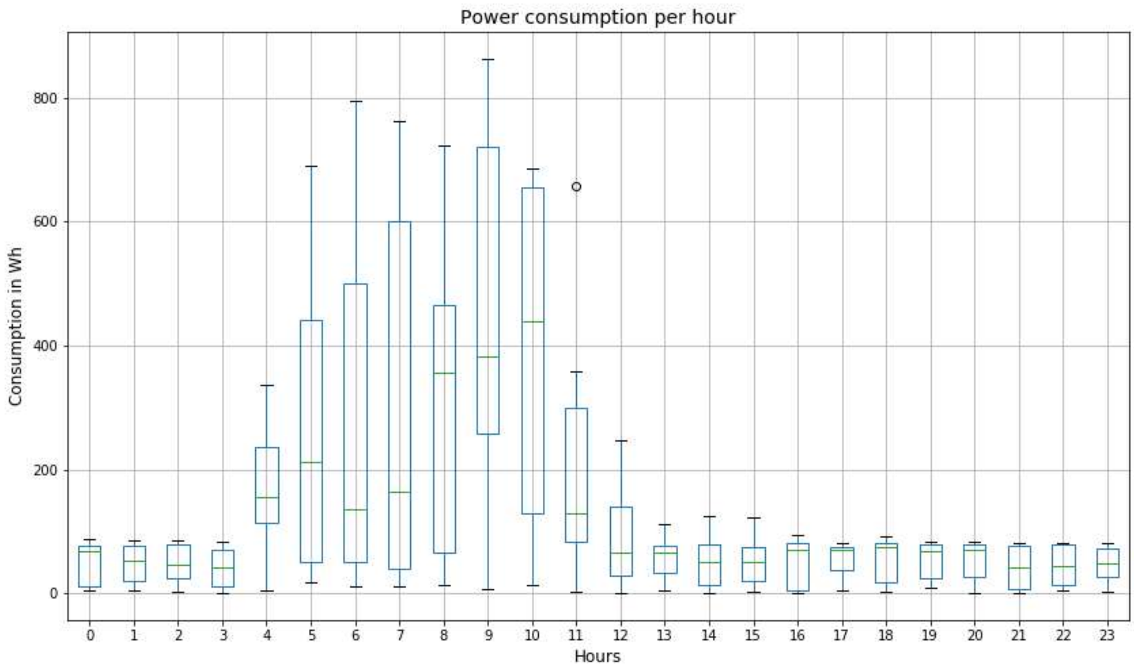
3. Directorates of Transport, Shipping & Communications of Achaia Prefecture

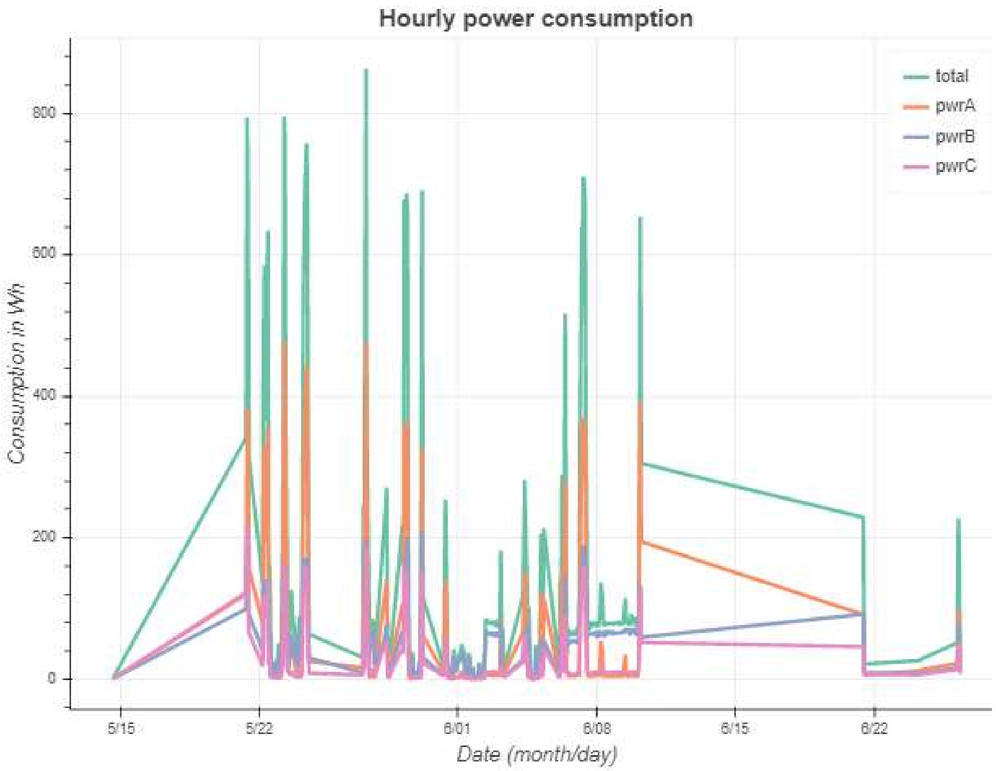


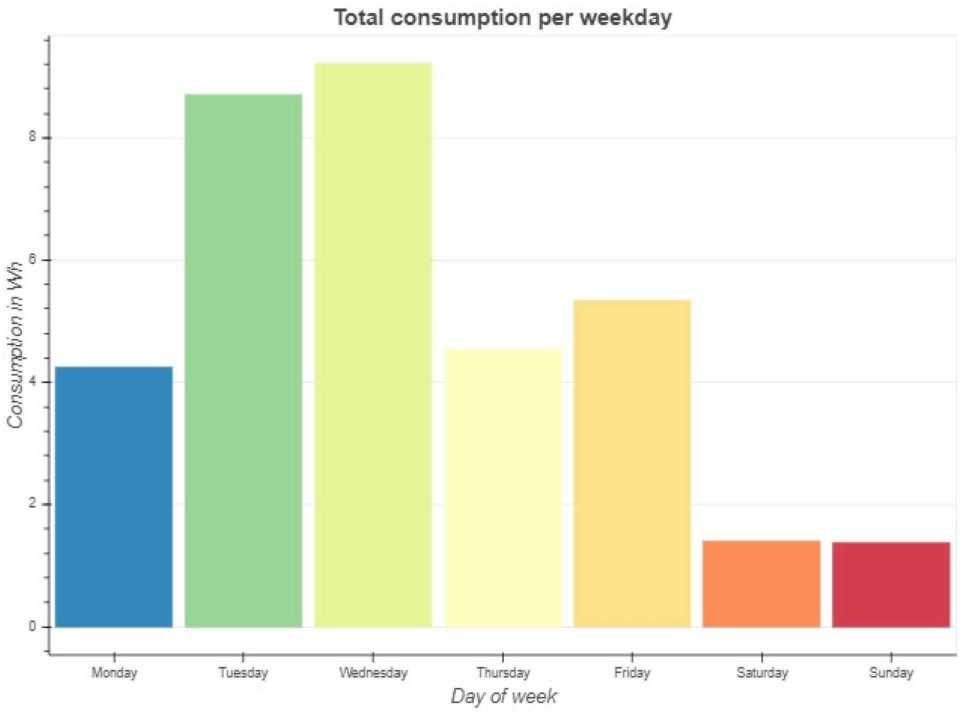




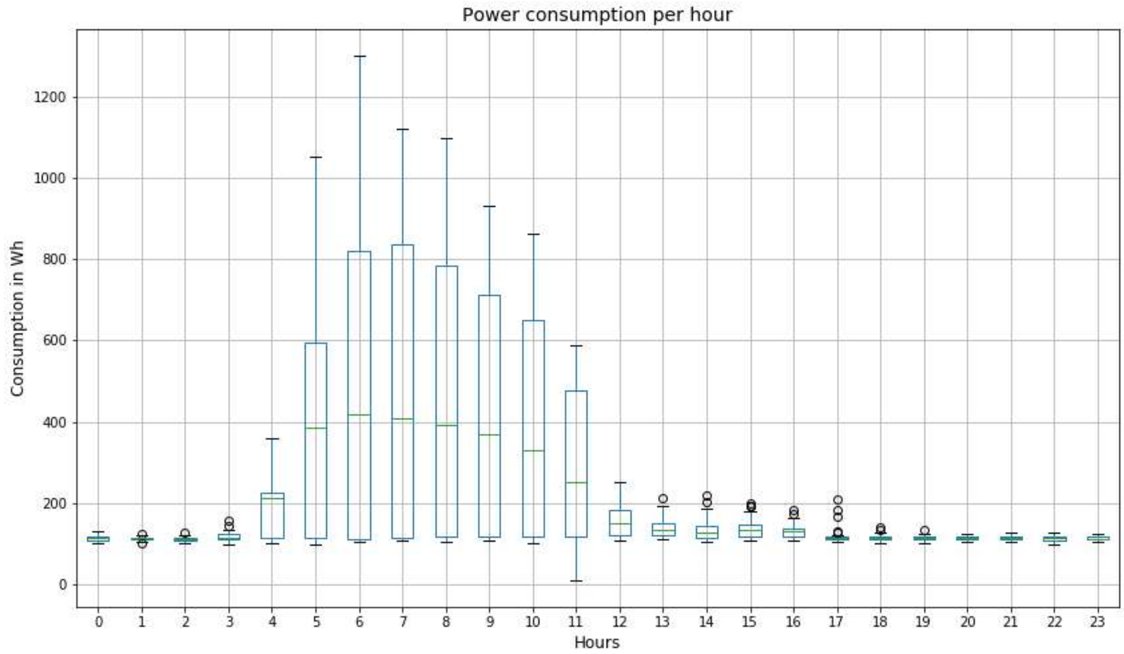
4. *Directorate of Engineering Constructions*

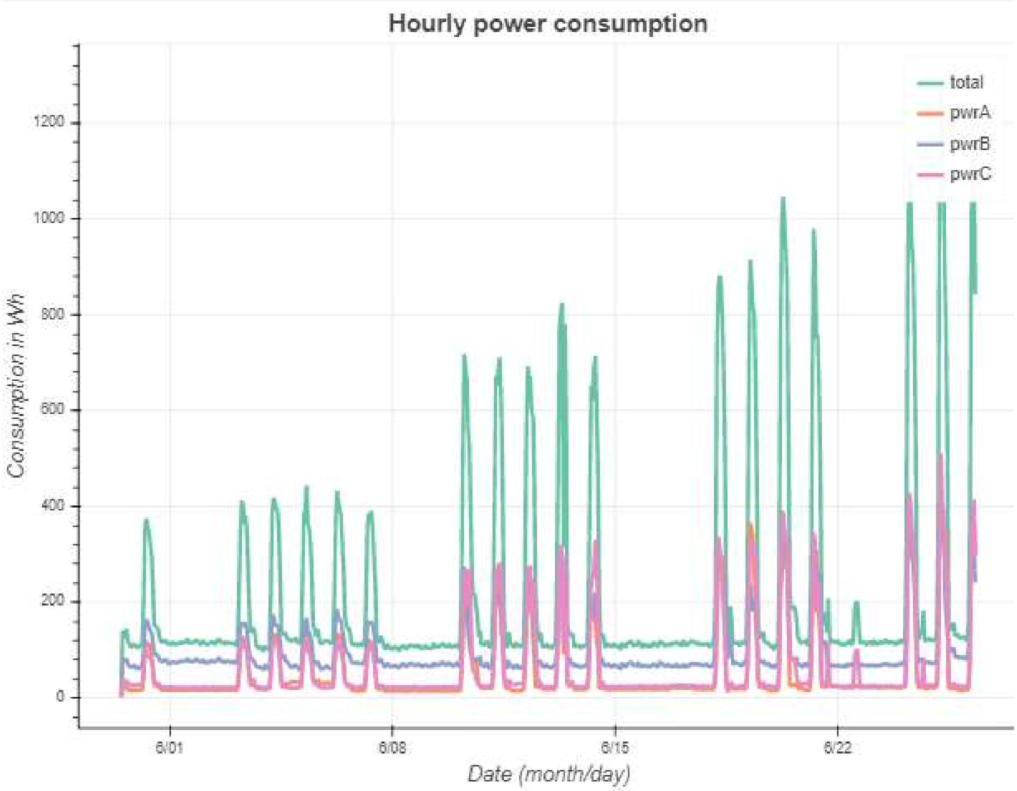


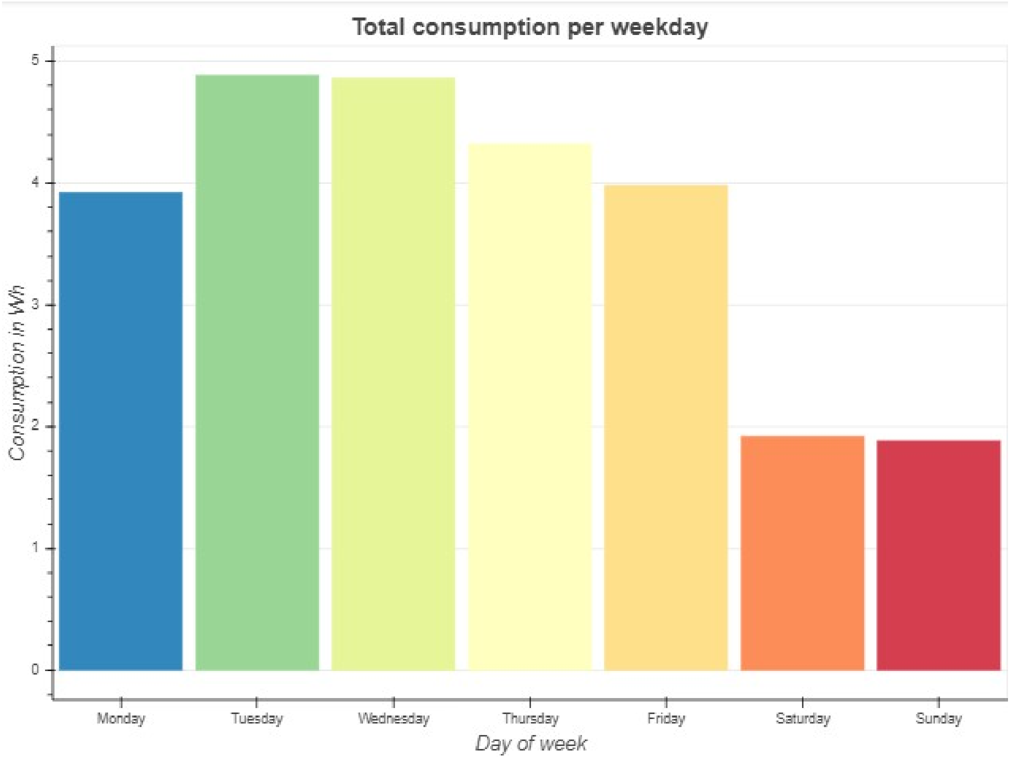

Hourly power consumption
total
pwrA
pwrB
pwrC
Consumption in Wh
0
200
400
600
800
5/15
5/22
6/01
6/08
6/15
6/22
Date (month/day)


Total consumption per weekday
Consumption in Wh
0
2
4
6
8
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of week

