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Research Paper

# Monitoring energy consumption of vending machines in university buildings

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ABSTRACT

Vending machines are a convenient source of food and drinks, but they can also be a significant source of energy consumption in public buildings. To reduce energy waste and improve energy efficiency, a low-cost sensor network was used to monitor the energy usage of vending machines. The sensor network consists of small, wireless sensors that are placed inside the vending machines, and a central hub that is connected to the internet via Wi-Fi. The sensors are able to collect data on the energy usage of the vending machines, including when they are idle, in use, or in a standby mode. This data is then transmitted to the central hub, where it is processed and made available to users through a web-based interface or mobile app. With this information, users can identify patterns in energy usage and make changes to reduce overall energy consumption. In a university in southern Spain, 53 vending machines of three types were monitored: snack, cold drinks, and hot drinks. The average monthly consumptions of these types of vending machines were snack (250 kWh), cold drinks (200 kWh), and hot drinks (100 kWh). By using a sensor network to monitor the energy usage of vending machines, it is possible to identify areas where energy is being wasted and make adjustments to reduce this waste. This can help to reduce the environmental impact of the vending machines, by reducing the amount of energy that is consumed and the associated greenhouse gas emissions. Additionally, by making the vending machines more energy efficient, it is possible to improve their overall productivity and cost-effectiveness. Overall, the use of a low-cost sensor network to monitor vending machines energy usage can be seen as a form of cleaner production, because it promotes the use of more sustainable and efficient industrial processes.

## 1. Introduction

Energy consumption in buildings plays a pivotal role in the global energy landscape (Yan et al., 2015). According to the International Energy Agency, buildings are responsible for over one-third of worldwide energy consumption and a corresponding share of energy-related greenhouse gas emissions. The imperative of monitoring energy consumption extends to both commercial establishments (Meier and Cautley, 2021) and public buildings, including educational institutions like schools (Ouf et al., 2016) and universities (Chihib et al., 2020). This monitoring is a crucial step towards mitigating their environmental impact and enhancing energy efficiency (da Silva et al., 2021). Examining the energy usage of vending machines aligns with the broader concept of energy conservation within buildings (Michael et al., 2017). In today's modern buildings, there is an ever-increasing presence of electrical equipment (AlFaris et al., 2017).

In 2006, more than 3 million vending machines for chilled beverages were operating in the United States, consuming over 12 billion kWh of electricity per year (Lewis, 2006). Ten years later, in 2017, it was estimated that there were only 4.6 million vending machines for chilled beverages in operation in the United States, highlighting that 56% of vending machine sales were for cold drinks (Capps and Gvillo, 2020), which have the highest energy consumption.

Every day, millions of kilowatt-hours go to waste globally due to devices remaining powered on but unused, leading to accelerated device wear and higher wasteful costs. Fortunately, technology offers

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promising solutions through the utilization of tools aimed at addressing this issue. The first of these refers to the commissioning of new buildings, which ensures that they deliver or exceed the performance and energy savings promised by their design and intended operation (Mills, 2011). Chakraborty and Pfaelzer (2011) identify numerous sources of standby power loss in electrical and electronic appliances and devices, and they suggest technical measures to be taken to minimize standby power consumption. Hafer et al. (2017) highlight that devices connected to the electrical outlet account for an average of 33% of a commercial building's total energy expenditure, and they propose the use of smart plugs to 1) measure energy consumption (kWh) over time, and 2) turn off devices when they are not in use, thus saving energy.

Refrigerated vending machines represent a wide range of a daily energy use depending on their level of efficiency, the U.S National Renewable Energy Laboratory (NREL) have shown that a typical machine that dispenses 500 12-oz cans with an illuminated front consumes between 7 and 11 kWh/day in an office environment (Deru et al., 2003). On the other hand, on average, the Energy Star certified vending machine use 40% less energy than standard models (Sanchez et al., 2008), where the daily Energy Use is about 9.5 kWh/Day for cold drink vending. Other studies have come to the same conclusion at the University of British Columbia's Vancouver campus (UBC), where the baseline consumption for conventional beverage vending machine showed minor fluctuations between 9 kWh/day and 10 kWh/day, and for snack machine between 1.2 kWh/day and 1.4 kWh/day (Harnanan and Zaremba, 2015). Note that in this last study, the snack machine is not temperature controlled.