5. Directorate of Public Health and Social Welfare

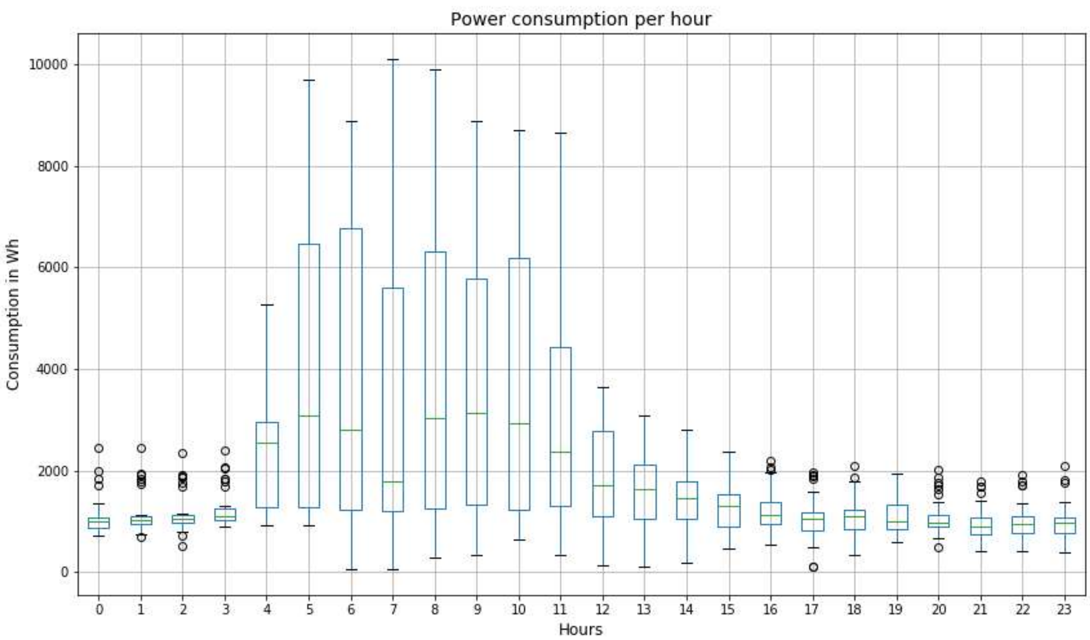


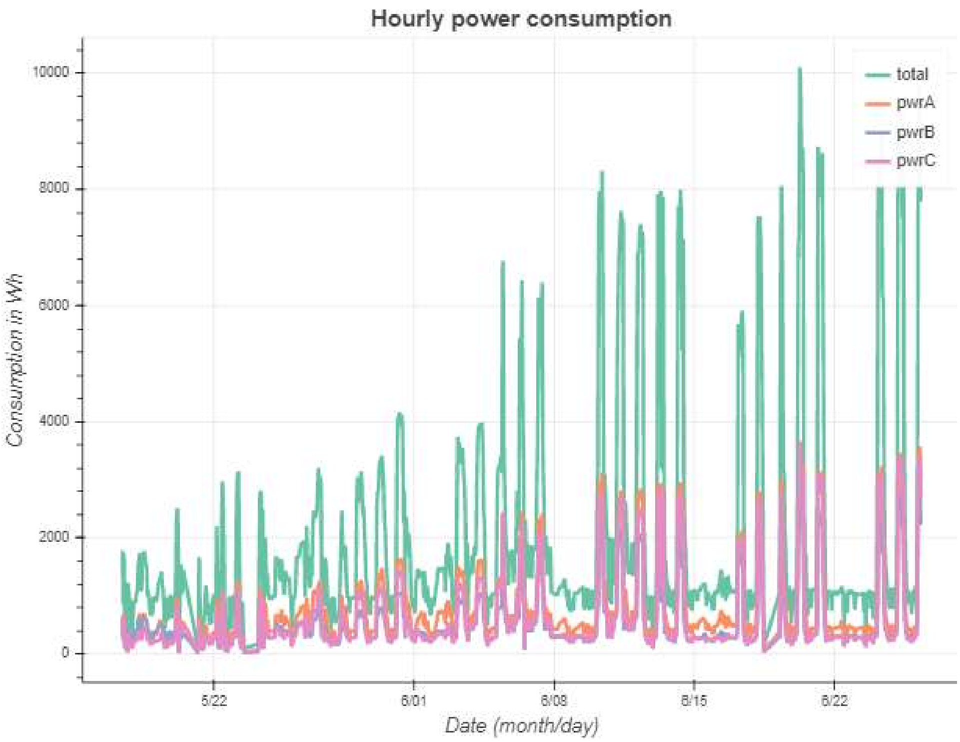


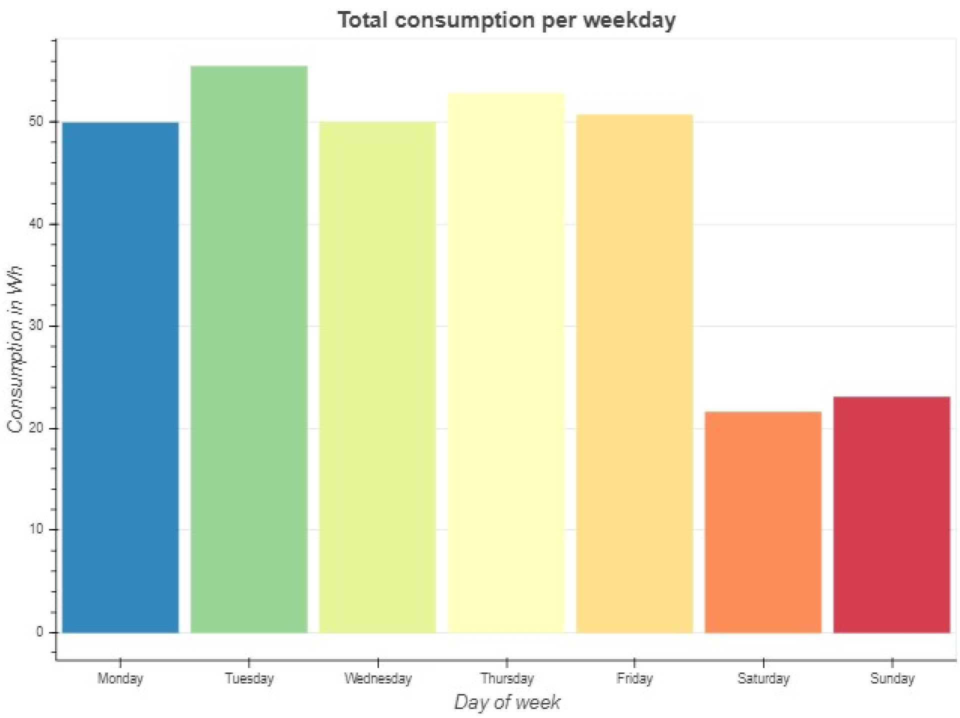


6. Central Directorates ofRWG of Achaia Prefecture

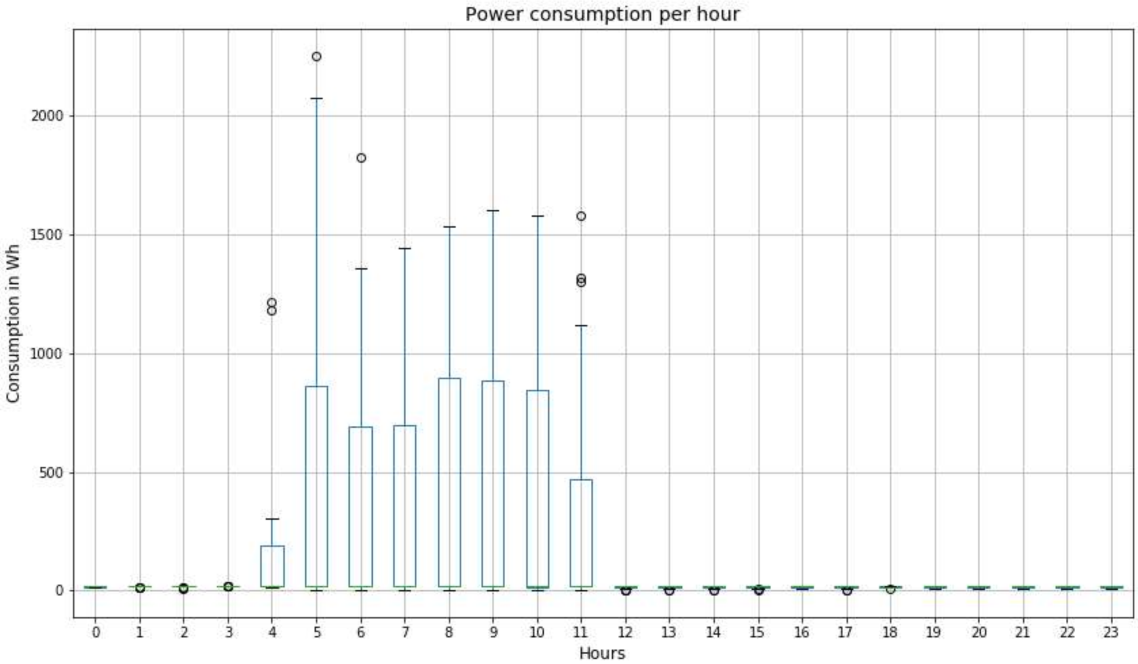
i) 1st submeter

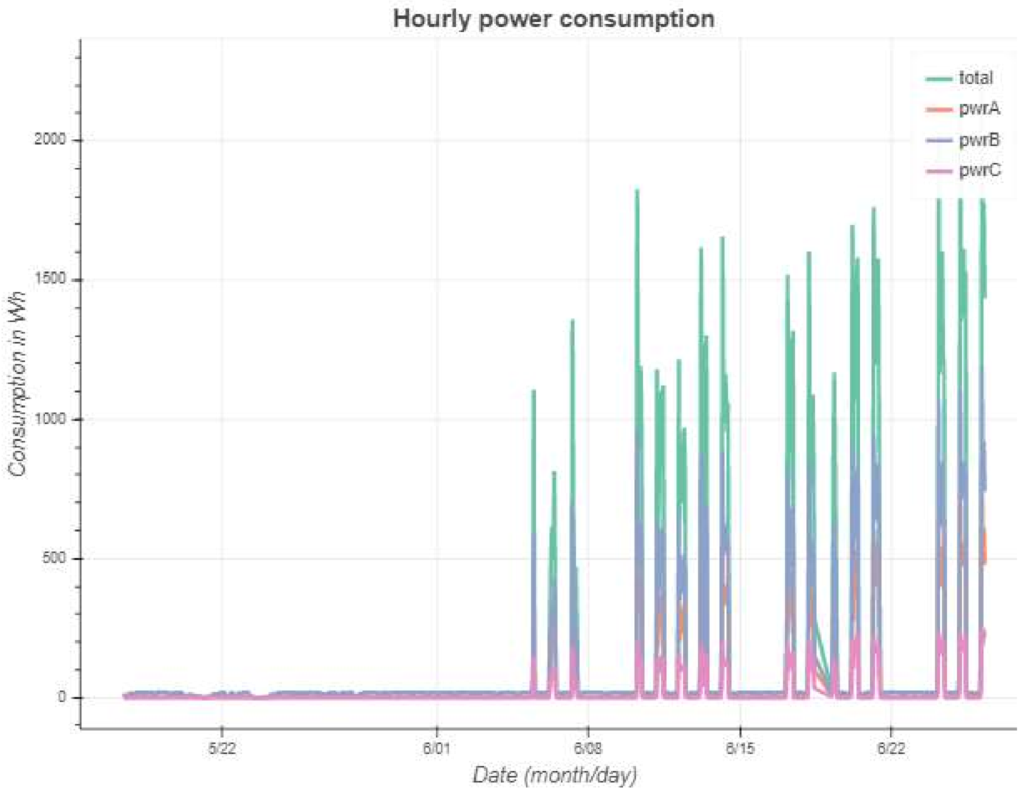


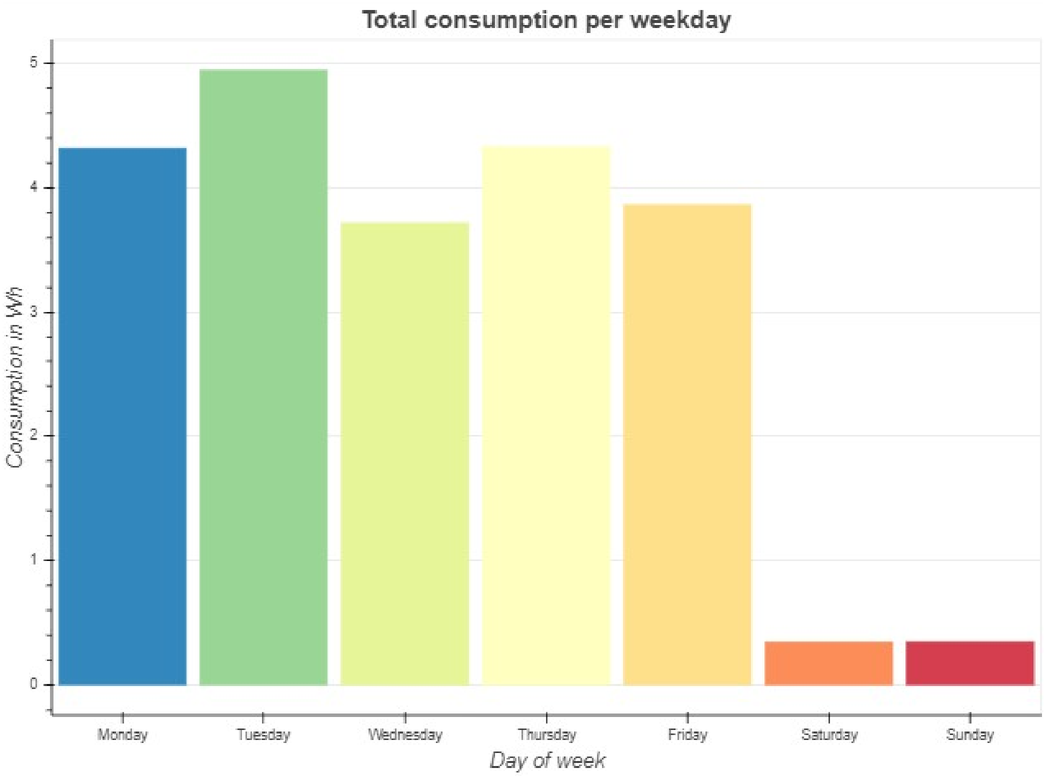

Hourly power consumption
total
pwrA
pwrB
pwrC
Consumption in Wh
10000
8000
6000
4000
2000
0
5/22
6/01
6/08
6/15
6/22
Date (month/day)


Total consumption per weekday
Consumption in Wh
50
40
30
20
10
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of week

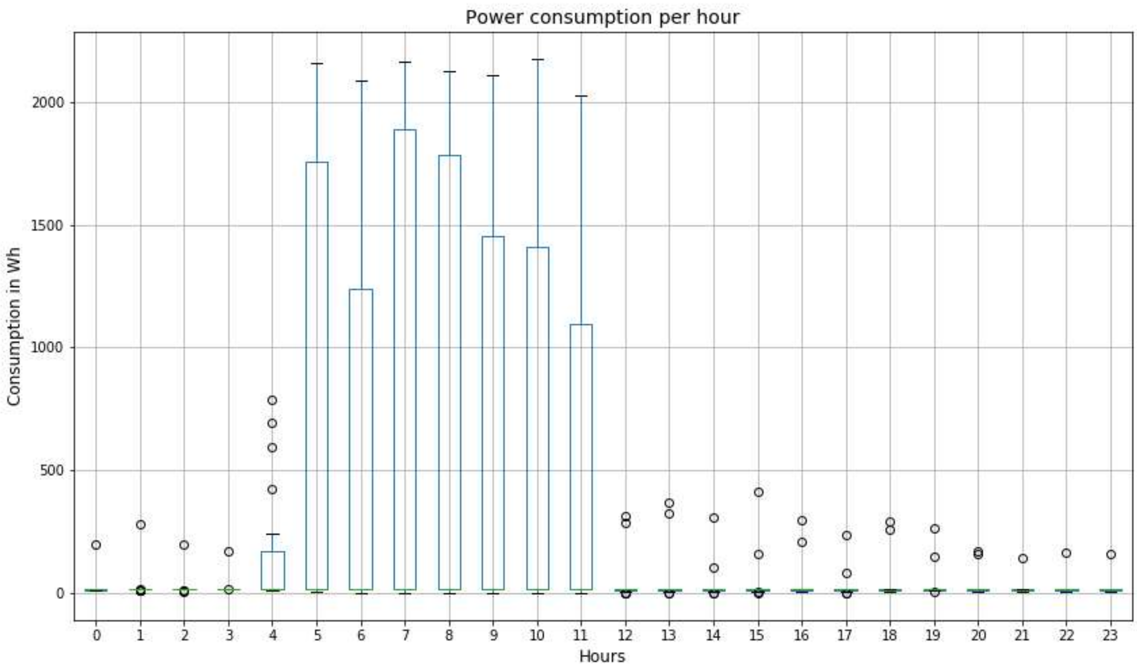
ii) 2nd submeter

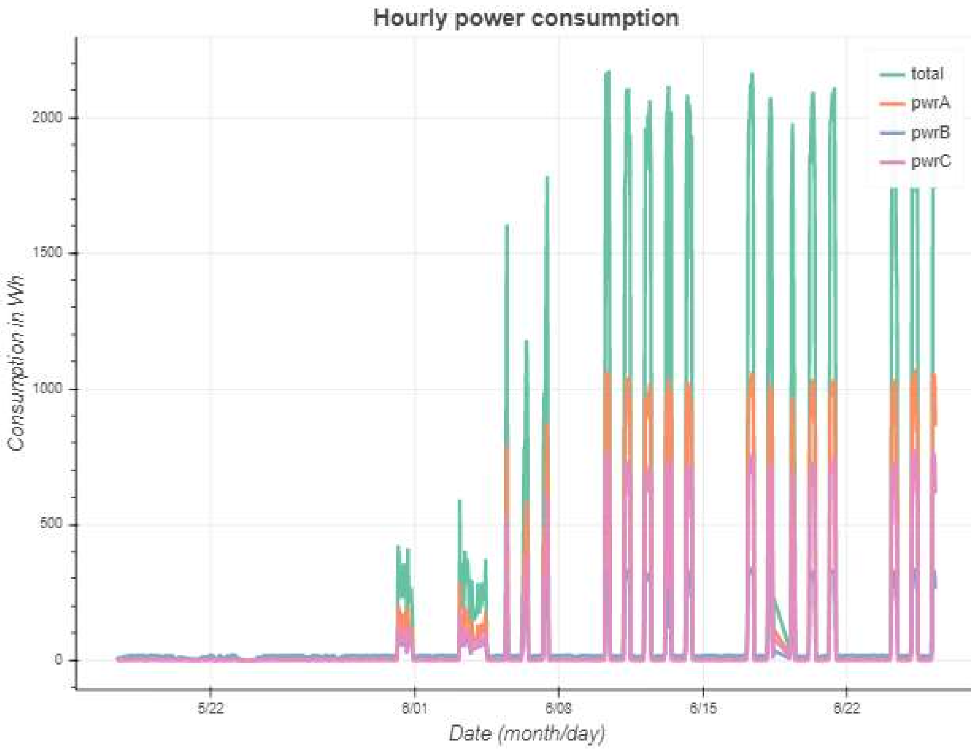


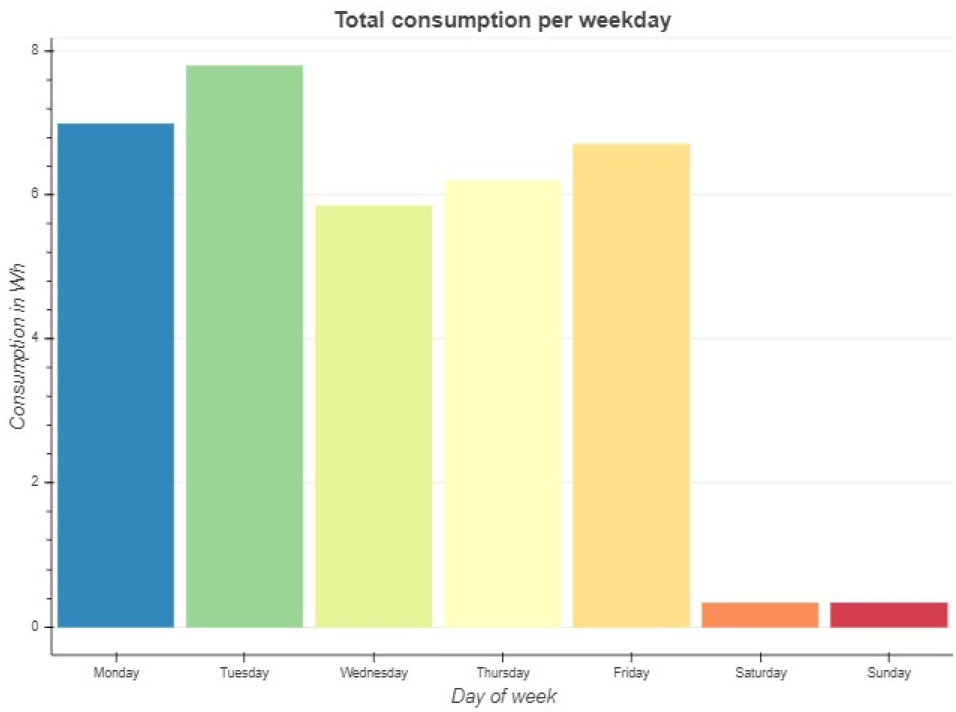




iii) 3rd submeter

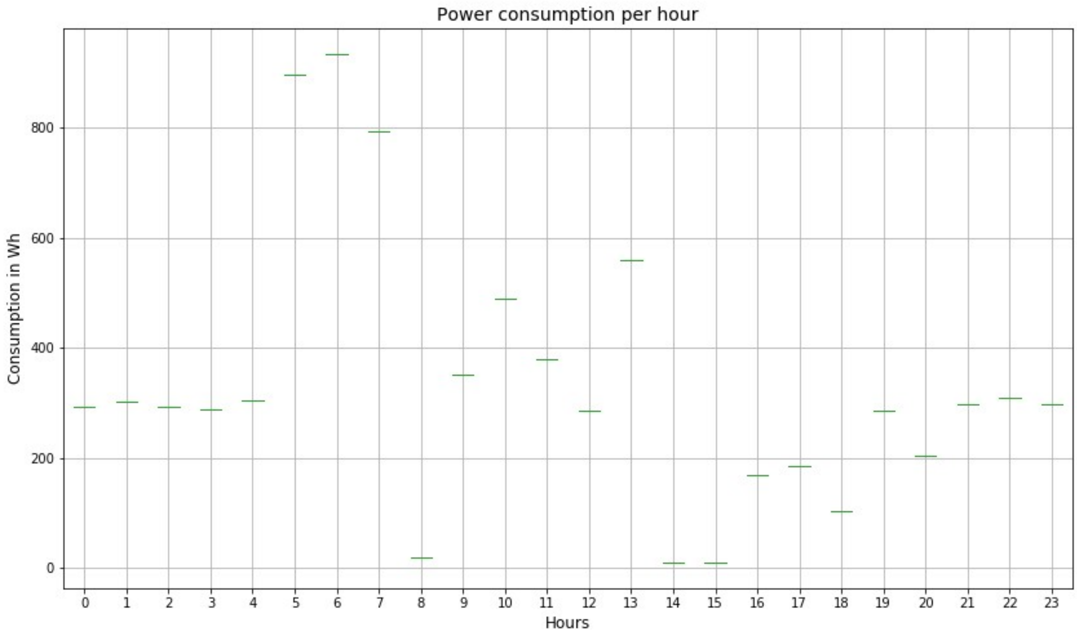


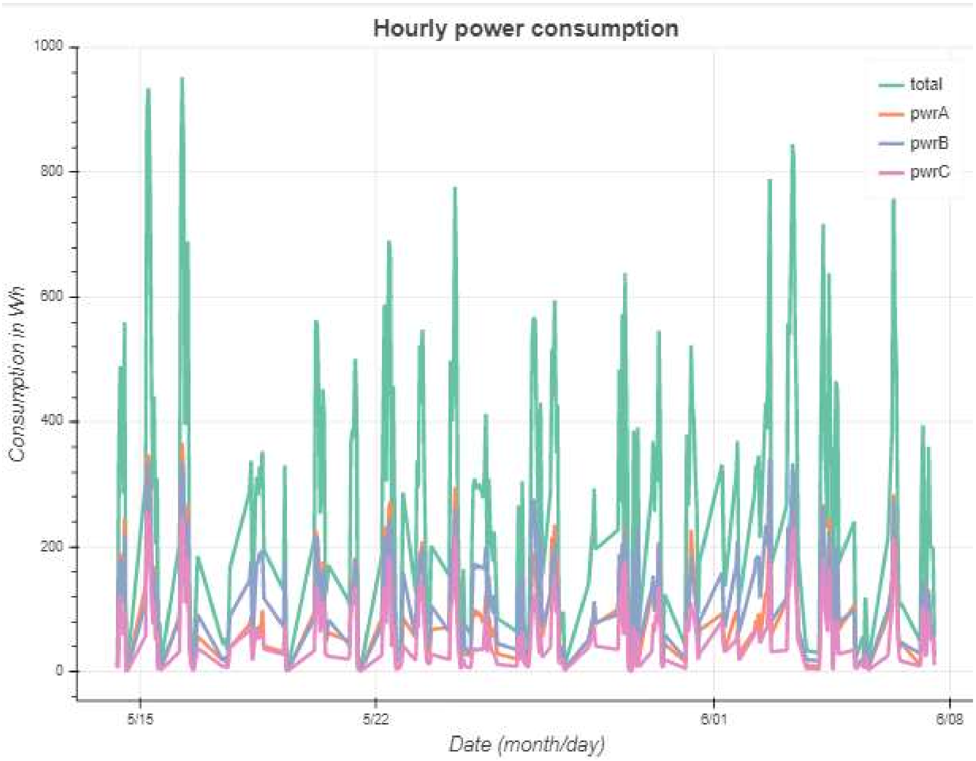

Hourly power consumption
total
pwrA
pwrB
pwrC
2000
1500
1000
500
0
Consumption in Wh
5/22
6/01
6/08
6/15
6/22
Date (month/day)

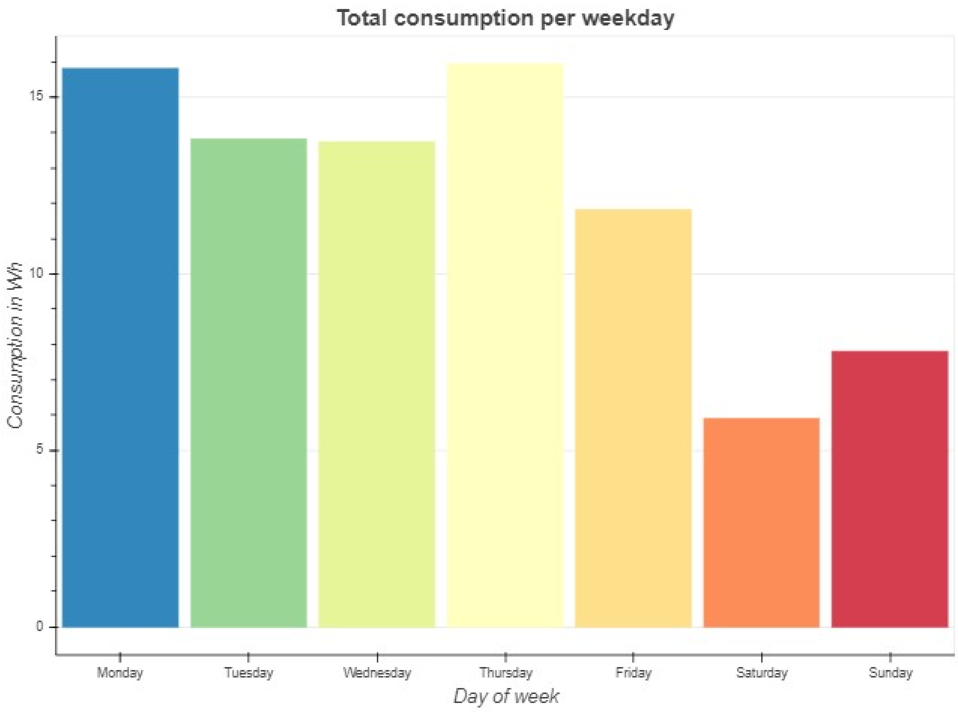

Total consumption per weekday
8
6
4
2
0
Consumption in Wh
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of week

7. *Building of Head of Regionand Directorates of RWG*

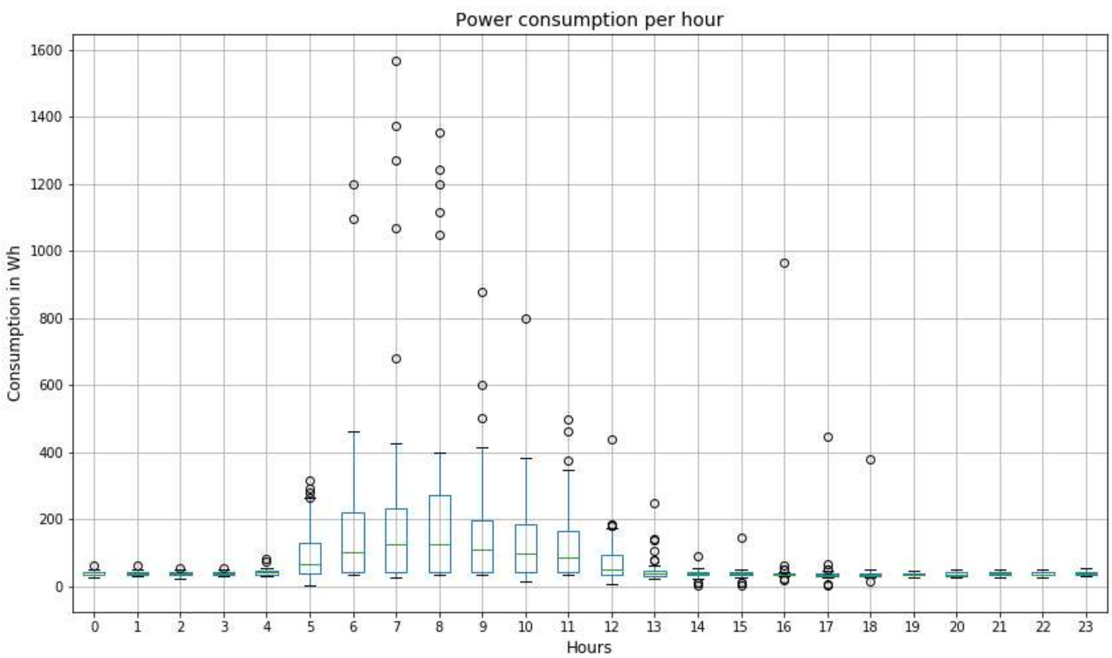
   i) *1st submeter*

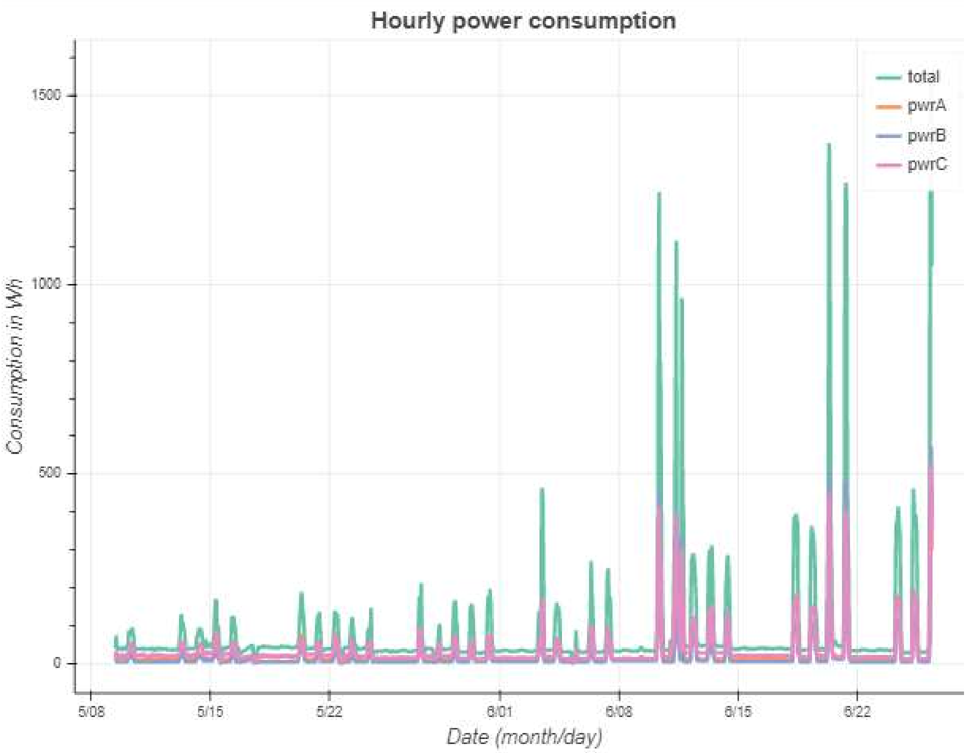


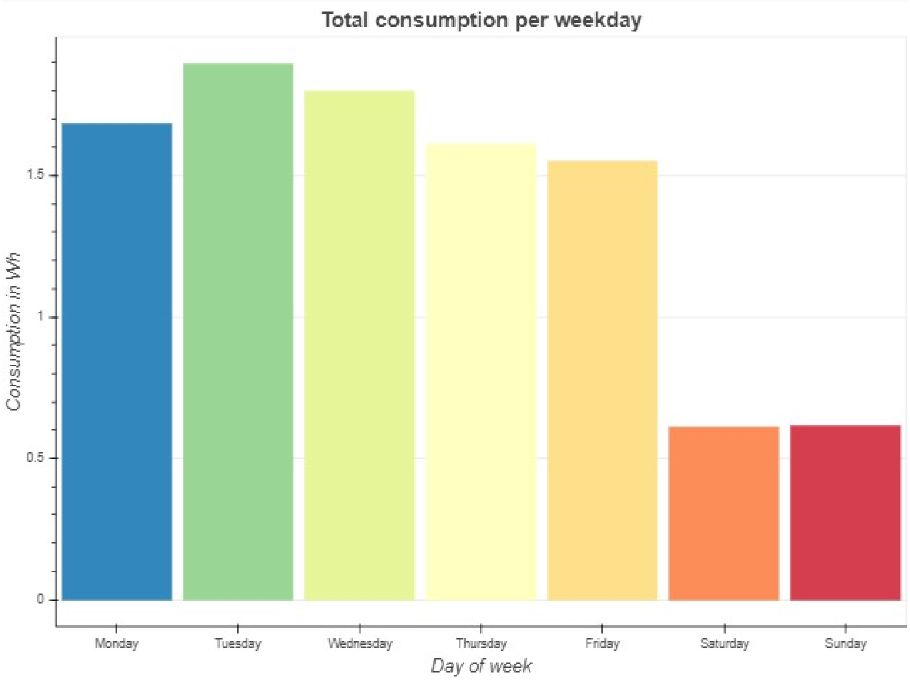




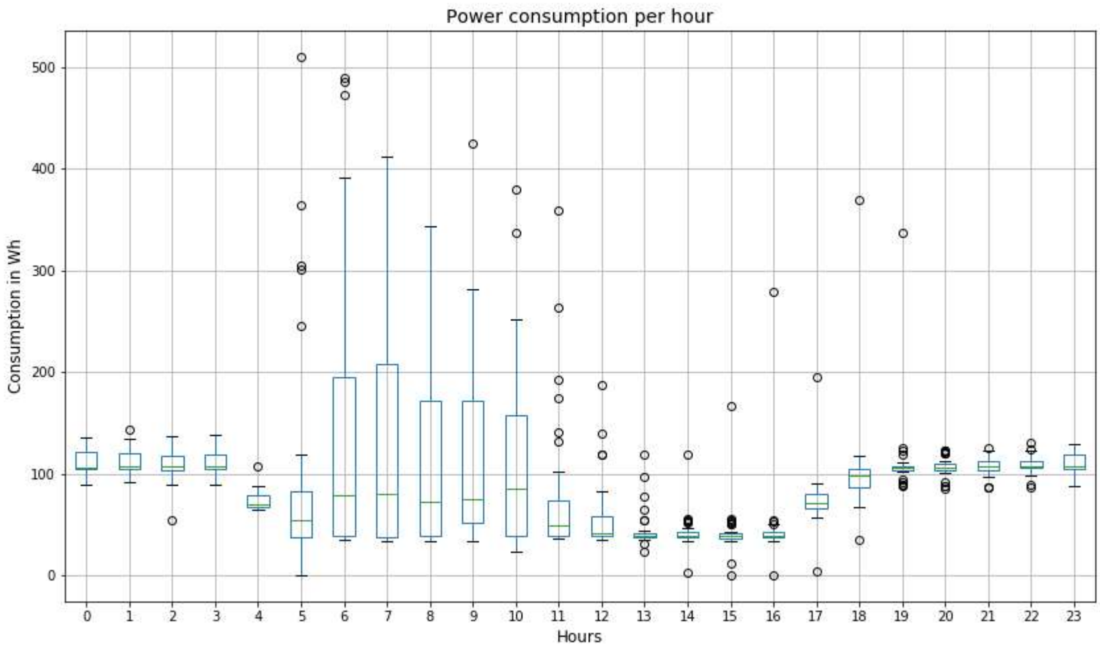
ii) 2nd submeter

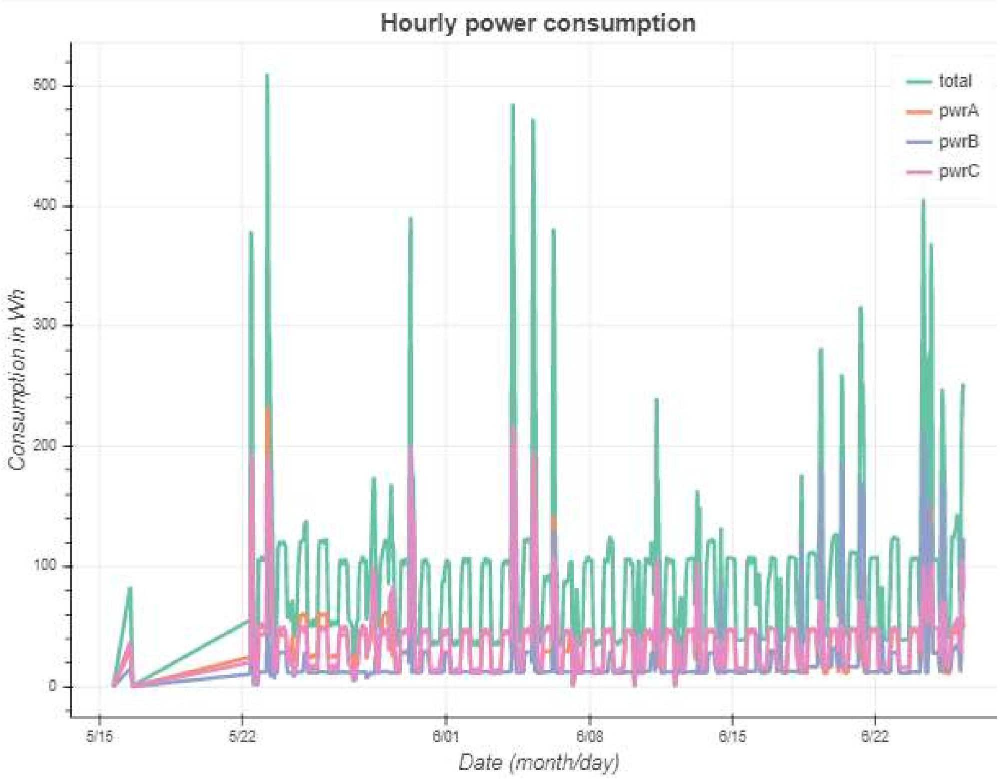


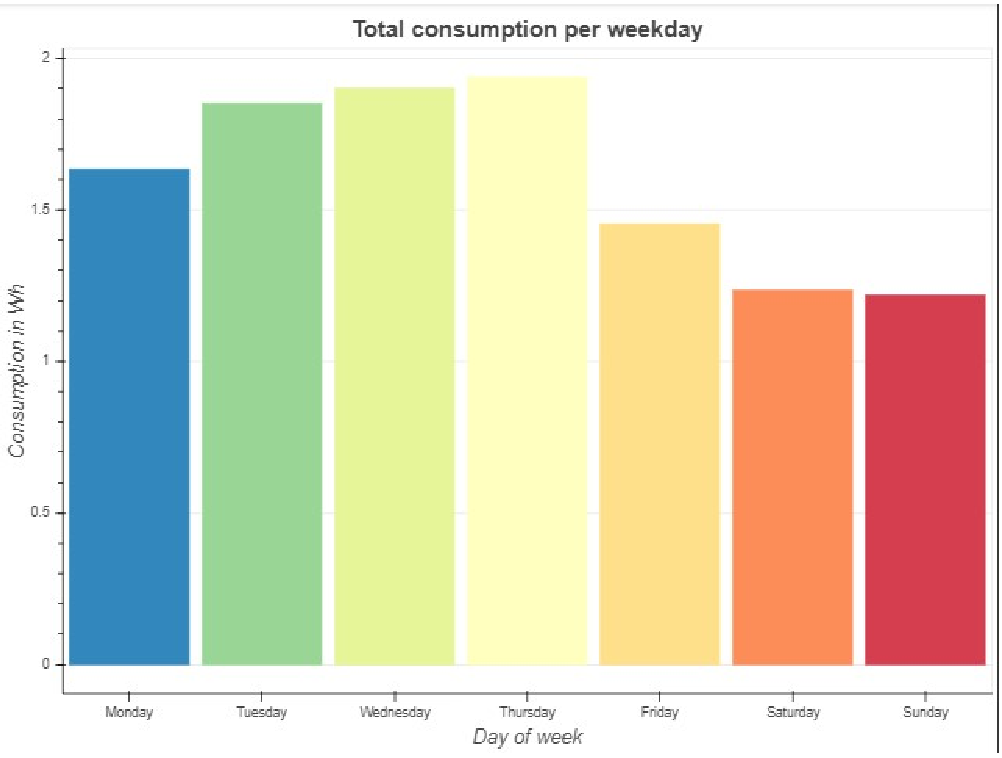

Hourly power consumption
total
pwrA
pwrB
pwrC
1500
1000
500
0
Consumption in Wh
5/08
5/15
5/22
6/01
6/08
6/15
6/22
Date (month/day)


Total consumption per weekday
1.5
1
0.5
0
Consumption in Wh
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of week

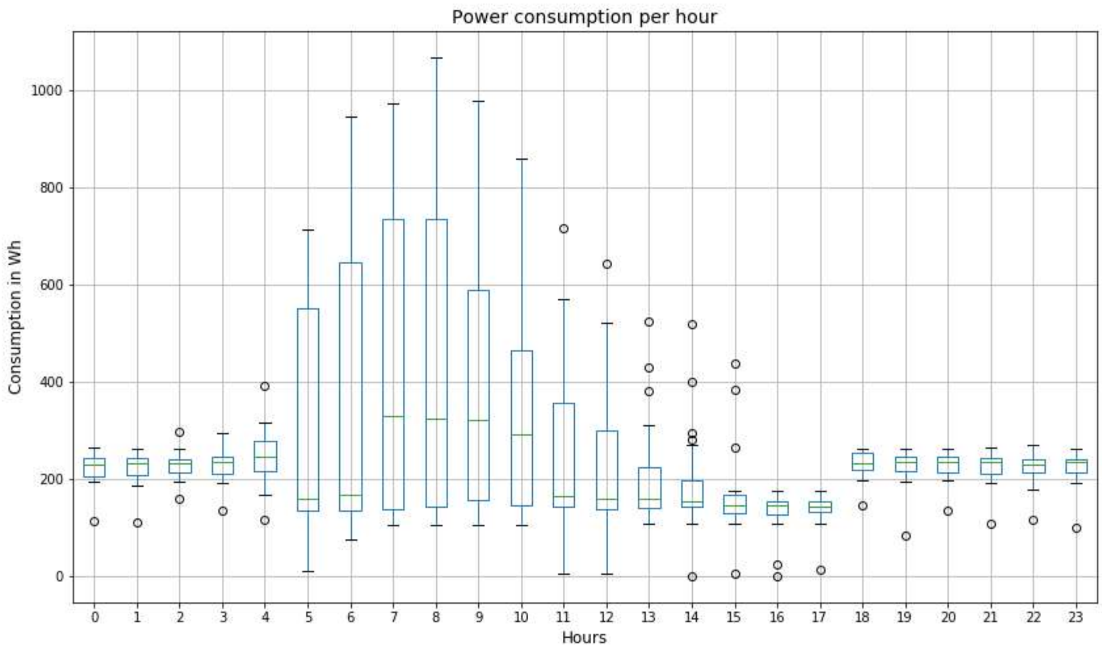
8. Experimental High Schoolof University of Patras(Secondary School)

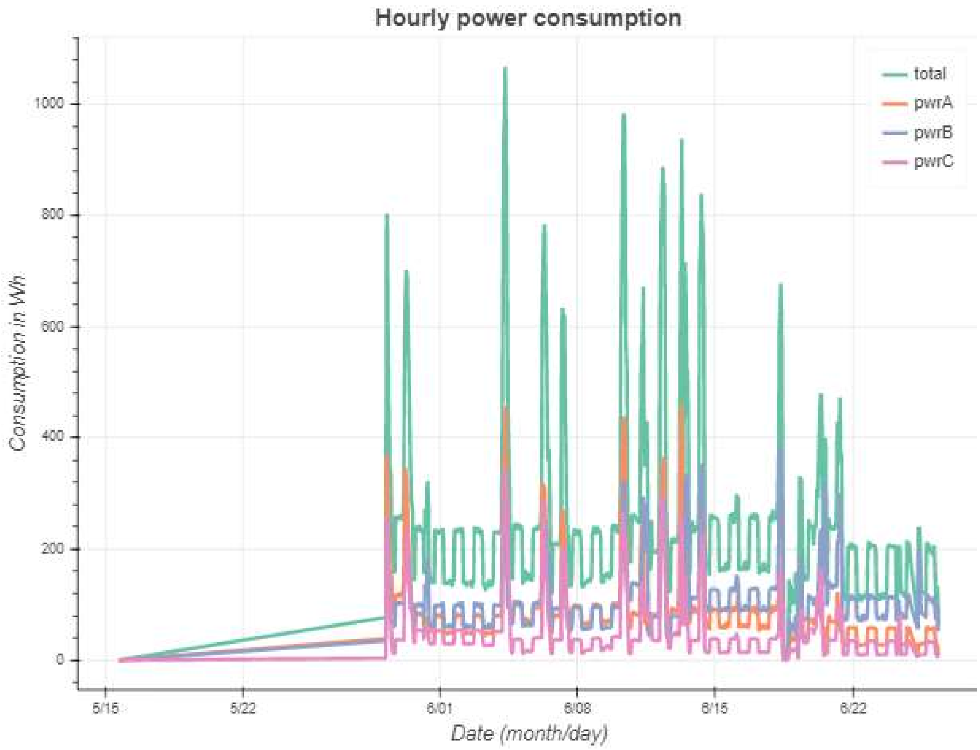


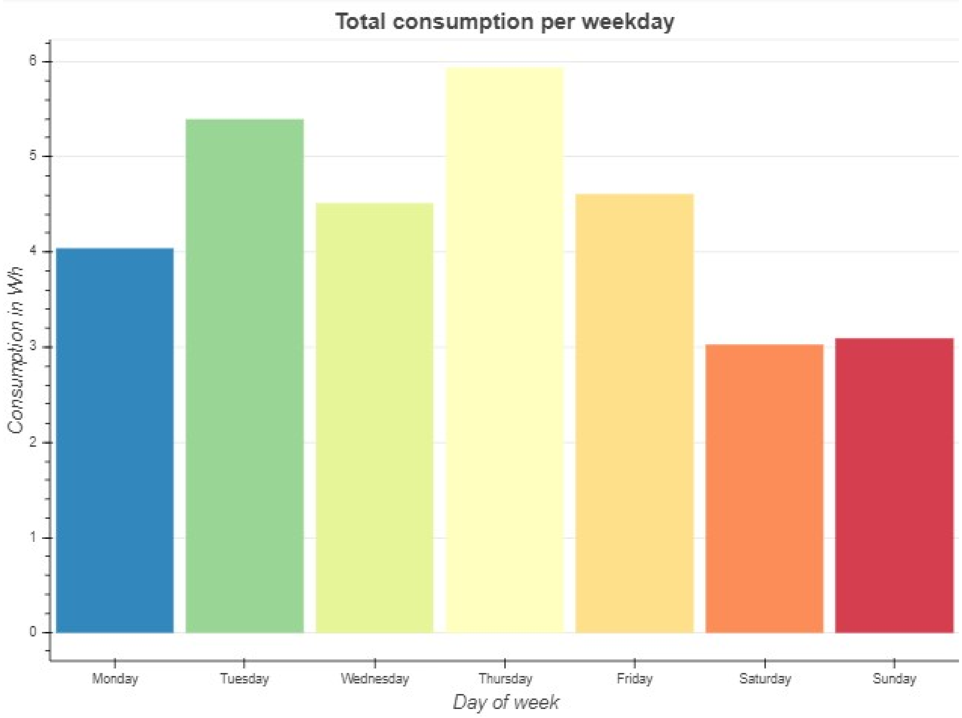




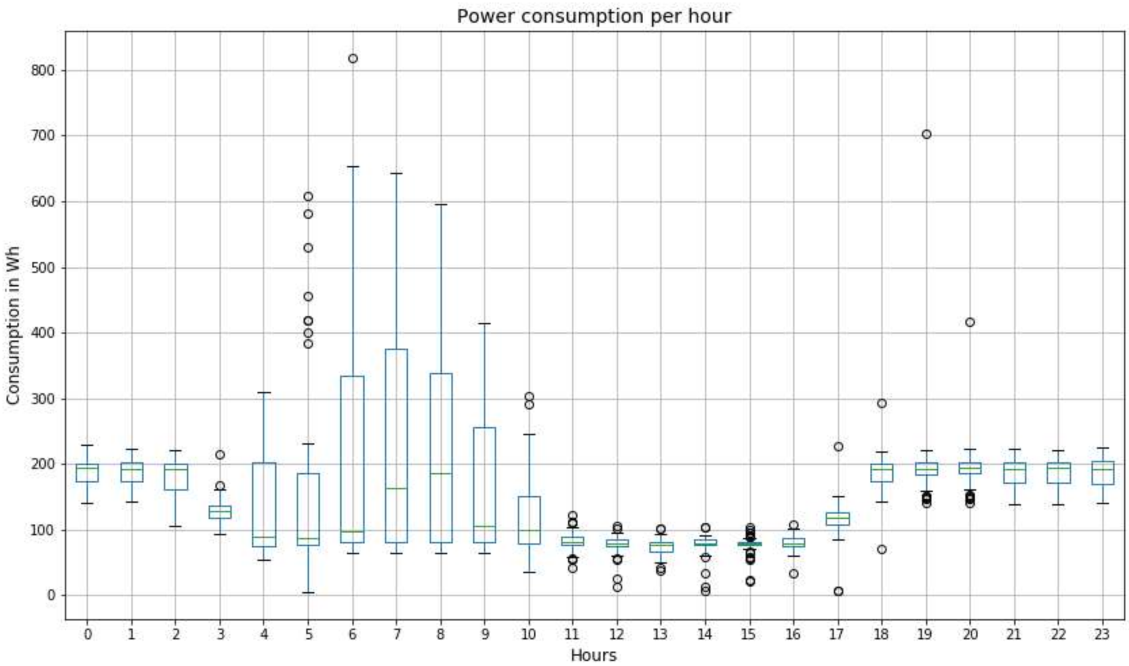
9. Experimental Schoolof University of Patras(Primary School)