A study was conducted in Spain and Portugal interviewing 620 university students, and the outcomes indicated that over 51% uses the vending machines occasionally, and the daily use rate is 13.4% in Spain against 3.9% in Portugal. In addition, overweight and obesity shows higher spread among the Spanish than the Portuguese student community (Raposo et al., 2018).

Energy data can be sourced from various channels and collected through diverse techniques, such as indoor sensors (Dong et al., 2019) or the development of low-cost, open-source energy and power meters (Viciana et al., 2018). These meters generate data encompassing various behavioral patterns, which can subsequently be harnessed to provide insights and recommendations for enhancing efficiency and reducing costs.

Professionals in the field are offering intelligent energy management and control solutions through plug devices. These devices primarily serve to quantify the energy usage of machines and appliances. However, they offer additional functionalities, such as remotely powering connected appliances on and off during non-operating hours, thanks to their integration with the internet. These plug devices collect and transmit data to the system, enabling subsequent processing and analysis (Yao et al., 2014).

Moreover, modern appliances are capable of operating across a spectrum of power levels and modes, rather than being limited to simply 'on' or 'off' states. This versatility encourages sustainable and efficient utilization (Wever et al., 2008). For instance, a typical printer/fax/scanner device with a version 4.0 ENERGY STAR qualification features four modes: Active, Idle, Sleep, and Standby. The Idle mode facilitates quick start-up for imaging tasks while reducing energy consumption by 64% compared to the Active mode. In contrast, the Sleep and Standby modes are exceptionally energy-efficient, consuming 88% and 98% less power than the Active mode, respectively (Wilkins and Hosni, 2011).

Many previous studies have focused on plug loads in commercial and office buildings, with limited attention given to educational facilities, which present a unique and promising case study for potential energy savings. In a specific case study conducted on Stanford University's campus, it was estimated that plug loads account for 32% of the total energy consumption across the university's 220 buildings (Hafer, 2017). University buildings, in particular, offer spaces where the public can connect their devices to the electrical system, such as cell phones and personal computers, making it challenging to accurately estimate and control plug loads (Chihib et al., 2021).

A study carried out at the University of British Columbia employed management devices to control all the vending machines on campus, effectively reducing their energy consumption. This technique resulted in a remarkable 40% reduction in energy use for conventional chilled beverage vending machines, with a payback period of just 3.3 years (Harnanan and Zaremba, 2015).

In the E.U, new energy regulation refrigerators with direct sales function is implemented, and appliances placed on the market after 1 March 2021 must be labeled with the new energy label that allows to identify the level of efficiency, compare appliances helps the decision makers to purchase a cost-effective machine, this product data sheet, must indicates the appliance scale energy efficiency classes that varies from A to G, and. And it also must include the QR-Code to EPREL database, the Supplier's name or trademark and model identifier, the annual energy consumption (kWh/yr), the TDA (m2) or net resp. gross volume (L) for chilled and frozen compartments, the temperature class (testing conditions), and the Number of EU regulation (EU, 2019). This legal regulation should apply to the following refrigerating appliances with a direct sales function: supermarket refrigerating (freezer or refrigerator) cabinets, beverage coolers, ice-cream freezers, gelato-scooping cabinets and refrigerated vending machines.

Therefore, there is a growing global concern over the energy consumption of vending machines. As these ubiquitous machines become more prevalent in various settings, such as offices, schools, and public spaces, their collective energy usage has become a significant environmental issue. The continuous operation of refrigeration systems, lighting, and electronic components in vending machines contributes to increased electricity consumption and carbon emissions. To address this concern, there is a pressing need for the development and adoption of energy-efficient vending machine technologies, as well as greater awareness among consumers and operators about the environmental impact of these devices. The goal of this research is monitoring the energy consumption with low-cost sensors of different types of vending machines in university buildings and for this purpose use the Wi-Fi networks of public buildings for data transmission. The novelty of the work consists of the development of a low-cost sensor network to continuously monitor all the vending machines, in this way the cost is invoiced to the company that owns the machines, which can then proceed to establish energy saving measures that will be suggested as a conclusion of this work.