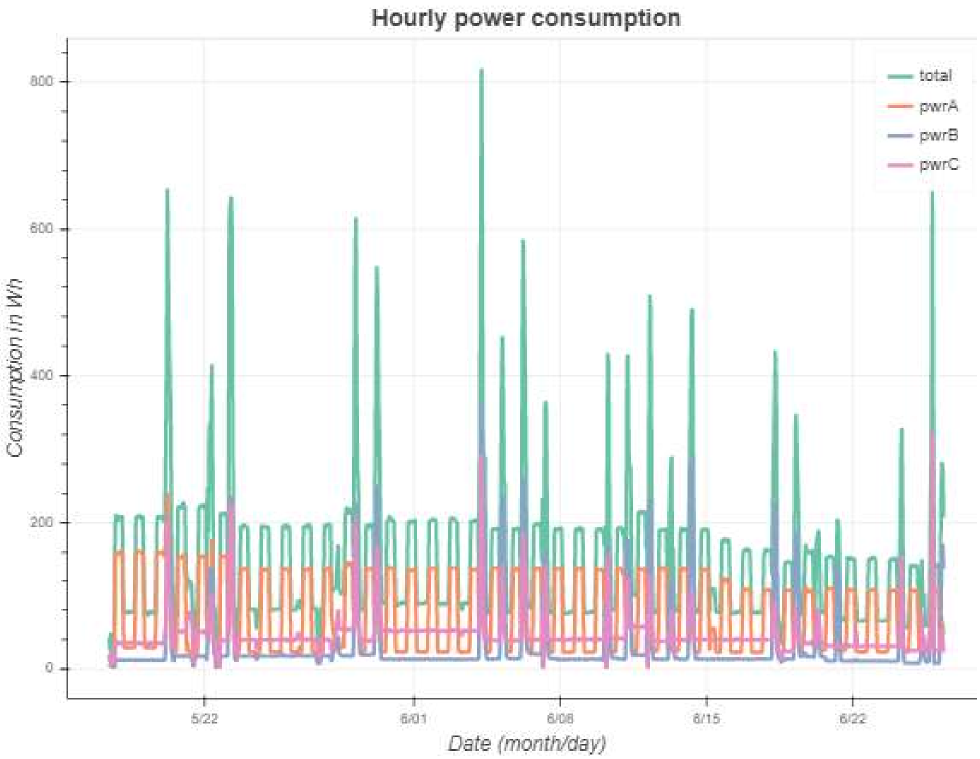


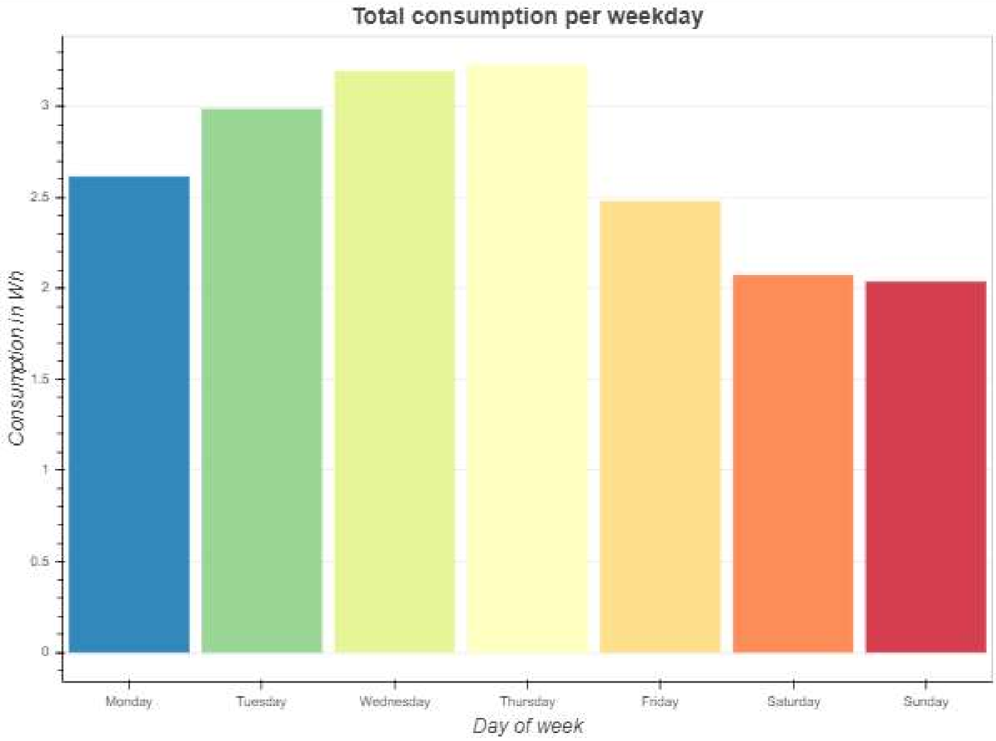

Hourly power consumption
total
pwrA
pwrB
pwrC
1000
800
600
400
200
0
Consumption in Wh
5/15
5/22
6/01
6/08
6/15
6/22
Date (month/day)


Total consumption per weekday
6
5
4
3
2
1
0
Consumption in Wh
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of week

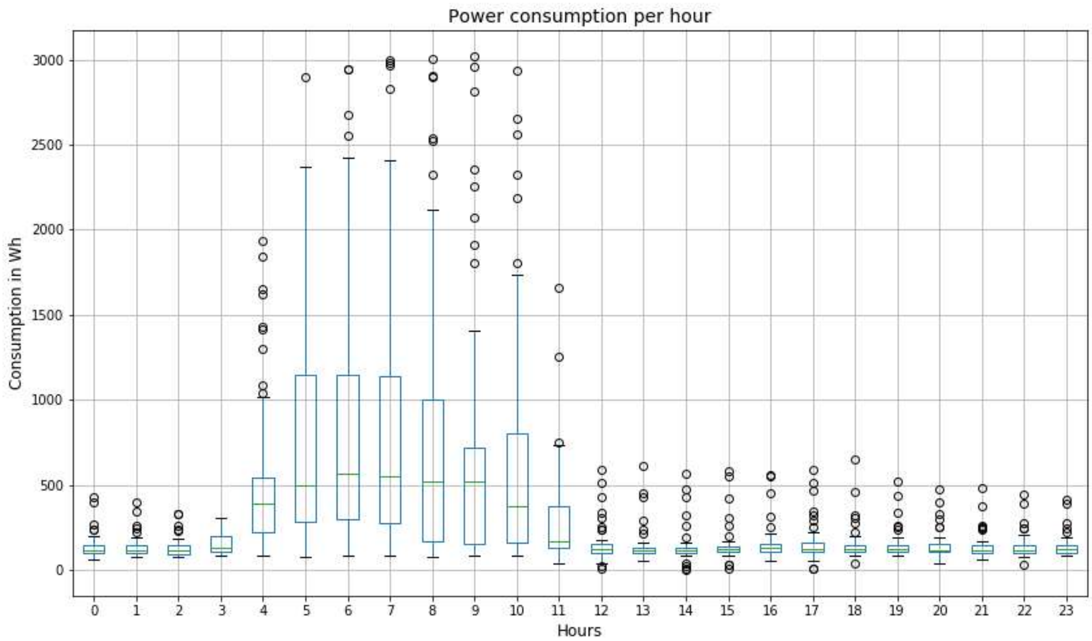
10. Experimental High Schoolof University of Patras(Lyceum)

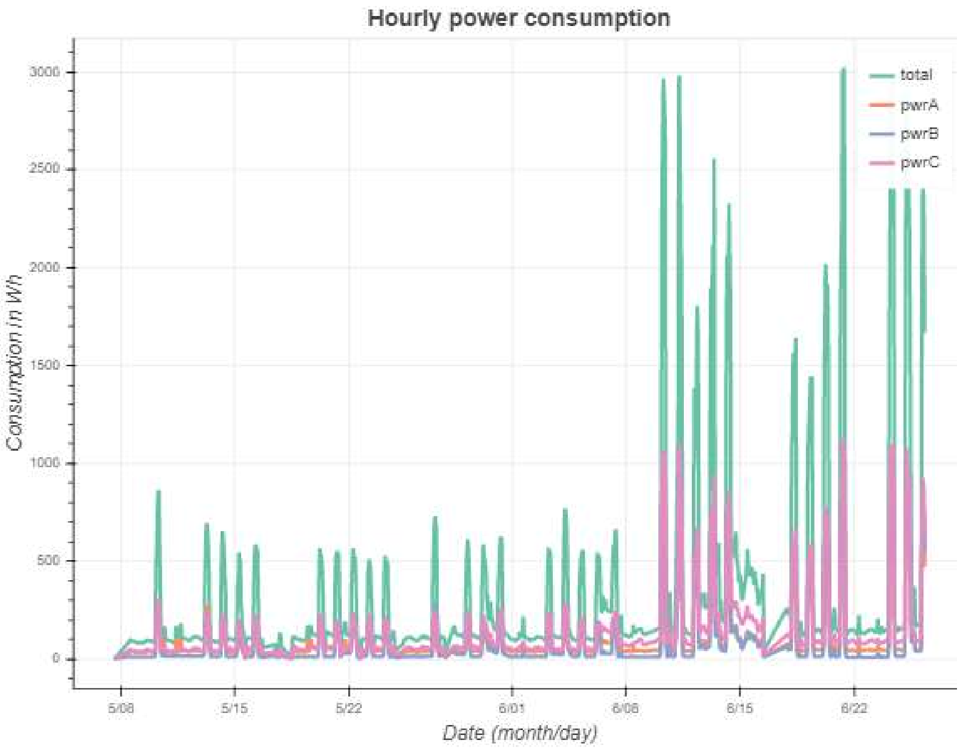


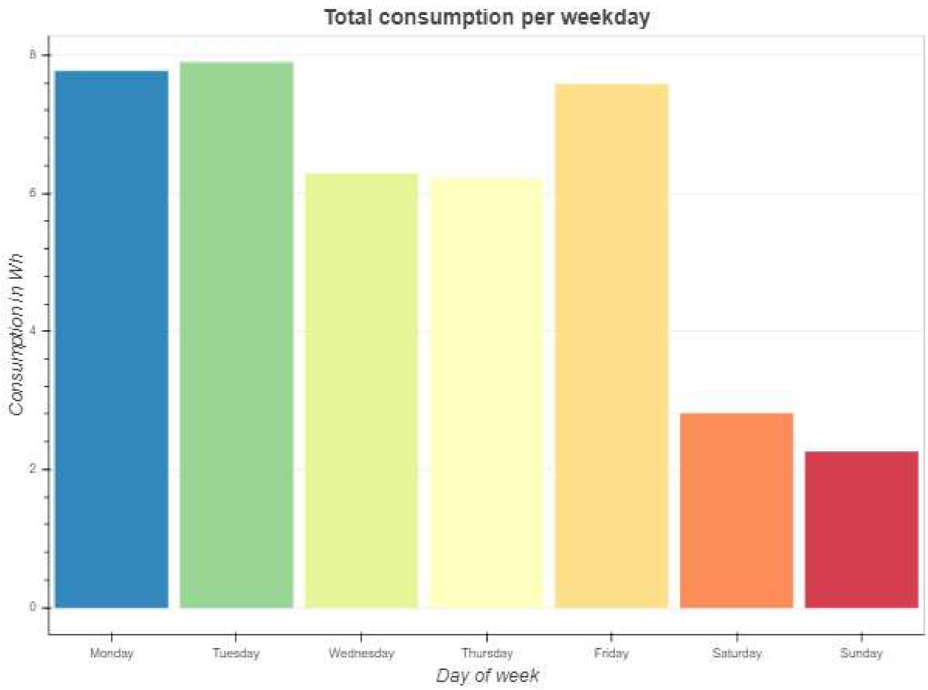




11. Directorates of RWG ofAitolokarnania Prefecture

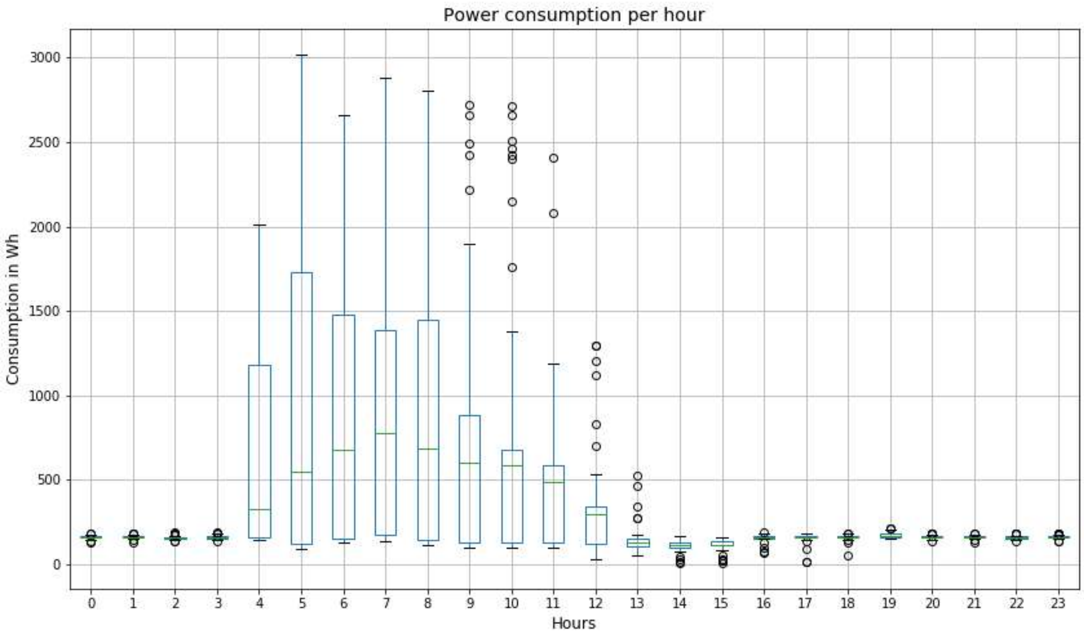


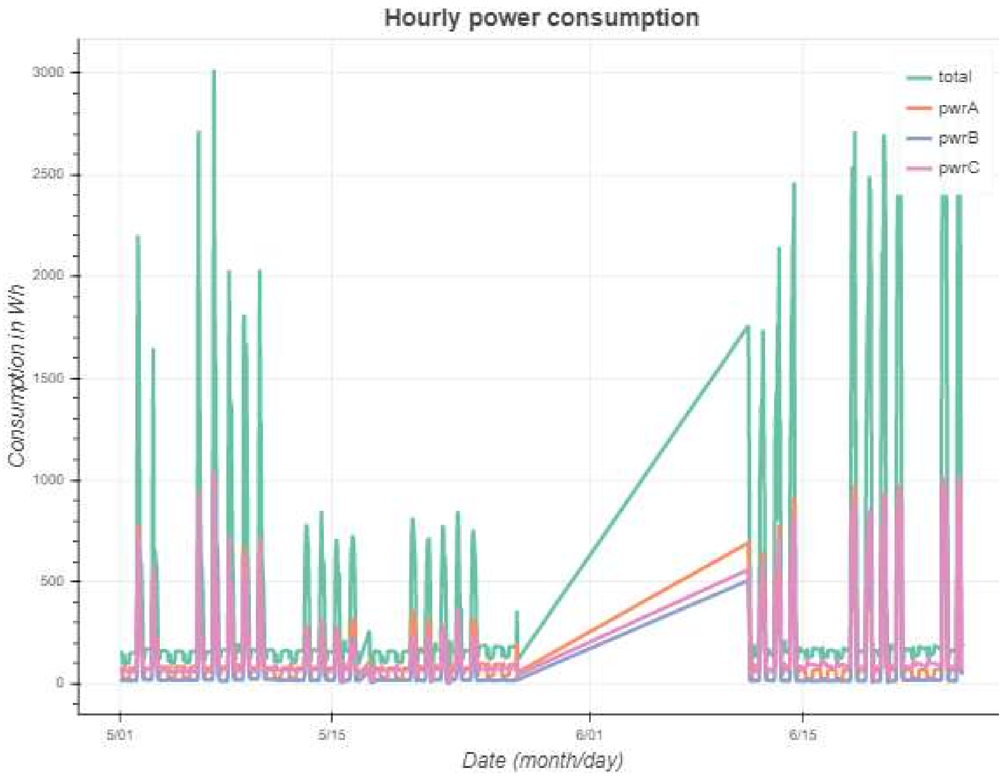


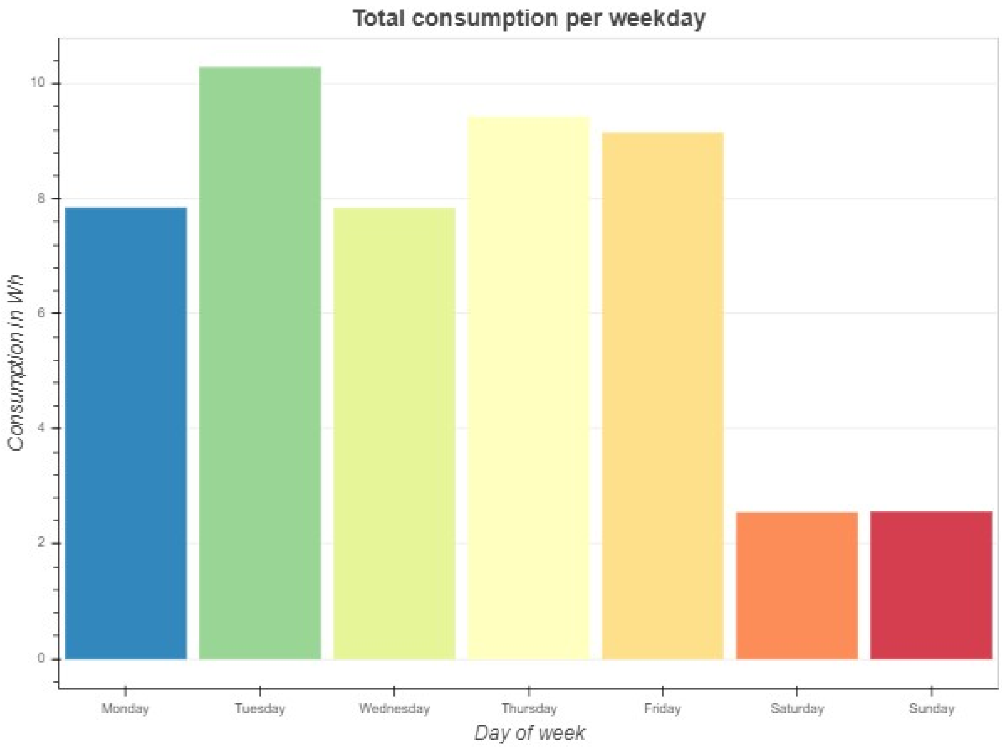


Project co-financed by the European Regional Development Fund

12. Directorate of RWG ofAchaia Prefecture







In the following we describe the general findings from the data screening process.

First of all, all buildings are dominated by a circulating pattern between the working and non-working hours, as well as the weekends versus working days. Of course, the working hours differ from building to building, but there is a clear pattern in the energy consumption and the difference between the working and non-working hours is significant. The same observation is made for the weekends versus working days, where the loads are significantly lower within the weekends. Nevertheless, there are some cases (e.g. building 2) where even during the weekend the consumption is relatively high, pointing out the existence of devices in active operation mode.

While most of the buildings appear to consume less energy during the night hours, there are cases like the experimental schools where the outdoor lights that operate during night raise the consumption to high levels.More specifically the Lyceum and Primary schools have a standard load of 200Wattsand 300Wats respectively during the night hours, while the Secondary school consumes half this load (120Watts) during the same hours. This finding can lead to further exploration of the potential of replacing the existing lighting equipment with LED lights of the same luminosity, towards energy saving.

Another interesting finding is the case of building 6, where a standard load of around 1000Watts appears to exist during many hours of the day. Further investigation of the devices that are responsible for this consumption is needed in order to decide whether there is an energy saving potential or not.

The screening process that we described above aimed at extracting the buildings' energy profiles and detecting interesting and/or suspicious behaviors. In the next section we further analyze each building's consumption in the direction of time.

5.3 Smart monitoring of energy consumption in buildings

Energy monitoring in buildings can be conducted through multiple ways.Our approach contains two kinds of analyses that are expected to further explain energy consumption.But first, we illustrate a detailed table of some basic characteristics of the buildings under investigation, along with the consumed energy as it has been reported up to now.Although we have some information about whether there are thermal losses or not, we still don't have a clear picture of the relation between energy consumption and constructive characteristics. Further information about the occupancy of the buildings and/or the orientation (to measure solar radiation on the buildings) will enable us to explain the energy consumption more thoroughly.

Table 6: Constructive characteristics of buildings along with energy consumption

SELECTED BUILDINGS IN THE REGION OF WESTERN GREECE FOR THE INSTALLATION OF SMART ENERGY METERS								
PREFECTURE OF ACHAIA								
	SERVICES	**AREA (m^2)**	**Thermal Insulation**	**Double glass panes**	**Consumed energy (kWh)**	**# of days**	**Consumption per day**	**Daily consumption per m^2**
1	Directorate of Public Health and Social Welfare	953.12	YES	YES	3995.48	37	107.98	0.113
2	Directorate of RWG of Achaia Prefecture	1605.00	NO	YES	9777.12	62	157.69	0.097
3	Directorates of Transport, Shipping & Communications of Achaia Prefecture	2040.00	NO	YES	8686.39	44	197.41	0.096
4	Central Directorates of RWG of Achaia Prefecture	2166.18	YES	YES	63680.96	35	1819.45	0.839
5	Building of Head of Region and Directorates of RWG	2430.00	YES	YES	11279.05	37	304.83	0.125
6	Directorate of Agricultural Economy and Veterinary	2311.56	NO	NO	3461.97	40	86.54	0.037

	Medicine							
7	Directorate of Engineering Constructions	301.29	NO	YES	4569.82	50	91.39	0.303
PREFECTURE OF ILEIA								
8	Administration Building	8650	NO	NO	17892.22	44	406.64	0.047
9	Conference Center	715	YES	YES	7614.46	44	173.05	0.242
10	Directorate of Transport, Shipping & Communications of Ileia Prefecture	436.31	YES	YES	8647.75	38	227.57	0.521

5.3.1 Comparative analysis

To thoroughly investigate the energy consumption of the selected buildings and enable meaningful comparisons between different time spaces, we exploit Meazon's IoT platformthat provides such a module.Our aim is to reveal the different energy consumption patterns that occur during the working days, the weekends, the hours of day etc.

In addition to the energy profile extraction of the monitored buildings, we performed a comparative analysis to examine differences in the consumption of the buildings at different days. A subset of the entire set of buildings has been selected for this purpose.

Case 1: Directorate of Public Health and Social Welfare

In the first case we illustrate the total consumption of an office building during a whole day, for two different dates. More specifically, we choose the first day to be the 3rdth of June, and the second the 20th of June. As illustrated below, the building appears to have the same behavior but during the (apparently) working hours the consumption has been shifted by almost 10 kW higher. This behavior makes sense since the temperature has increased significantly during these days, thus the A/C units are hypothesized to be working intensively.

Figure 18: Daily consumption comparison of working days

In the next figure we illustrate the daily consumption of the building with one of the working days (Monday to Friday), and a day within the weekend (Saturday/Sunday). The difference is significant especially during the working hours where the consumption is 15 kW higher on average during the working days.

Figure 19: Daily consumption of a working day and a weekend day

As a last case we selected to compare the weekly consumption of the same building, for a week in early June and a week in late June. Here again the weekly consumption during the second week is significantly higher (red line) within the working hours, which is explained by the temperature increase.

Figure 20: Weekly consumption comparison of early and late week

Case 2: Experimental High School of University of Patras (Lyceum)

We repeat the same process for a different building, namely a school in Patras. Here again we see a significant shift of the consumption between a day in May and a day in June, during the working hours. The guess here is also the increase of the outside temperature, thus the operation of A/C units causes this shift.

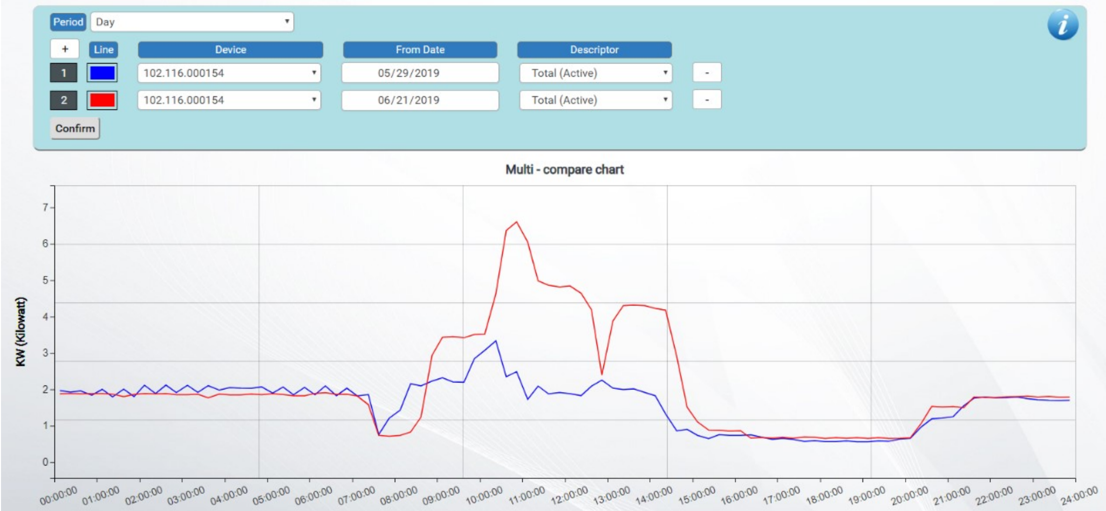


Figure 21: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. We observe again the existence of the night lights consumption, as well as the morning-to-noon consumption within the weekday that is about 3kW higher than the weekend day within May.

Figure 22: Daily consumption of a working day and a weekend day

Followingly, we compare two different weeks, one within May and one within June. Here we must take into account the special conditions of the building's operation, aka the fact that within May the semester exams take place and thus the days/hours that the school is occupied may differ. Nevertheless, there is a standard consumption within the night, which corresponds to the lights at the school yard.

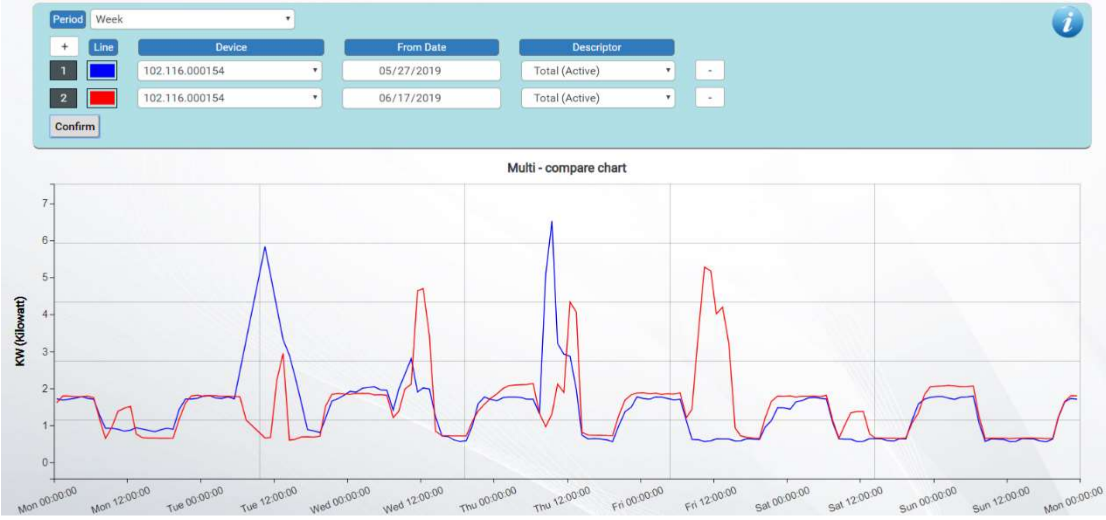


Figure 23: Weekly consumption comparison of early and late week

Case 3: Directorate of Agricultural Economy and Veterinary Medicine

We repeat the same process for the building Directorate of Agricultural Economy and Veterinary Medicine. Here again we see a significant shift of the consumption between a day in early June and a day in Mid-June, during the working hours. The guess here is also the increase of the outside temperature, thus the operation of A/C units causes this shift.

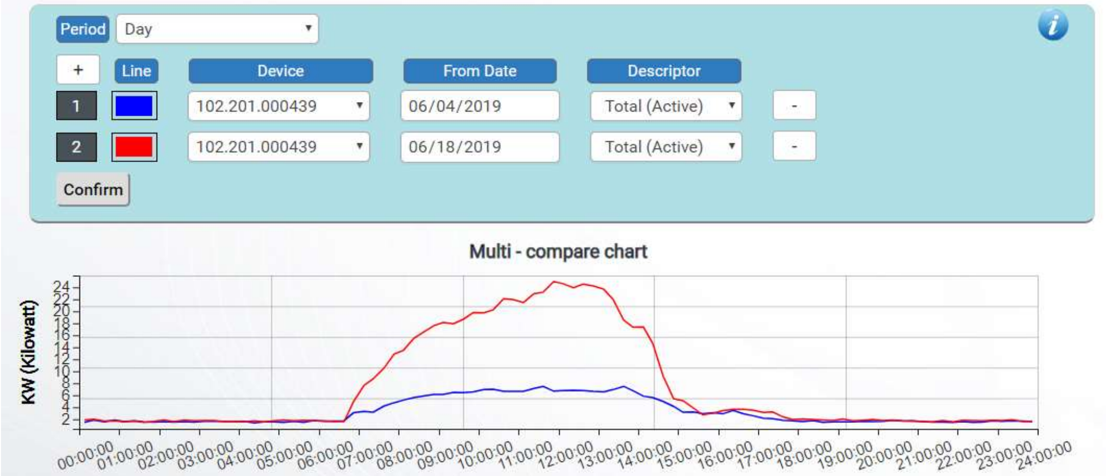


Figure 24: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. We observe again the existence of a standard load during the non-working hours, as well as the morning-to-noon consumption within the weekday that is about 5kW higher than the weekend day within June.

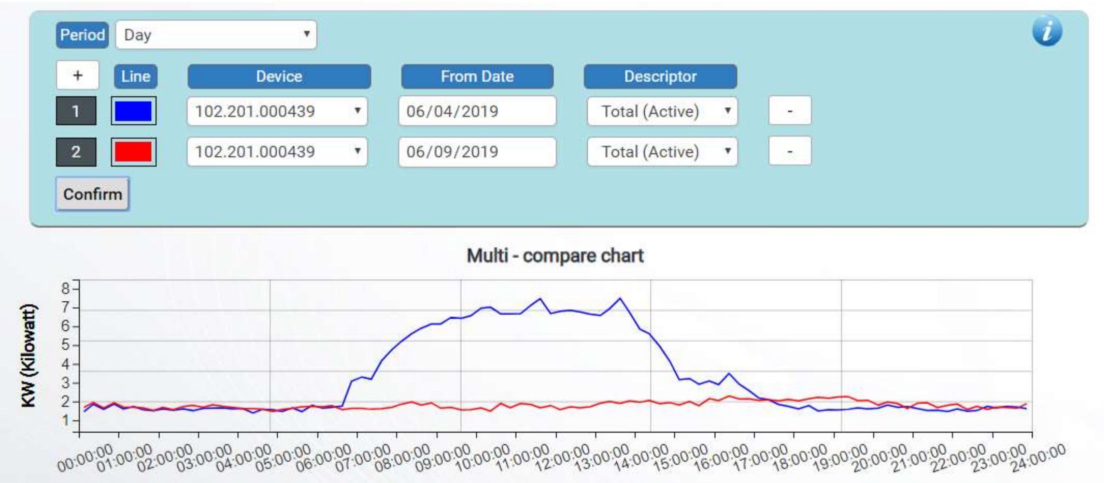


Figure 25: Daily consumption of a working day and a weekend day

In the next figure we illustrate the weekly consumption of the same building, for a week in early June and a week in mid-June. Here again the weekly consumption during the second week is significantly higher (red line) within the working hours, which is explained by the temperature increase.

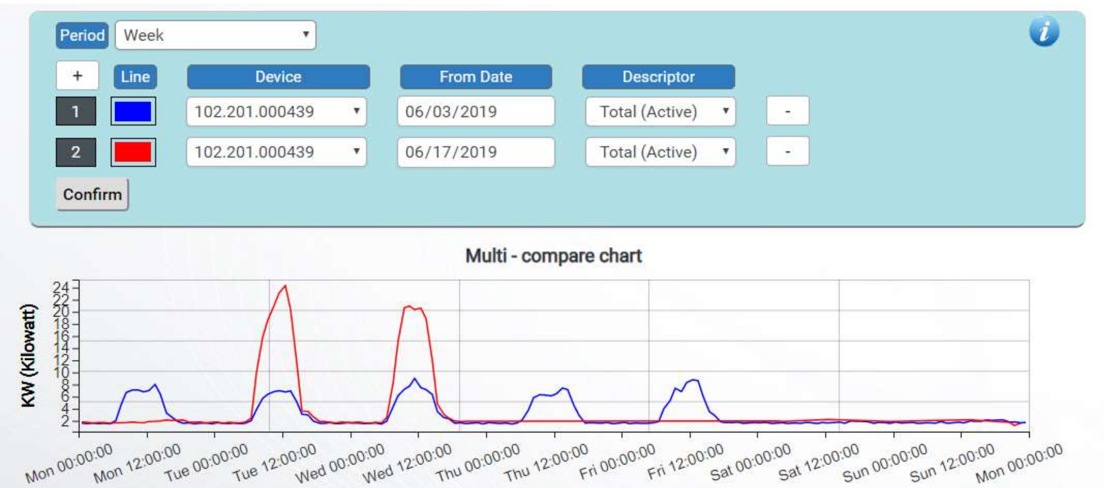


Figure 26: Weekly consumption comparison of early and late week

Case 4: Directorates of Transport, Shipping & Communications of Achaia Prefecture

Here again we see a significant shift of the consumption (around 18kW higher) between a day in early June and a day in late June, during the working hours. The guess here is also the increase of the outside temperature, thus the operation of A/C units causes this shift.

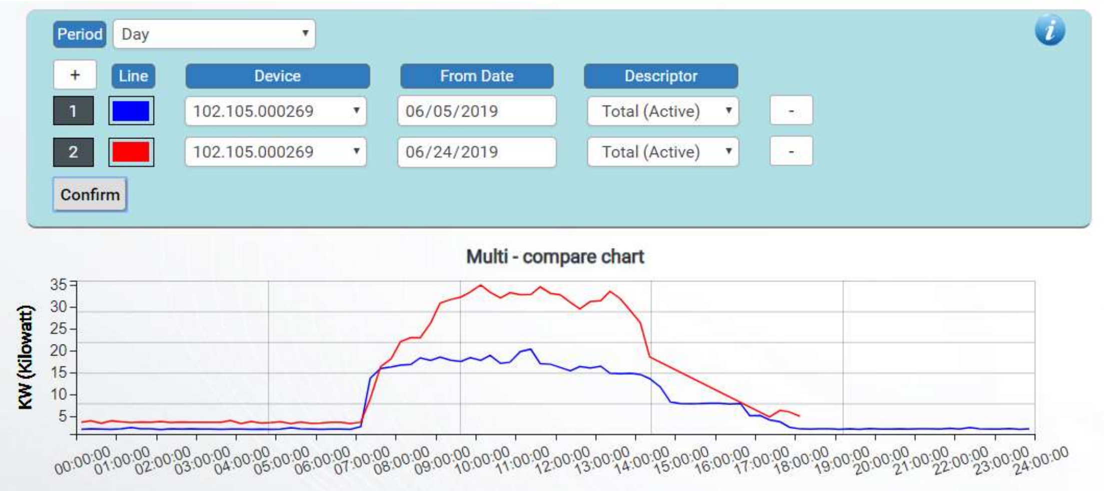


Figure 27: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. We observe that the morning-to-noon consumption within the weekday is higher than the weekend day within June.

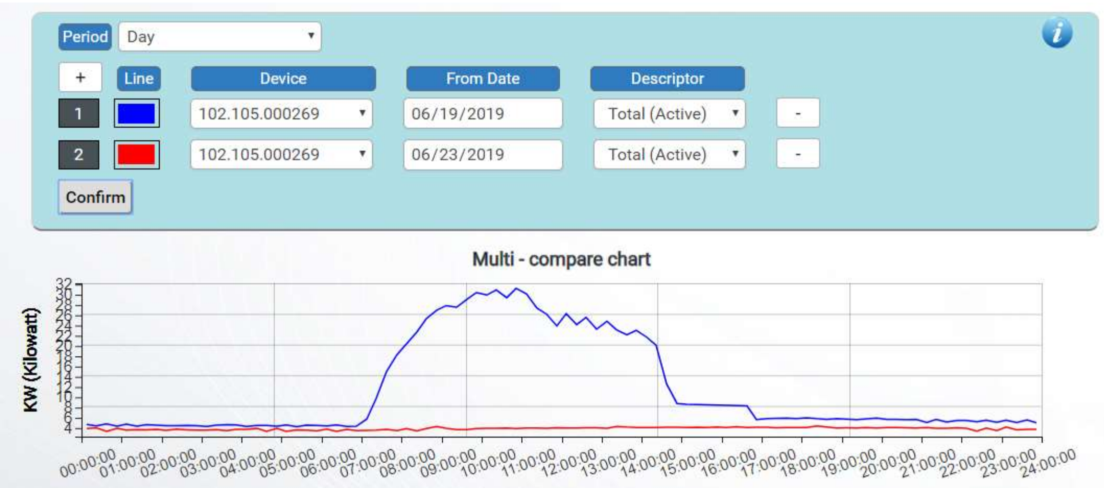


Figure 28: Daily consumption of a working day and a weekend day

In the next figure we illustrate the weekly consumption of the same building, for a week in lateMay and a week in mid-June. Apart from the observation of the higher consumption during June, we note here that the 17th of June is a public holiday, thus the consumption that day is similar to a weekend day.

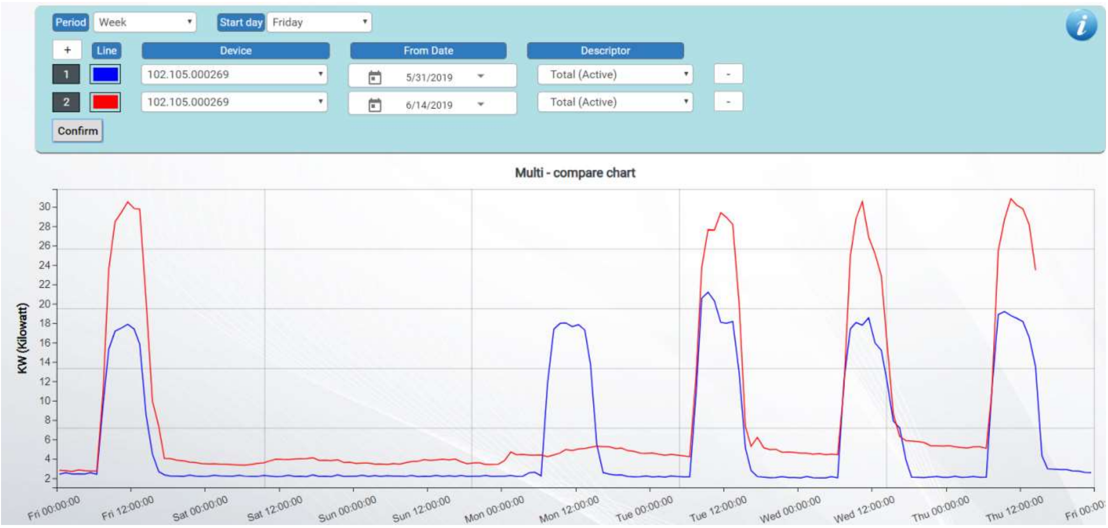


Figure 29: Weekly consumption comparison of early and late week

Case 5: Directorate of Transport, Shipping & Communications of Ileia Prefecture

Here again we see a significant shift of the consumption between a day in early June and a day in late June, during the working hours. What is of interest here, is the fact that the consumption is raised not only during the working hours, but also during the night hours.

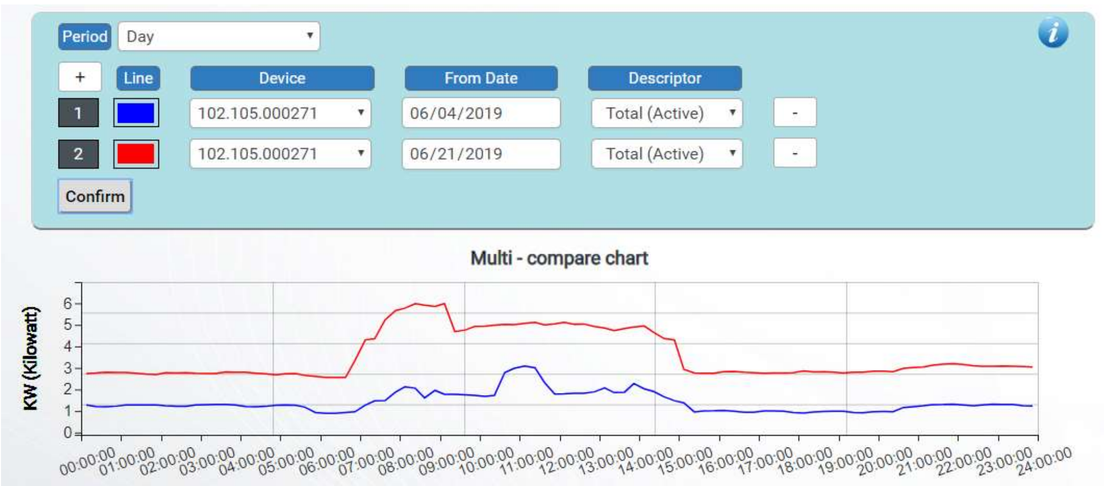


Figure 30: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. Although the load during the night hours is almost the same during the weekend, we observe a load during the early morning hours of the weekend.

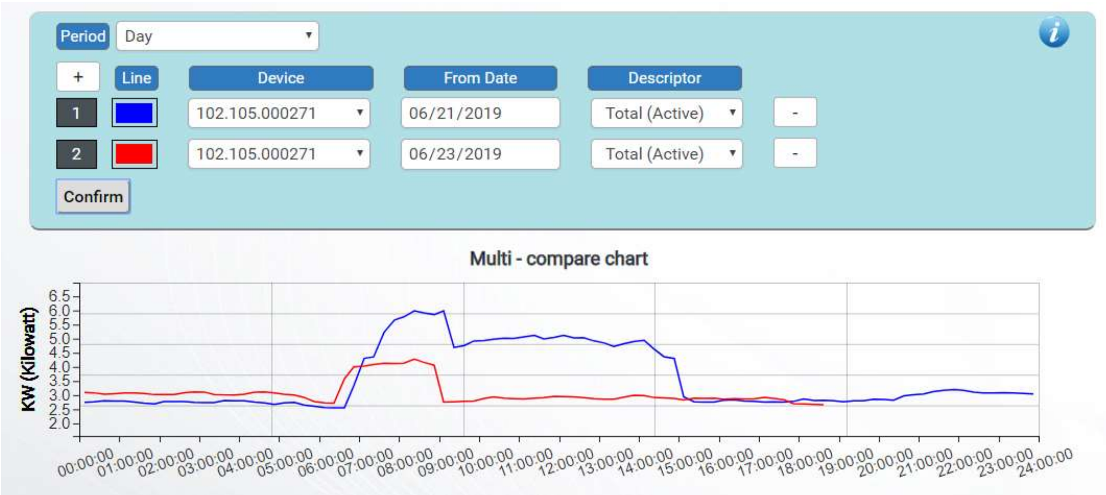


Figure 31: Daily consumption of a working day and a weekend day

In the next figure we illustrate the weekly consumption of the same building, for a week in late May and a week in mid-June. The peaks are higher during the working days of mid-June, nonetheless we observethat within the 17th of June (public holiday) there is still a small load during different time range than usual. Additionally, there is a reduction of the usual consumption on the 14th of June, which requires further investigation to declare the reason behind this behavior.

Figure 32: Weekly consumption comparison of early and late week

Case 6: Central Directorates of RWG of Achaia Prefecture

For this building we also see a significant shift of the consumption between a day in lateMay and a day in late June, during the working hours. The operation of A/C units is considered to cause this shift.

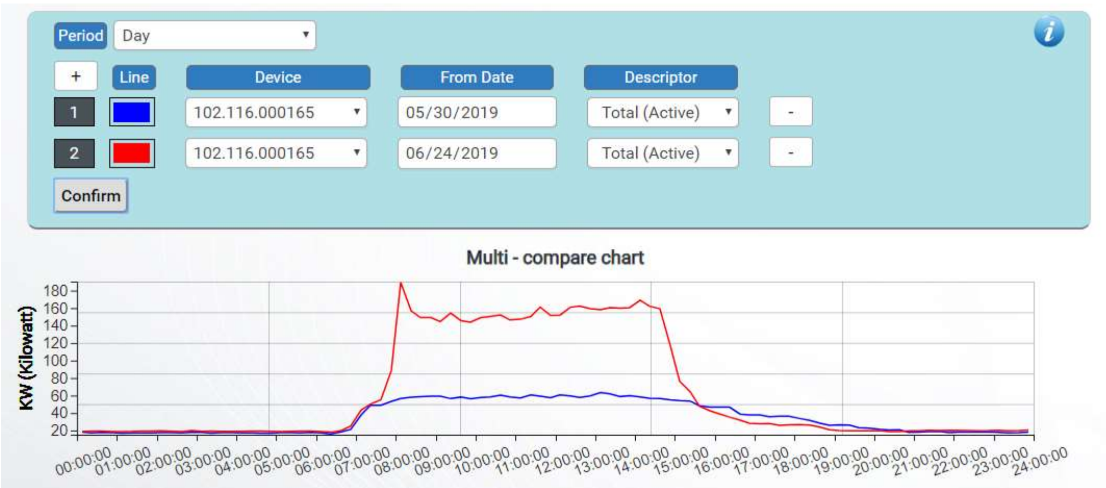


Figure 33: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. The morning-to-noon consumption within the weekday is significantly higher (around 140kW higher) than the weekend day within June.

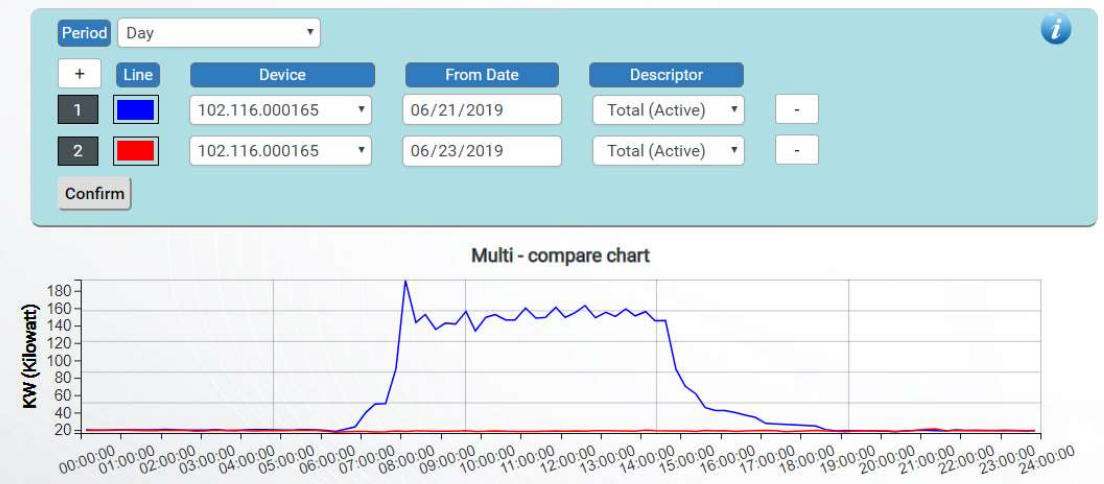


Figure 34: Daily consumption of a working day and a weekend day

In the next figure we illustrate the weekly consumption of the same building, for a week in late May and a week in mid-June. Here again the weekly consumption during the second week is significantly higher (red line) within the working hours, which is explained by the temperature increase.