## 2. Data and methodology

The University of Almeria is a Spanish Public University located in the southeast coast of Spain, with the coordinates of latitude 36°49′45″N and longitude −2°24′16″E. The university campus spreads on a surface of 17 ha and has 37 buildings (see Fig. 1). In the 2022–2023 academic year, the university offered 38 different degree programs for almost 13,000 students, with a staff of more than 1000 people. It has a Mediterranean climate, characterized by hot and dry summers with an average temperature of 28 °C and mild winters with an average temperature at 16 °C. July boasts the highest number of daily sunshine hours, while January takes the title for the wettest month in this region. Throughout the year, this locale experiences minimal rainfall, earning it the distinction of being one of Europe's driest regions. These unique climatic conditions have transformed it into a prime location for solar power generation, benefitting from abundant sunlight that creates an ideal environment for solar panels. Additionally, the arid climate enhances the efficiency of other renewable energy sources, including wind power. In summary, Almeria's climatic attributes position it favorably for renewable energy production, offering a pathway to reduce the region's reliance on fossil fuels and contribute to a more sustainable energy future.

**Fig. 1.** Location and distribution of the buildings of the University of Almeria.

The University of Almeria campus hosts a total of 53 vending machines strategically placed across 33 buildings. These vending machines are operated by an external entity that rents space within the university buildings and are connected to the local electrical outlets, as illustrated in Fig. 2. They operate on a standard 220 V power supply, with nominal power ratings ranging from 500 W to 800 W. These vending machines

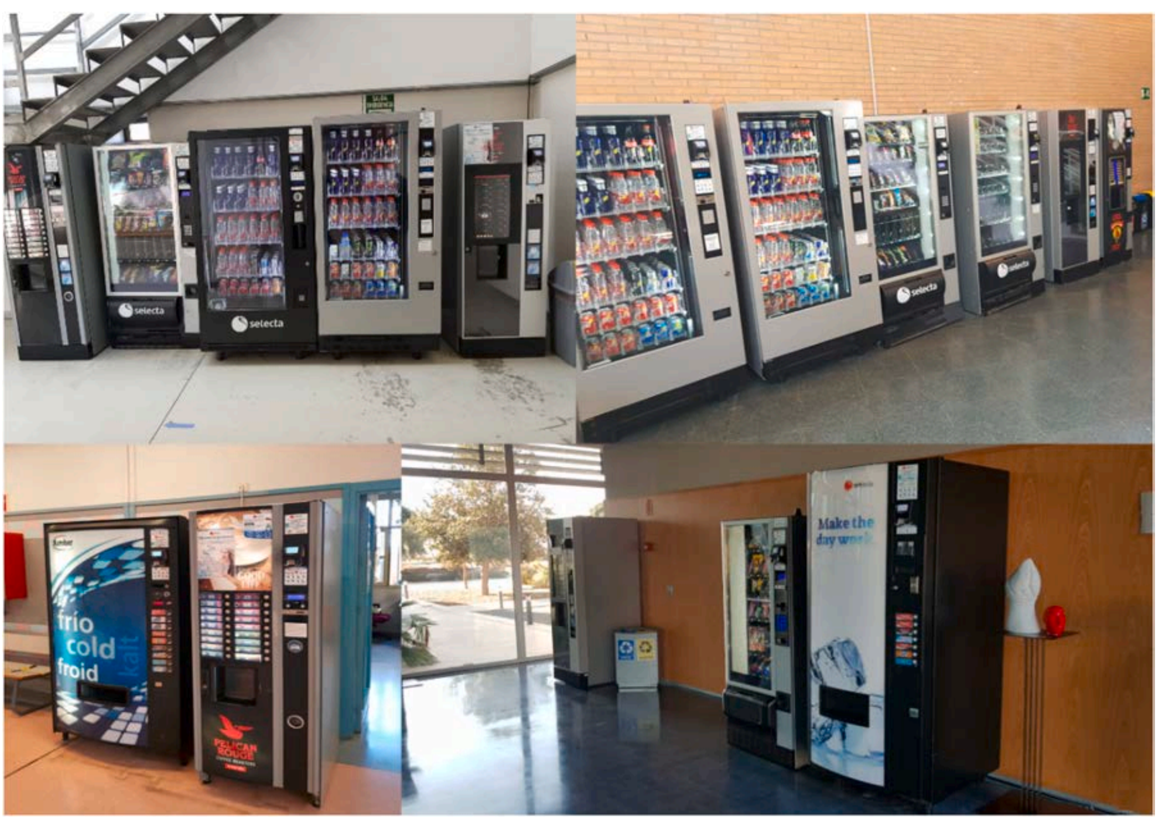


**Fig. 2.** Vending machines inside the University buildings.

have been categorized into three primary groups, as depicted in Fig. 3: 14 fall under the "Snacks Refrigerated" (SR) category, 17 are designated as "Cold Drinks" (CD), and 22 fall into the "Hot Drinks" (HD) category.