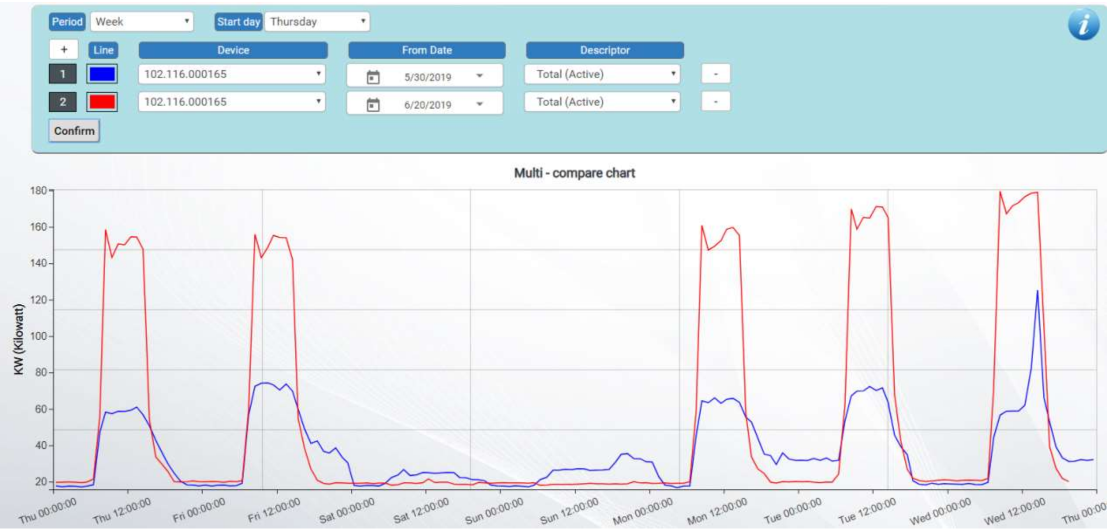


Figure 35: Weekly consumption comparison of early and late week

Case 7: Building of Head of Region and Directorates of RWG

The same pattern of load shift is observed between a day in earlyJune and a day in late June, during the working hours.

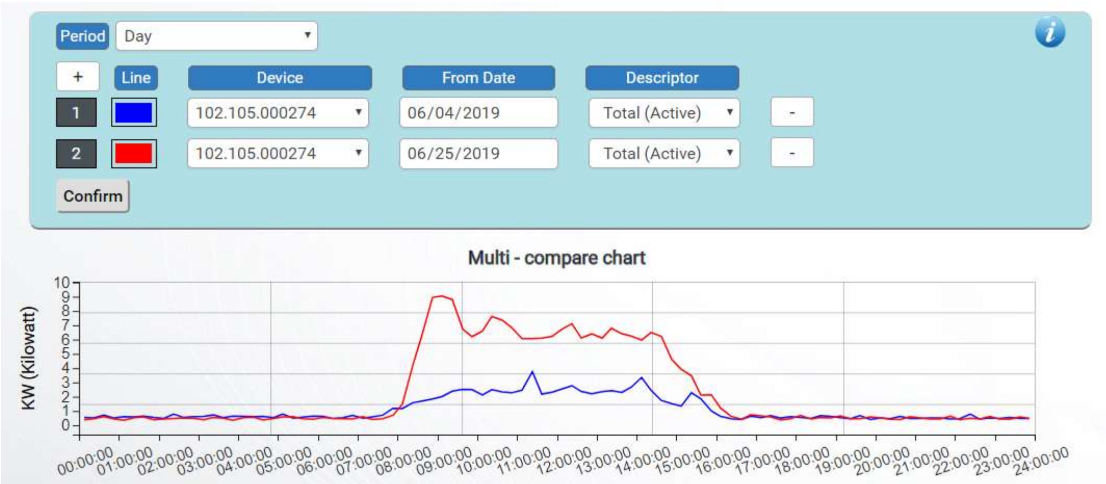


Figure 36: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. Here again the load during the working hours is what makes the difference between the working and non-working days.

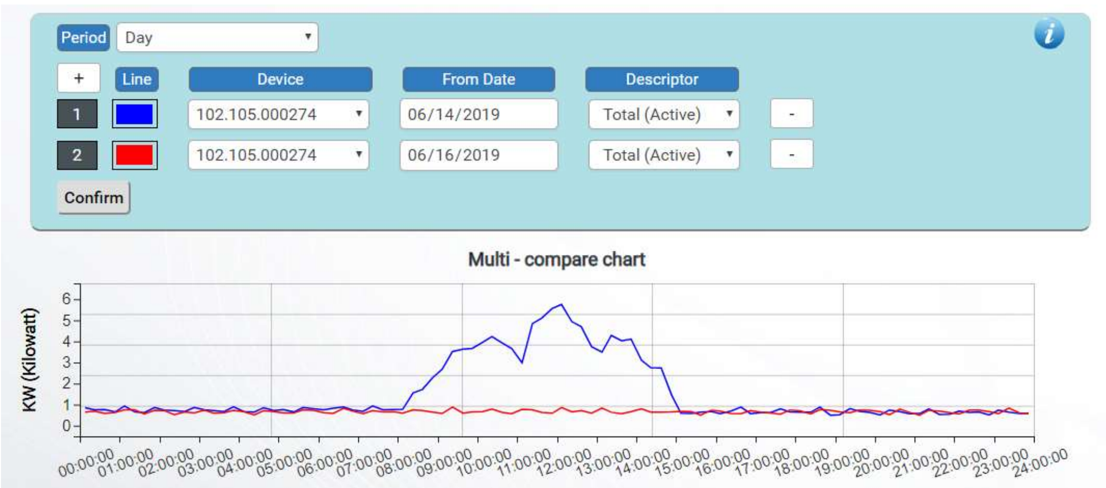


Figure 37: Daily consumption of a working day and a weekend day

In the next figure we illustrate the weekly consumption of the same building, for a week in late May and a week in mid-June. Here again the weekly consumption during the second week is significantly higher (red line) within the working hours, especially after a certain day where a load is hypothesized to have been added to the building.

Figure 38: Weekly consumption comparison of early and late week

Case 8: Experimental School of University of Patras (Primary School)

Here again we see a significant shift of the consumption between a day in late May and a day in late June. The guess here is that the schools do not work in late June.

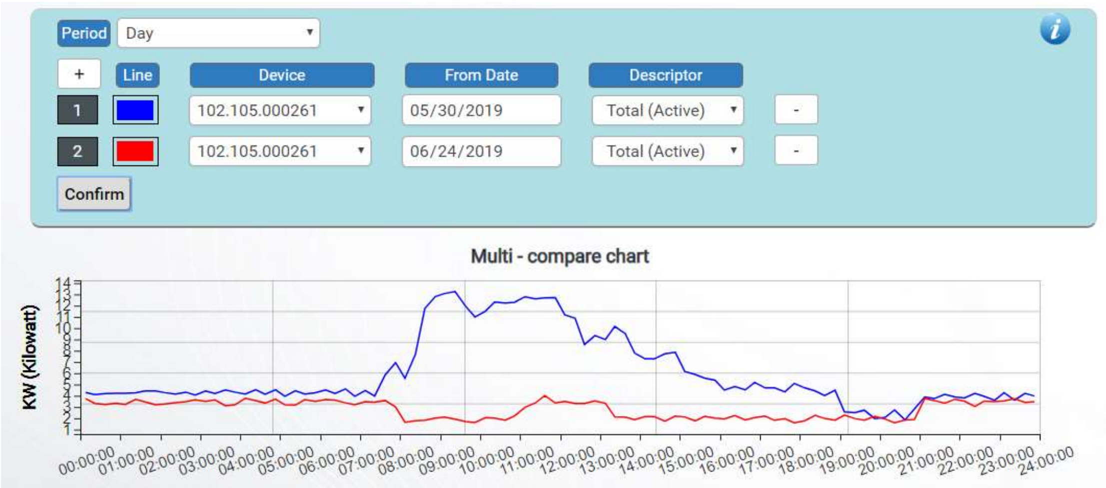


Figure 39: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. We observe again the existence of the night lights consumption, as well as the morning-to-noon consumption within the weekday that is significantly higher than the weekend.

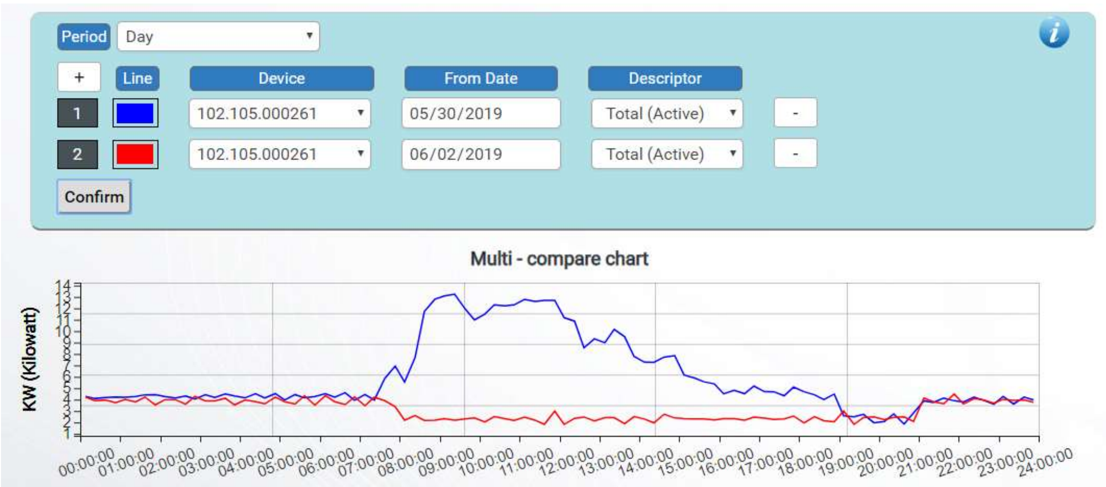


Figure 40: Daily consumption of a working day and a weekend day

In the next figure we illustrate the weekly consumption of the same building, for a week in early June and a week in mid-June. Here the weekly consumption during the first week is higher (blue line) within the working hours, which is explained by the non-functioning of schoolsin mid-June.

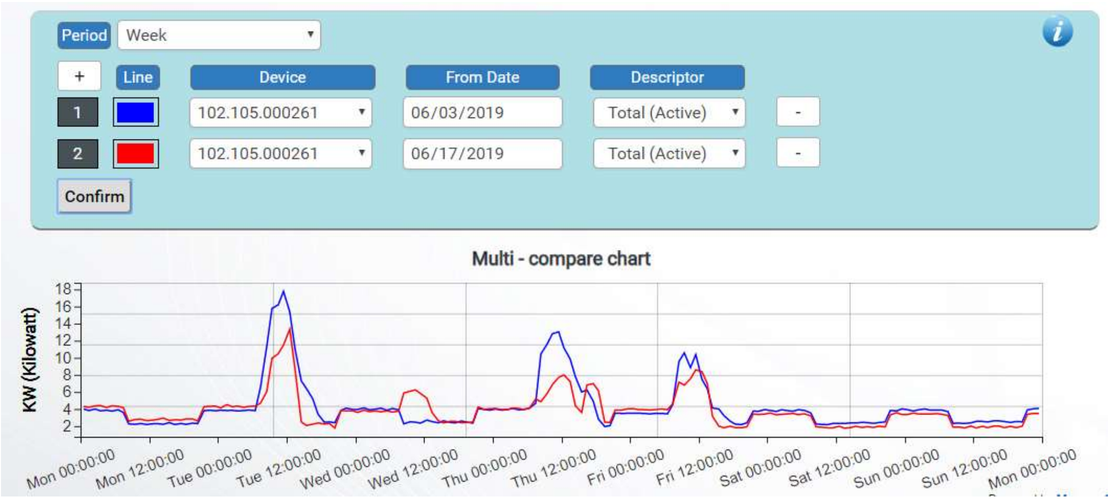


Figure 41: Weekly consumption comparison of early and late week

Case 9: Experimental High School of University of Patras (Secondary School)

We repeat the same process for the building Experimental High School of University of Patras (Secondary School). Here again we see a significant shift of the consumption between a day in late May and a day in mid-June. The guess here is that the schools do not work in mid-June.

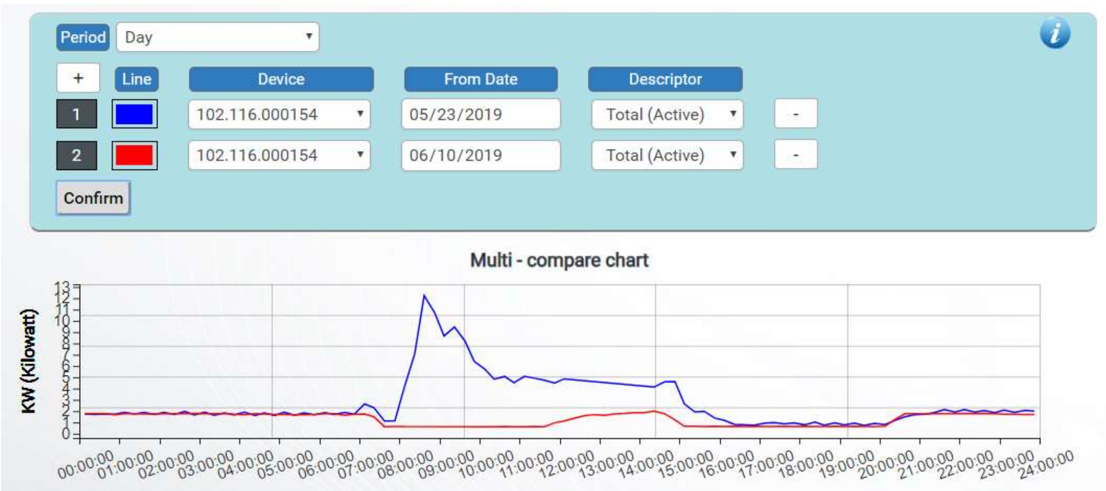


Figure 42: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. We observe again the existence of the night lights consumption, as well as the morning-to-noon consumption within the weekday that is significantly higher than the weekend.

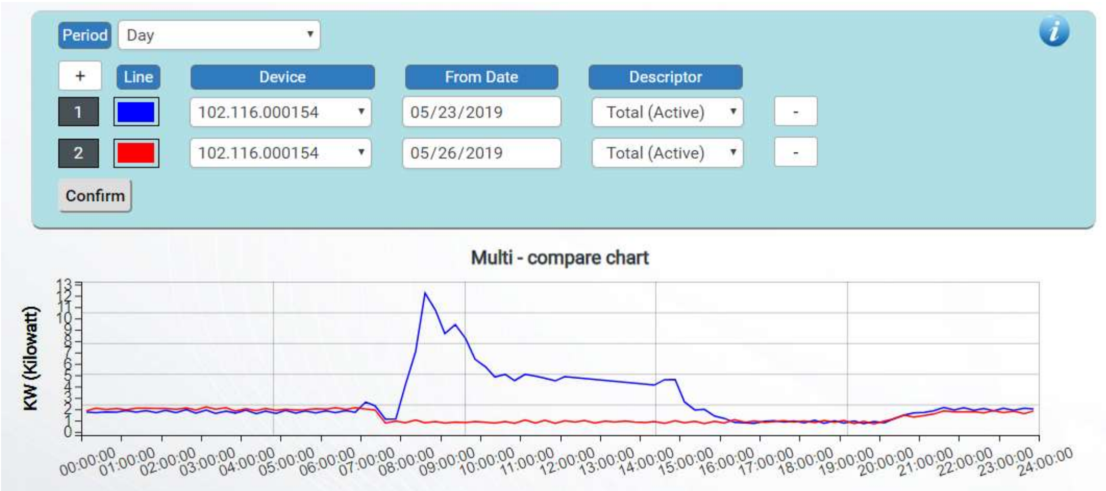


Figure 43: Daily consumption of a working day and a weekend day

In the next figure we illustrate the weekly consumption of the same building, for a week in lateMay and a week in mid-June. Here the weekly consumption during the first week is higher (blue line) within the working hours, which is explained by the non-functioning of schools in mid-June.

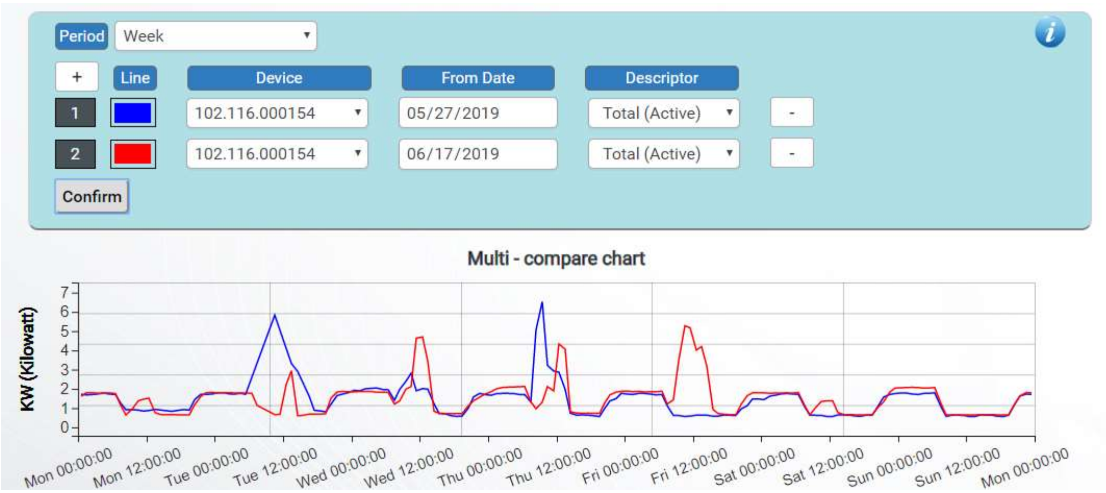


Figure 44: Weekly consumption comparison of early and late week

Case 10: Directorates of RWG of Aitolokarnania Prefecture

Once again we see a significant shift of the consumption between a day in lateMay and a day in late June, during the working hours. The guess here is also the increase of the outside temperature, thus an additional load due to the A/C units is supposed to cause this shift.

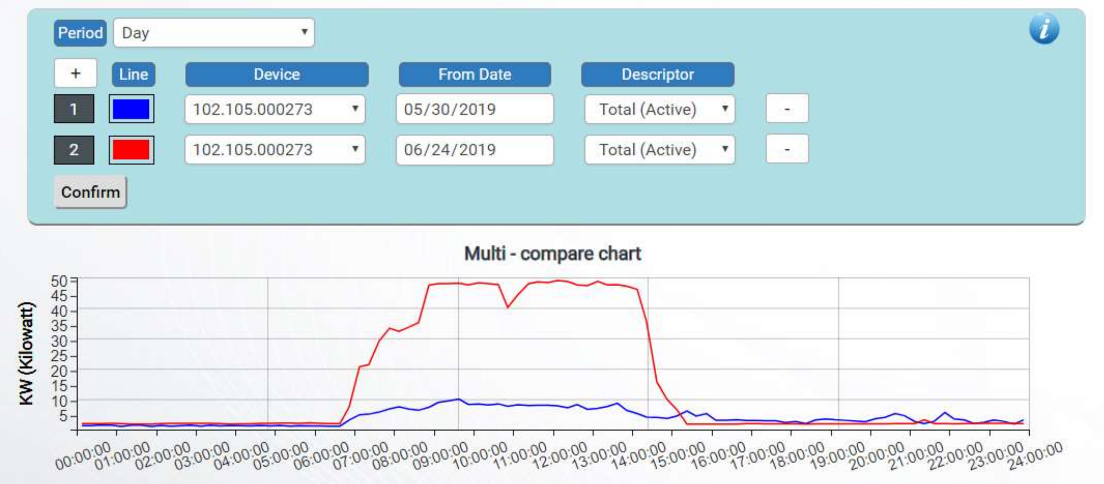


Figure 45: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. The consumption during the working hours within the week is significantly higher than the weekend day in late June. The load during the non-working hours seems to be the same in both cases.

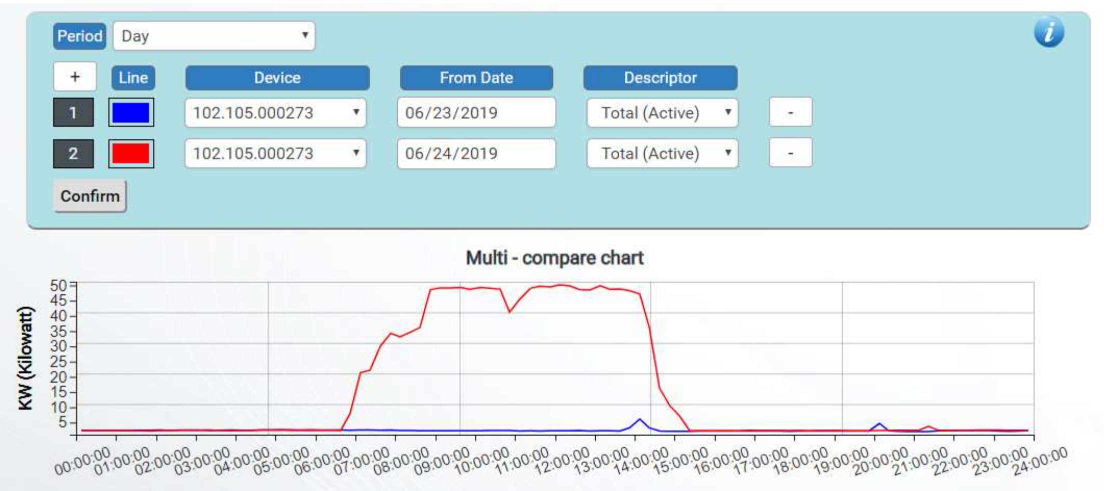


Figure 46: Daily consumption of a working day and a weekend day

In the next figure we illustrate the weekly consumption of the same building, for a week in earlyJune and a week in mid-June. Here again the weekly consumption during the second week is significantly higher (red line) within the working hours, which is explained by the temperature increase.