The low-cost sensor network designed for monitoring vending machines comprises individual sensors, including plug-in sensors and power meters, which are installed in each vending machine across various university buildings. These cost-effective sensors are interconnected with a central hub or gateway, typically connected to the internet via a Wi-Fi network, as illustrated in Fig. 4. These sensors have the capability to actively monitor and measure the energy consumption of the vending machines, transmitting this real-time data to the central hub.

The central hub can process this data and make it accessible to users through either a web-based interface or a mobile app, often referred to as the dashboard. This functionality empowers users to monitor their energy consumption in real-time and store the data for subsequent analysis. In Fig. 5A, you can observe the sensors being calibrated in the electrical engineering laboratory of the University of Almeria, while Fig. 5B depicts them connected to the power sockets that supply electricity to the vending machines. The plug-in sensors were configured to connect to the University's Wi-Fi network and were subsequently plugged into the electrical outlets that power the vending machines. These devices are capable of providing energy usage data on an hourly basis, similar to other studies focused on building energy consumption (Raftery et al., 2011), with the data being stored and aggregated on a daily basis.

Once the sensors are installed, they have the capability to monitor instantaneous energy consumption. Fig. 6 illustrates the monitoring process during the purchase of coffee from a hot drink vending machine, providing a real-time view of energy usage. Fig. 7, on the other hand, offers a comprehensive daily monitoring snapshot, showcasing the energy consumption patterns of four vending machines throughout the day.

## 3. Results

The vending machines underwent monitoring for a duration of one year, spanning from June 2021 to May 2022, encompassing all 53 machines. In Appendix 1, the monthly consumption data for the snack vending machines is presented. Out of the 14 SR machines, they collectively consumed 41,590 kWh over the course of the year, resulting in a monthly average of 3465 kWh. These consumption patterns are depicted in Fig. 8.

Notably, one vending machine exhibited significantly reduced energy consumption starting from November. This reduction can be attributed to the machine remaining connected but being either empty or containing minimal contents, thus leading to its diminished energy usage. Consequently, this particular machine is excluded from the calculation of the average monthly consumption, which is determined to be 256.57 kWh. In practical terms, it can be concluded that the average monthly consumption for a refrigerated snack vending machine is approximately 250 kWh.

Appendix 2 presents the monthly consumption data for the cold drinks vending machines (CD). All 22 CD machines collectively consumed 38,290 kWh throughout the year, resulting in an average monthly consumption of 3085 kWh. This data is visually represented in Fig. 9. Notably, one of the machines, named "SPORTS," displays a descending consumption trend that corresponds with temperature variations due to the climate zone, particularly from October to March, with the lowest consumption occurring in January. The average monthly consumption for the cold drinks vending machines is calculated to be 192.61 kWh. In practical terms, it can be concluded that the average monthly consumption for a cold drinks vending machine is approximately 200 kWh.