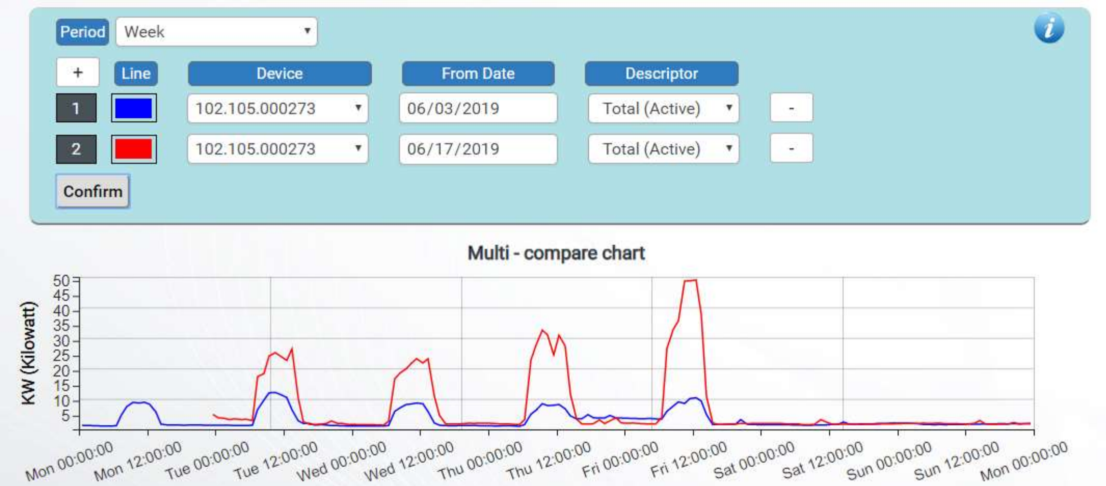


Figure 47: Weekly consumption comparison of early and late week

Case 11: Directorate of RWG of Achaia Prefecture

For the last building we observe of the consumption between two days in June, where the consumption is higher during the working hours in late June. That again is explained by the increase of the outside temperature.

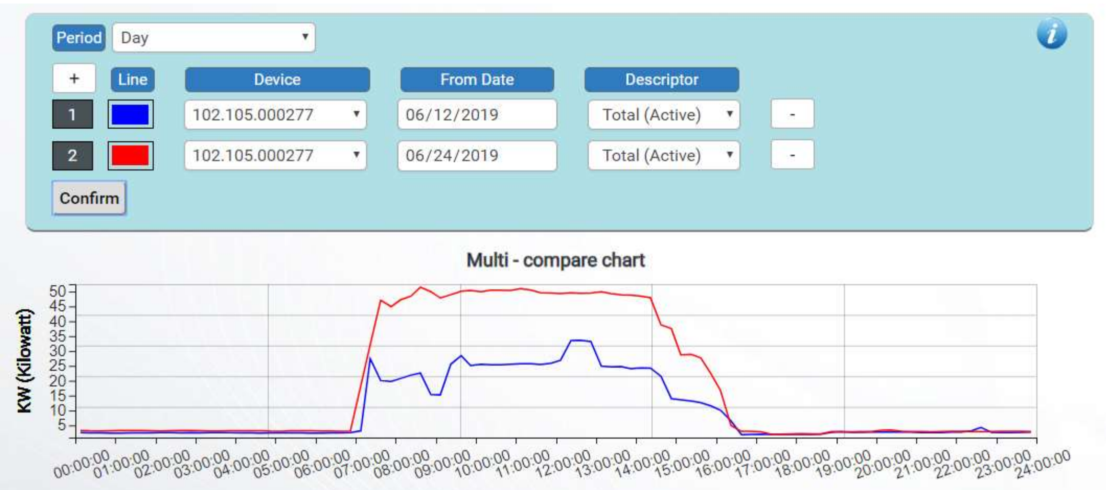


Figure 48: Daily consumption comparison of working days

The working day versus weekend day comparison is depicted in the next figure. The working hours load is what makes the difference, as observed in previous buildings too.

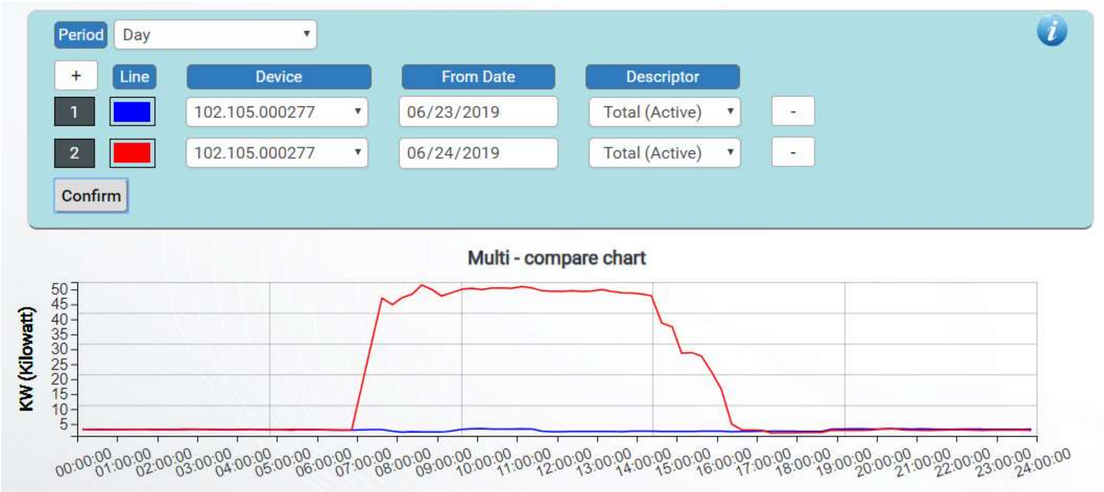


Figure 49: Daily consumption of a working day and a weekend day

In the last figure we illustrate the weekly consumption of the same building, for two weeks in mid-June. Here the weekly consumption during the two weeks is not significantly different within the working hours,although there is a small difference.

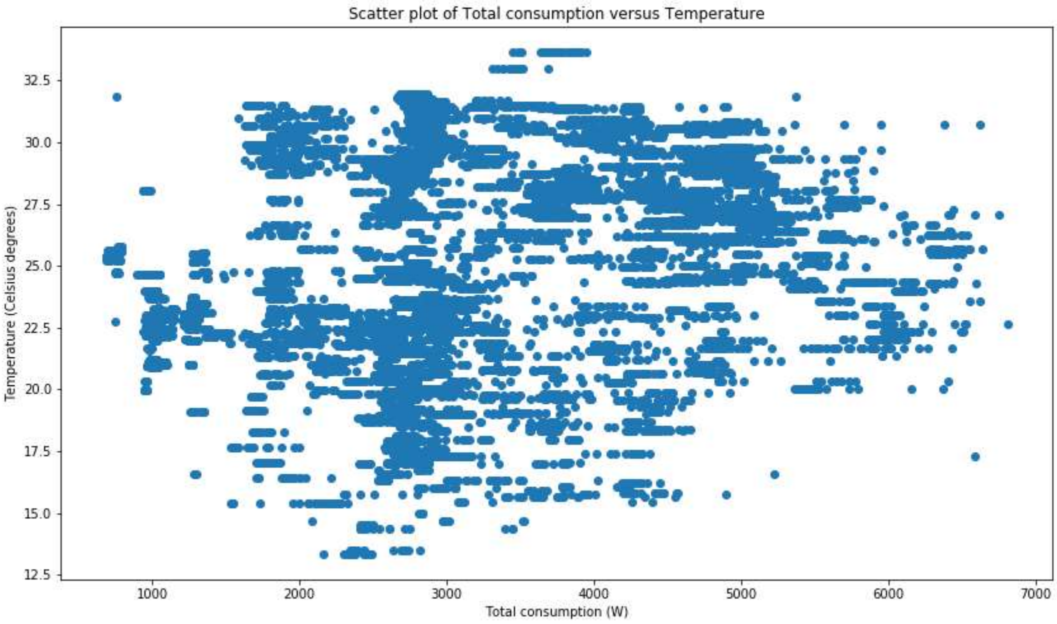
Figure 50: Weekly consumption comparison of early and late week

The comparative analysis conducted above revealed many interesting aspects of the buildings' energy-related behavior, thus gives us theopportunity to target specific conditions that will help the energy efficiency process succeed.

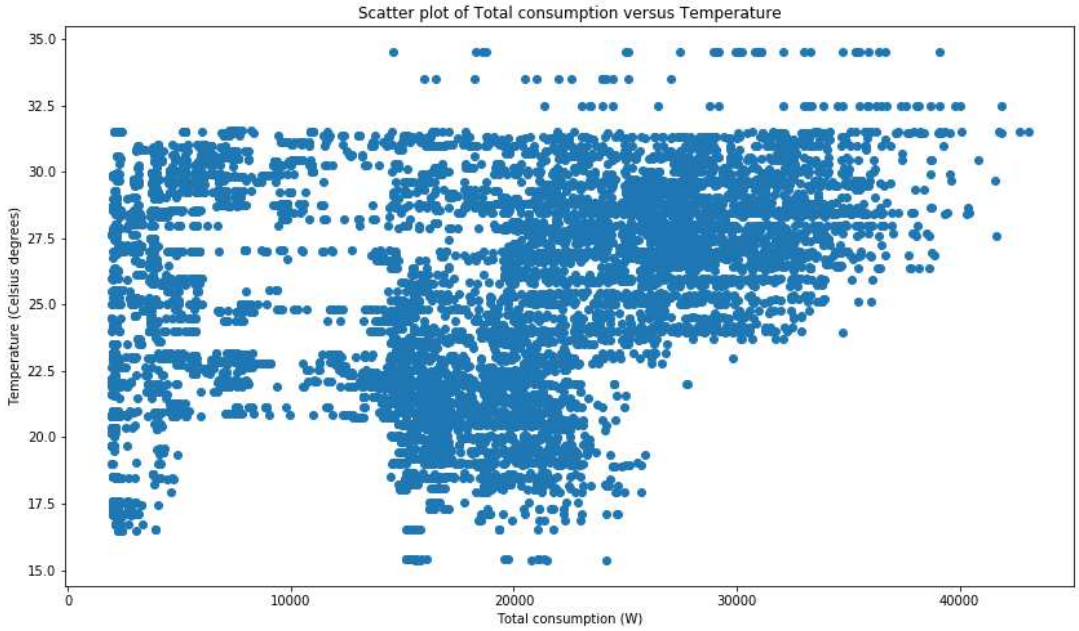
5.3.2 Correlational analysis

Every systemthat includes energy consumption is affected by external factors such as weather conditions.Meazon's IoT platform collects such data from nearby weather stations. More specifically, temperature and humidity are visualized in each building's dashboard. To that end, we performed a correlational analysis between temperature and energy consumption, to explore the relationship between these two measurements. The aforementioned analysiswas conducted for a subset of buildings, for which the measurements contained as few missing values as possible, so as to keep the imputation ratio as small as possible. For these buildings we illustrate the corresponding scatter plots that can easily interpret therelationship between two variables.It should be noted here that we have excluded the weekends and non-working hours from each building's measurements, so that we have a clear picture of the non-baseload consumption in relation to the outside temperature.

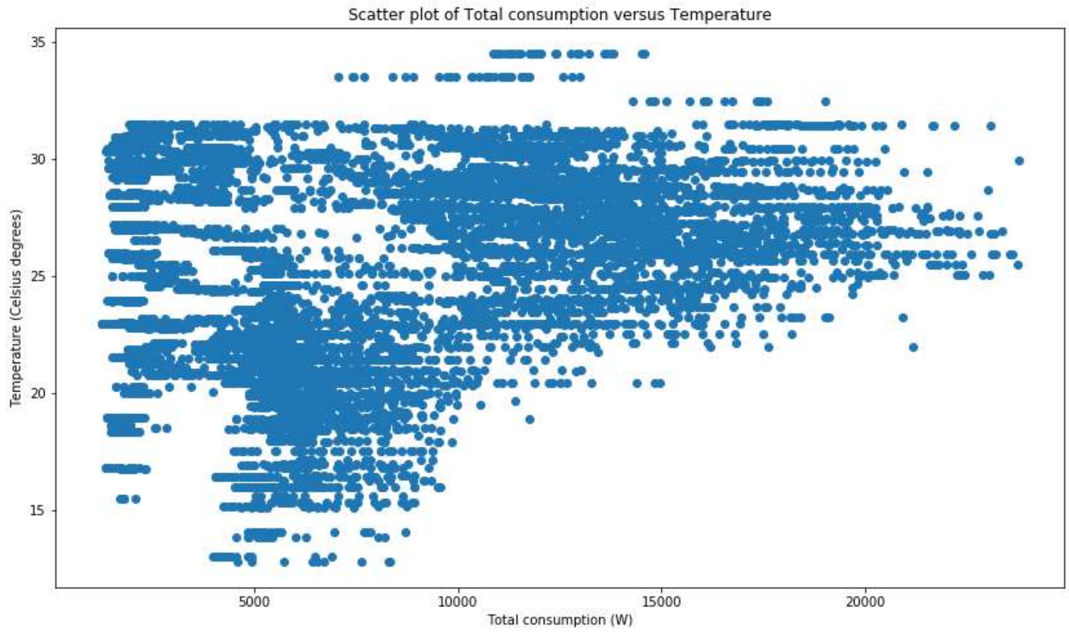
Case 1: Directorate of Transport, Shipping & Communications of Ileia Prefecture



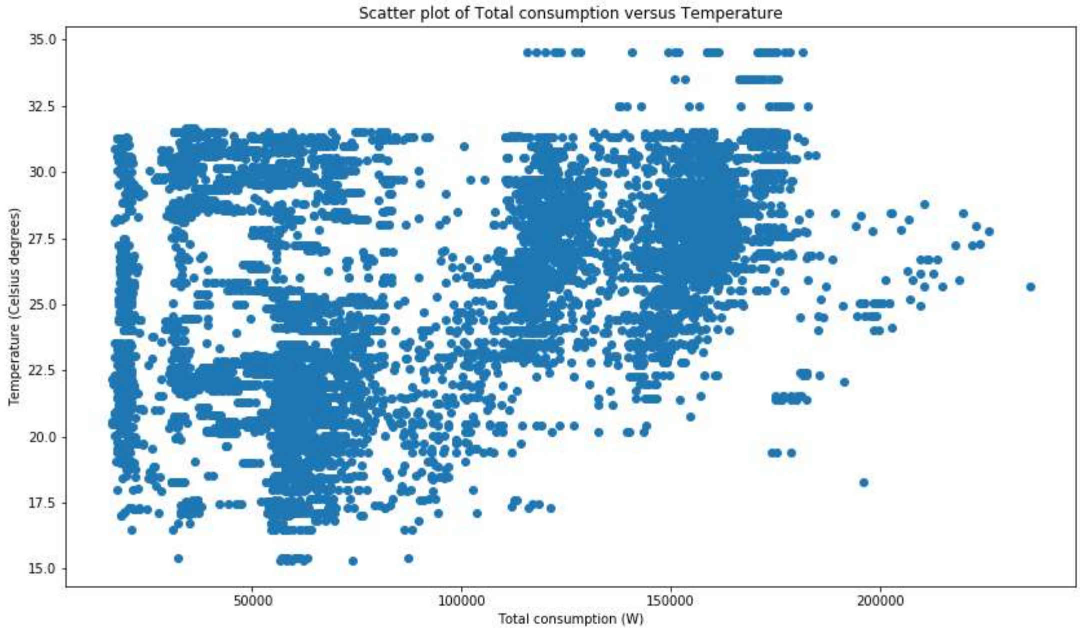
Case 2: Directorate of Transport, Shipping & Communications of Achaia Prefecture



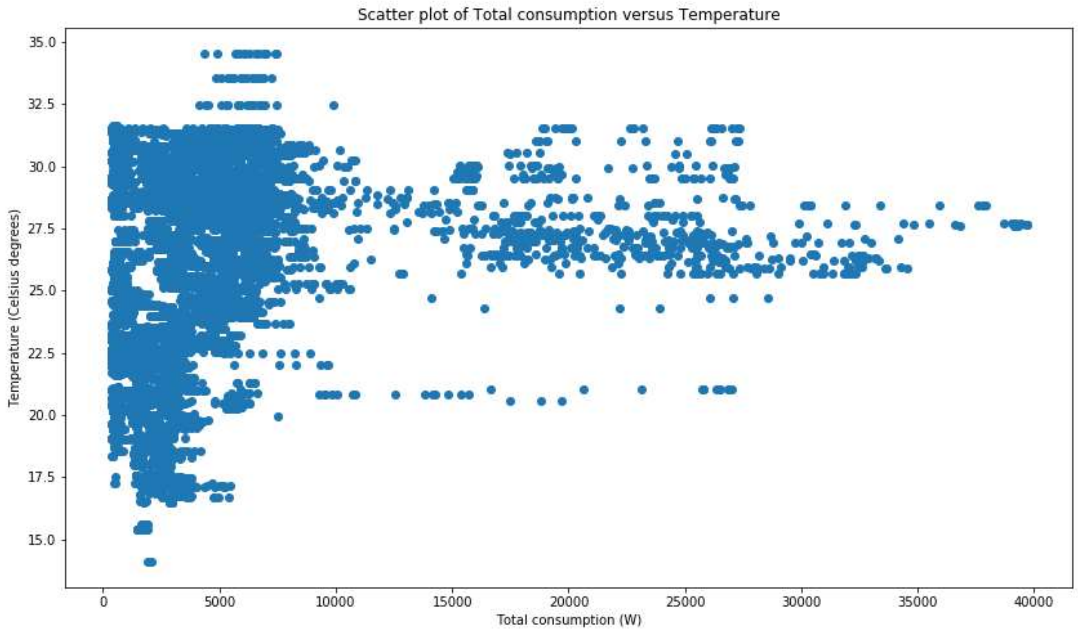
Case 3: Directorate of Public Health and Social Welfare



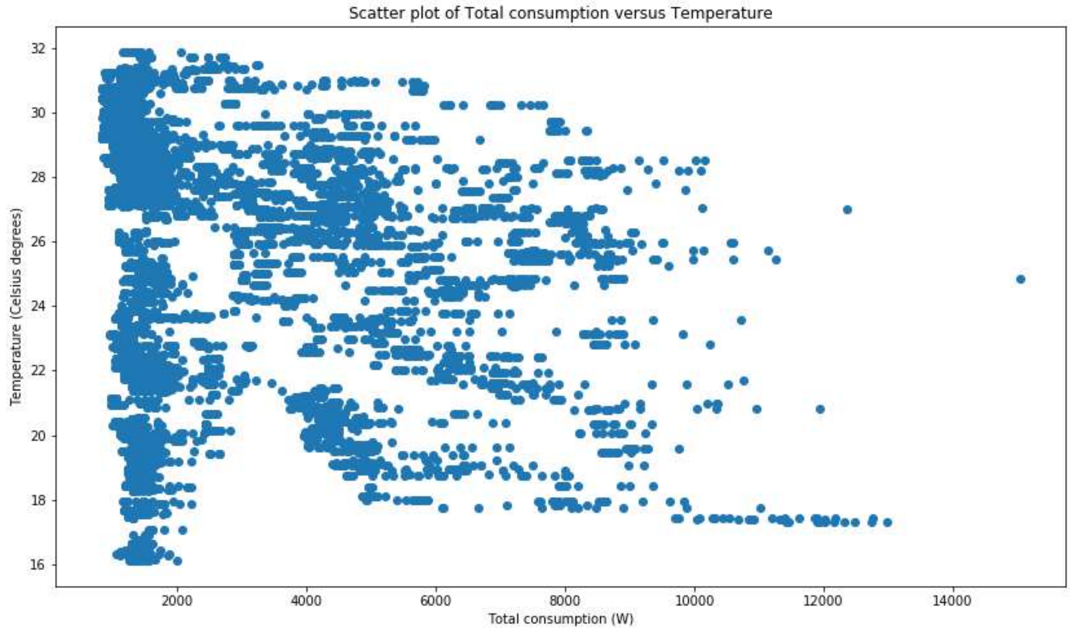
Case 4: Central Directorates of RWG of Achaia Prefecture



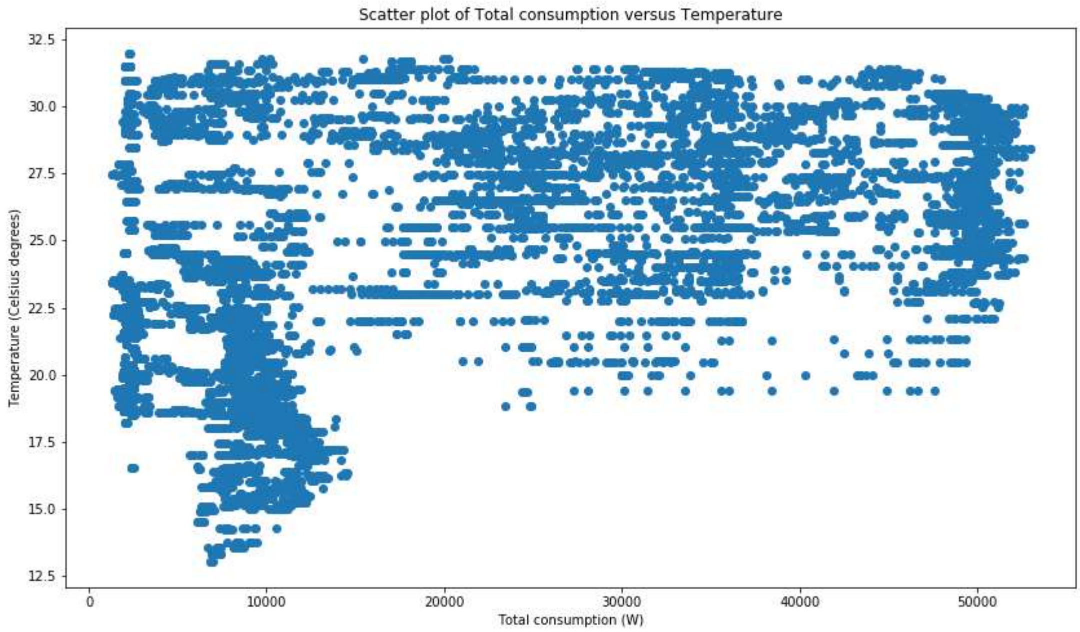
Case 5:Building of Head of Region and Directorates of RWG



Case 6: Experimental High School of University of Patras (Lyceum)



Case7: Directorates of RWG of Aitolokarnania Prefecture



We observe that in most cases there is a straightforward relationship between temperature and consumption (cases 2, 3, 4), meaning that as the temperature increases, the consumption is increased too. Of course, after a certain value of the temperature, the consumption remains the same. This makes sense, because after this threshold the A/C units continue to operate at the same consumption level, no matter if the temperature increases up to 5 or 10 degrees higher.

On the other hand, there are buildings like the Lyceum where there is not a clear picture of the relationship between temperature and consumption. Nonetheless, we should keep in mind that during the days that this building was recorded, schools operated with different time schedules than usual (exam period). To that end, there might be a temperature increase in some cases, but the corresponding consumption is relatively low. This indicates an unusual operation of the building.

The overall pictureindicates that temperature plays a certain role in the electric power consumption increase but is not the only factor that affects this phenomenon. Consumption may also rise and fall due to external reasons (e.g. public holidays, special occasions). Thus, additional information related to occupancy and external characteristics are needed to further explain the changes in electric power consumption.

6. Conclusions

6.1 Decision support framework towards energy efficiency in buildings

The information gathered from the energy monitoring and data analysis can be subsequently exploited to build a decision support framework that will enable smart control on buildings, energy-wise. Real-time reporting from smart meters can be applied through IoT platforms.To strengthen the capabilities of such a tool, energy consumption data can be augmented with other type of sensory data that measure occupancy, indoor temperature and humidity, solar radiation, luminosity etc. This kind of external information when coupled with energy data may provide meaningful information regarding the factors that affect energy consumption.

A decision support system should, among others, be able to raise alarms when abnormal operation is observed according to the buildings' energy profile. The side sensory data are important for making decisions about changes on the building's operation (turn on/off lights, raise temperature inside a room etc.). Additionally, the platform that will be responsible for integrating and visualizing this data, might also have a state icon that will represent in an easy and interpretable way the general consumption level of each building. For example, a simple classification of the energy consumed during a specific time interval (week, month) in low, medium and high levels may help understand if corrective actions are needed and how necessary they are.

The aim is to provide an easily accessible and interpretable tool that will enable the building managers control the buildings' behavior. Access to the tool will be possible with credentials that will be provided to the building managers and/or the corresponding stakeholders that must be informed for each building's operation.

Another important component of the aforementioned framework might be the extraction of periodic reports (weekly, monthly)that will be presented to the building managers, including a summary of each building's behavior within this time space. This way the managers will have a clear picture of the energy consumption and can work towards corrective actions if necessary.

6.2 Users' awareness towards buildings' energy efficiency

The purpose of the project, among others, is to save energy, which depends not only on the appliances and their good maintenance but also on the use of its own by the users of the buildings. This is why we need to suggest ways to inform and raise awareness among the tenants. Initially, educating users starts by informing them of the impact of unsustainable energy use. This can be done by posting informative posters, share articles and documentaries that address the issues of energy waste and their environmental impact.

Also, a better way to raise awareness among the building users is by organizing social events, in which can be a constructive face-to-face discussion on the subject and create green teams. By creating annual reports that contain elements, such as real-time results and measurements which prove that the economic use of the building can provide environmental and financial benefits is another way of informing the occupants. Rewarding users who save energy will lead them to continue their good habits and will set a good example to the other users. In keeping with the above, users can acquire eco-friendly habits, so as not to let the appliances run unnecessarily and for a long time.

In addition to informing building users, it is essential to raise awareness among all citizens of issues of environmental awareness and energy consciousness that can be achieved through education. In this context, events and workshops in schools should be organized or even better courses should be taught in the context of acquiring young people's environmental awareness. In addition to helping with education, it is also necessary to promote the environmental crisis in the mass media and to encourage citizens to reduce their energy footprint.Therefore, with the creation of one or more intelligent spotlights, citizens can be informed about good energy-saving practices as well as the economic, social and environmental benefits that can arise from them. Also, it would be advisable to set up interactive seminars among the public building users in order to assess the extent to which citizens pay for the waste of energy at both environmental and economic levels.

6.3 Dissemination activities

All actions that take place towards energy efficiency in this study are expected to bring change to a more general framework. None of the above will eventually make a difference if they are not communicated to the authorities and citizens. Towards this direction, a series of actions are needed to inform and educate people about the importance of searching for new ways to save energy and therefore protect the environment. Such communication activities may include public talks, informative posters, and in general social events that might draw the attention to citizens and therefore learn more about energy efficiency within the city.

Also of great importance is the education about living in an energy-efficient way during the everyday activities. This should be performed within the school environment, to students who will eventually be the future responsible citizens and thus should be aware of the energy saving policy that we are trying to establish within the urban environment. Interventional talks as part of the schools' curriculum can be very effective if organized in a way that will draw the children's attention. Demonstrative actions might also help a lot towards convincing the students that energy saving strategies are necessary.

Organizing talks and events such as the ones described above will eventually have a positive effect to people's everyday lives and will help draw the actions needed to encourage citizens and authorities put their effort to become more aware of the energy-related problems.

7. Proposals for energy waste products exploitation

The destruction of the planet must lead to the use of alternative forms of energy that are environmentally friendly. If we consider that Greece is a country in which the electricity consumption of buildings is among the highest in Europe and that this energy is generated by the burning of lignite, we can realize how harmful this is to the planet and how important it is to use other forms of energy. One measure to combat global warming is to reduce carbon emissions by using renewable energy sources. So solar energy can be utilized by using solar panels and photovoltaic systems. With solar panels, solar energy is converted into heat, so that it can heat the water, that is to operate as a solar water heater, or to act as an auxiliary system in the conventional heating system.

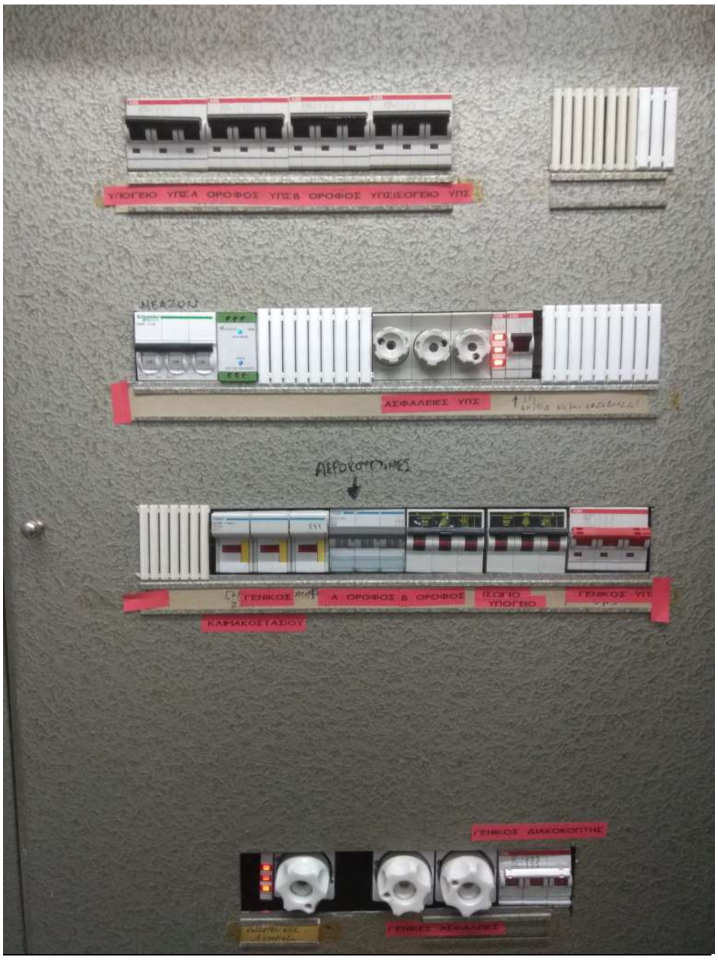
In addition, it is legitimate to reduce dependence on oil as its burning is very harmful to the planet. That is why it is important to strengthen gas supply, which is expected to penetrate significantly in the coming years in almost all sectors of final consumption as well as in the electricity sector. This will lead to a reduction of pollutant emissions, as natural gas is less harmful to the environment.

Apart from the effort to reduce energy consumption in buildings, it is of great interest to try to reuse the waste that is produced by energy consumption. Actions that may take place towards this direction include storing the energy waste to a unit so as to reuse this as another form of energy later.A form of energy that is reusable is the energy which is stored in the form of high pressure compressed air and consumed in a different form of energy converted from the compressed, which is known as CAES. In supporting power network operation, compressed air energy storage works by compressing air to high pressure using compressors during the periods of low electrical energy demand and then the stored compressed air is released to drive an expander for electricity generation to meet high load demand during the peak time periods. These are examples of the use of energy products that lead us to save energy with economic and ecological benefit.

8. Appendix

1. Directorate of Public Health and Social Welfare

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWay JANUS	103.110.000188	124B0011EEEA26	• 1 pcCABLE ETHERNET L=1m • 1 pc POWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 250A	102.105.000270	5149013020672224	• 3 pc Current Transformer SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE



Directorate of Public Health and Social Welfare

Project co-financed by the European Regional Development Fund

2. Directorate of RWG of Achaia Prefecture

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWay JANUS	103.110.000108	124B00060D5FDF	• 1 pcCABLE ETHERNET L=1m • 1 pc POWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 250A	102.105.000277	124B00040A8028	• 3 pcCurrent Transformer SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE
1	MeazonBizy Plug - Button	101.301.002279	124B0002CBABEF	
1	Meazon Panel 1R 4M			• 3 pc FUSE 5*20mm 3A • 3pc FUSE HOLDER 5*20mm • 4 pc 2xFASTCONNECT OR • 1mCable Core • 1mCurrent Transformer's Cable

3. Directorates of Transport, Shipping &Communications of Achaia Prefecture

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWay JANUS	103.110.000235	124B000BE91B77	• 1 pcCABLE ETHERNET L=1m • 1 pc POWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 250A	102.105.000269	5149013020672285	• 3 pcCURRENT TRANSFORMER SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE
1	MeazonBizy Plug - Button	101.301.002195	5149012999777879	
1	Meazon Panel 1R 4M			• 3 pc FUSE 5*20mm 3A • 3 pc FUSE HOLDER 5*20mm • 4 pc 2xFASTCONNEC TOR • 1mCable Core • 1mCurrent Transformer's Cable

Directorates of Transport, Shipping & Communications of Achaia Prefecture

4. Central Directorates of RWG of Achaia Prefecture

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWay JANUS	103.110.000186	124B0011EEEA15	• **1**pcCABLE ETHERNET L=1m • **1** pcPOWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR Ultra 1700A 200-285 VAC	102.116.000165	5149012974259183	• **3** pc Rogowski coil 60cm 2000A/200mV 1m RED/BLACK CABLE
2	Meazon DR 3-Phase 400A	102.301.000919	5149013369617216	• **3** pcCURRENT TRANSFORMER SPLIT CORE XH-SCT-T36, 400A/133mA, 1:3000, 1m RED/BLACK CABLE
		102.301.000918	5149013369617087	
1	MeazonBizy Plug - Button	101.301.002151	124B00029285BB	

5. Building of Head of Region and Directorates of RWG

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWay JANUS	103.110.000187	124B0011EEEA05	• **1**pcCABLE ETHERNET L=1m • **1** pcPOWER ADAPTER 5V/2A, 0.9m LENGTH
2	Meazon DR 3-Phase 250A	102.105.000268	5149013020672212	• **3** pcCURRENT TRANSFORMER SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE
		102.105.000274	124B00040A8055	
1	Meazon Panel 1R 4M			• 3 pc FUSE 5*20mm 3A • 3 pc FUSE HOLDER 5*20mm • 4 pc 2xFASTCONNECTOR • 1mCable Core • 1mCurrent Transformer's Cable
2	MeazonBizy Plug - Button	101.301.002157	124B00029285A1	
		101.301.002158	124B0002928580	


Building of Head of Region and Directorates of RWG Building of Head of Region and Directorates of (ground floor) RWG (basement)

6. Directorate of Agricultural Economy and Veterinary Medicine

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWay JANUS	103.110.000214	124B0011EEE9E5	• 1 pcCABLE ETHERNET L=1m • 1 pc POWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 63A	102.201.000439	5149013020671552	• 3 pcCURRENT TRANSFORMERA TOΣ SPLIT CORE XH-SCT-T10, 50A/20mA, 1:2500, 1m RED/BLACK CABLE
1	Meazon Bizy Plug - Button	101.301.002295	124B0002CC8FC1	

Directorate of Agricultural Economy and Veterinary Medicine

7. Directorate of Engineering Constructions

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWayJANUS	103.110.000212	124B0011EEE8E4	• 1 pcCABLE ETHERNET L=1m • 1 pc POWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 250A	102.105.000276	5149013020672249	• 3 pcCURRENT TRANSFORMER SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE
3	MeazonBizy Plug - Button	101.301.002153	124B000292854C	
		101.301.002297	124B0002CBAF57	
		101.301.002159	124B00029285C3	
1	Meazon Panel 1R 4M			• 3 pc FUSE 5*20mm 3A • 3 pc FUSE HOLDER 5*20mm • 4 pc 2xFASTCONNECTOR • 1mCable Core • 1mCurrent Transformer's Cable

Directorate of Engineering Constructions

8. Experimental School of University of Patras (Primary School)

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWayJANUS	103.110.000200	124B0011EEE964	• 1 pcCABLE ETHERNET L=1m • 1 pc POWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 250A	102.105.000261	5149013020671602	• 3 pcCURRENT TRANSFORMER SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE
1	Meazon Panel 1R 4M			• 3 pc FUSE 5*20mm 3A • 3 pc FUSE HOLDER 5*20mm • 4 pc 2xFASTCONNECTOR • 1mCable Core • 1mCurrent Transformer's Cable

9. Experimental High School of University of Patras (Secondary School)

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWay JANUS	103.110.000202	124B0011EEE8FB	• 1 pcCABLE ETHERNET L=1m • 1 pc POWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR Ultra 100-240VAC 300A	102.116.000154	5149012974259662	• 3 pcCURRENT TRANSFORMERSPLIT CORE XH-SCT-T24, 300A/100mA, 1:3000, 1m RED/BLACK CABLE

10. Experimental High School of University of Patras (Lyceum)

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWay JANUS	103.110.000231	124B0011EEE958	• 1 pcCABLE ETHERNET L=1m • 1 pc POWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 250A	102.105.000262	5149013020672057	• 3 pcCurrent Transformer SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE
1	Meazon Panel 1R 4M			• 3 pc FUSE 5*20mm 3A • 3pc FUSE HOLDER 5*20mm • 4 pc 2xFASTCONNECTOR • 1mCable Core • 1mCurrent Transformer's Cable

11. Administration Building and Conference Center

11.α. Conference Center *(Ground floor – Box 1)*				
Number of items	**Device type**	**Serial Number**	**Mac Address**	**Accessories per item**
1	Meazon Advanced GateWay JANUS	103.110.000161	124B0011EEEA60	• 1 pcCABLE ETHERNET L=1m • 1 pcPOWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 250A	102.105.000257	124B00040A800F	• **3** pcCURRENT TRANSFORMER **SC** Split Core XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE
11.β. Administration Building *(Basement Boxes 2 & 3)*				
Number of items	**Device type**	**Serial Number**	**Mac Address**	**Accessories per item**
1	Meazon Advanced GateWayJANUS	103.110.000213	124B0011EEEA12	• 1 pcCABLE ETHERNET L=1m • 1 pc POWER ADAPTER 5V/2A, 0.9m LENGTH

3	Meazon DR 3-Phase 250A	102.105.000264 102.105.000263 102.105.000265	124B00040A80E2 124B00040A8190 124B00040A8557	• 3 pcCURRENT TRANSFORMER SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE
2	Meazon DR Ultra 200-285 VAC 400A	102.116.000394 102.116.000395	124B000145E0BB 124B0001464BDB	• 3 pcCURRENT TRANSFORMER SC XH-SCT-T36, 400A/133mA, 1:3000, 1m RED/BLACK CABLE
1	Meazon DR Ultra 200-285 VAC 600A	102.116.000198	124B0001464A9C	• 3 pcCURRENT TRANSFORMERSPLIT CORE XH-SCT-2000, 600A/120mA, 1:5000, 1m RED/BLACK CABLE
2	Meazon Panel 1R 4M			• 3 pc FUSE 5*20mm 3A • 3 pc FUSE HOLDER 5*20mm • 4 pc 2xFASTCONNECTOR • 1mCable Core • 1mCurrent Transformer's Cable
1	MeazonBizy Plug - Button	101.301.002294	124B0002CBAC0D	



Conferencecenter(Groundfloor – Box 1) Admin. Building (Basement–Box 2) Admin. Building (Basement –Box 3)

Details

Conference Center*(Ground floor-Box 1)*

1 pc DR 3 Phase 250A(**102.105.000257**)
1 pcMeazonAdvancedGateWayJANUS(**103.110.000161**)

Administration Building
(Basement - Box 2)

1 pcDR 3-Phase 250A(**102.105.000263**)
2 pcDR Ultra 200-285 VAC 400A(**102.116.000394 & 102.116.000395)**
1 pcMeazon Panel 1R 4M
1 pc Bizy Plug - Button (**101.301.002294**)
1 pc Meazon Advanced GateWayJANUS (**103.110.000213**)

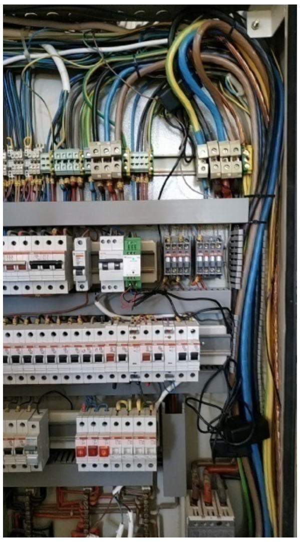
Administration Building
(Basement - Box 3)

2 pc DR 3-Phase 250A (**102.105.000264 &102.105.000265**)
1 pcMeazon Panel 1R 4M
1 pc DR Ultra 200-285 VAC 600A (**102.116.000198**)

***** Boxes 2 & 3 have the same Meazon Advanced GateWay – JANUS in common***

12. Directorate of Transport, Shipping & Communications of Ileia Prefecture

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWayJANUS	103.110.000198	124B0011EEE901	• **1**pcCABLE ETHERNET L=1m • **1** pcPOWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 250A	102.105.000271	5149013020673128	• **3**pcCURRENT TRANSFORMER SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE



Directorate of Transport, Shipping & Communications of Ileia Prefecture

Project co-financed by the European Regional Development Fund

13. Administration Building of Messolonghi

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon AdvancedGateWayJANUS	103.110.000199	124B0011EEEA45	• **1**pcCABLE ETHERNET L=1m • **1** pcPOWER ADAPTER 5V/2A, 0.9m LENGTH
4	Meazon DR 3-Phase 250A	102.105.000275	5149013020671976	• **3**pcCURRENT TRANSFORMER SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE
		102.105.000250	124B00040A83F9	
		102.105.000266	5149013020672357	
		102.105.000272	124B00040AB47F	
1	MeazonBizy Plug - Button	101.301.002200	5149012999777863	
2	Meazon DR 3-Phase 400A	102.301.000687	124B001110E0E1	• **3**pcCURRENT TRANSFORMER ΑΤΟΣ SPLIT CORE XH-SCT-T36, 400A/133mA, 1:3000, 1m RED/BLACK CABLE
		102.301.000925	5149013369626629	

14. Directorates of RWG of Aitolokarnania Prefecture

Number of items	Device type	Serial Number	Mac Address	Accessories per item
1	Meazon Advanced GateWayJANUS	103.110.000167	124B0011EEE963	• **1**pcCABLE ETHERNET L=1m • **1** pcPOWER ADAPTER 5V/2A, 0.9m LENGTH
1	Meazon DR 3-Phase 250A	102.105.000273	5149013020673171	• **3**pcCURRENT TRANSFORMER SC XH-SCT-T24, 200A, 1:2500, 1m RED/BLACK CABLE

Bibliography

[1] B. Rogers, "What are the benefits of electrical submetering?," Setra Systems, Inc., 2017. [Online]. Available: https://www.setra.com/blog/what-are-the-benefits-of-submetering/2015/03/23.

[2] Navigant Research, "Electricity Submeters: Market Analysis and Forecast," Navigant Consulting, Inc., 2014.

[3] Energy Manager Today, "7 Benefits of Submetering," 2013. [Online]. Available: https://www.energymanagertoday.com/7-benefits-of-submetering-097498/.

[4] [Online]. Available: http://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT.

[5] S. Al-Sarawi, M. Anbar, K. Alieyan and M. Alzubaid, "Internet of Things (IoT) communication protocols: Review," in *8th International Conference on Information Technology (ICIT)*, Jordan, 2017.

[6] Sierra Wireless, "What is LPWA?," Sierra Wireless, Inc., 2018. [Online]. Available: https://www.sierrawireless.com/resources/infographics/lpwa/.

[7] "The Many Flavors of Bluetooth IoT Connectivity," [Online]. Available: http://www.silabs.com.

[8] C. Zhang, M. Zhang, Y. Su and W. Wang, "Smart home design based on ZigBee wireless sensor network," in *7th International Conference on Communications and Networking*, China.

[9] "About X-Wave Technology," [Online]. Available: https://z-wavealliance.org/about_z-wave_technology/.

[10] S.-C. L. Q. W. Chia-Wen Lu, "Interconnecting ZigBee and 6LoWPAN wireless sensor networks for smart grid applications," in *Fifth International Conference on Sensing Technology (ICST)*, New Zeland, 2011.

[11] R. Want, "Near field communication," *IEEE Pervasive Computing,* vol. 10, no. 3, 2011.

[12] [Online]. Available: http://www.sigfox.com.

[13] [Online]. Available: http://neul.com/neul-news/news-nb-iot-standard/.

[14] A. Lavric and V. Popa, "Internet of Things and LoRa Low-Power Wide-Area Networks: A

survey," in *2017 International Symposium on Signals, Circuits and Systems (ISSCS)*, 2017.

[15] [Online]. Available: http://blog.teleplanglobe.no/what-is-nb-iot.

[16] K. Mekki, E. Bajic, F. Chaxel and F. Meyer, "A comparative study of LPWAN technologies for large-scale IoT deployment," *ICT Express,* 2018.

[17] Lux Research, "NB-IoT Standard Poised to Take 90% Share of Low-Power Wide-Area Networks for IoT," 2017. [Online]. Available: http://www.marketwired.com/press-release/nb-iot-standard-poised-to-take-90-share-of-low-power-wide-area-networks-for-iot-2212479.htm.

[18] "Meazon," [Online]. Available: http://www.meazon.com.

[19] "Microsoft Azure," [Online]. Available: https://azure.microsoft.com/en-us/.

[20] "BRESAER - REakthrough Solutions for Adaptable Envelopes in building Refurbishment," [Online]. Available: http://www.bresaer.eu.

[21] L. T. Services, "L&T Technology Services," [Online]. Available: https://www.lnttechservices.com/solutions/i-bems.

[22] S. Wuppertal Institut - Gokarakonda, C.-. p. Moore, L. Tholen and C. Xia-Bauer, "Handbook Building Energy Management in Large Shopping Malls and Medium-Sized Hotels," Wuppertal Institute 2017.

[23] Siemens, "HVAC building technology – quality and energy efficiency from strong partners: Answers for infrastructure.," Siemens Switzerland Ltd.

[24] M. B. E. &. E. U. Becker, " Research on building automation and intelligent building design in the zafh.net research network," 2010.

[25] "7 Features of the Best Building Energy Management Systems," [Online]. Available: https://internet-of-things-innovation.com/insights/the-blog/7-features-of-the-best-building-energy-management-systems/#.XEGwFaeB1p9.

[26] "Microsoft Power BI Interactive Data Visualization BI Tools," [Online]. Available: https://powerbi.microsoft.com/en-us/.