**Fig. 3.** Types of vending machines: A) Snack Refrigerated (SR), B) Hot Drink (HD), and C) Cold drink (CD).

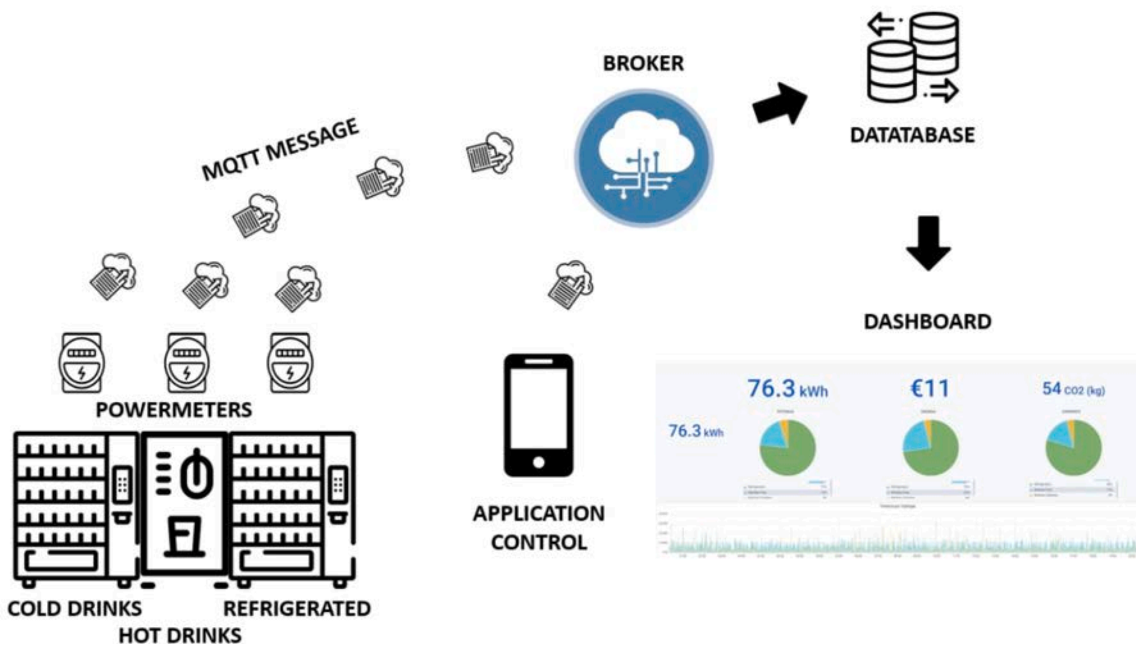


**Fig. 4.** Methodology.

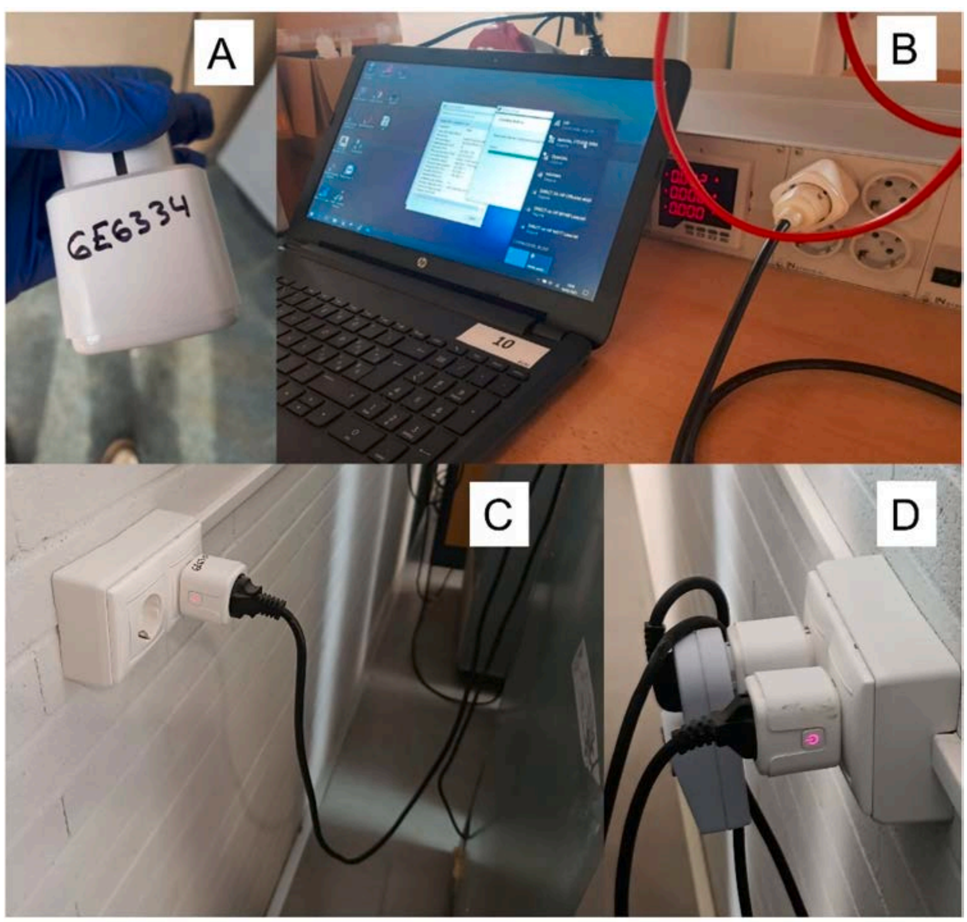


**Fig. 5.** Plug-in sensors (Power meters): A) Sensor, B) Calibration at laboratory, C) Sensor installed, D) Installed sensors and one with vending machine controller.

Appendix 3 displays the monthly consumption data for the hot beverage (HD) vending machines. All 17 HD machines collectively consumed 27,713 kWh over the course of one year, resulting in an average monthly consumption of 2309 kWh. This data is visually depicted in Fig. 10. Remarkably, one of the machines, named "DEPORTES," exhibits a declining consumption pattern that correlates

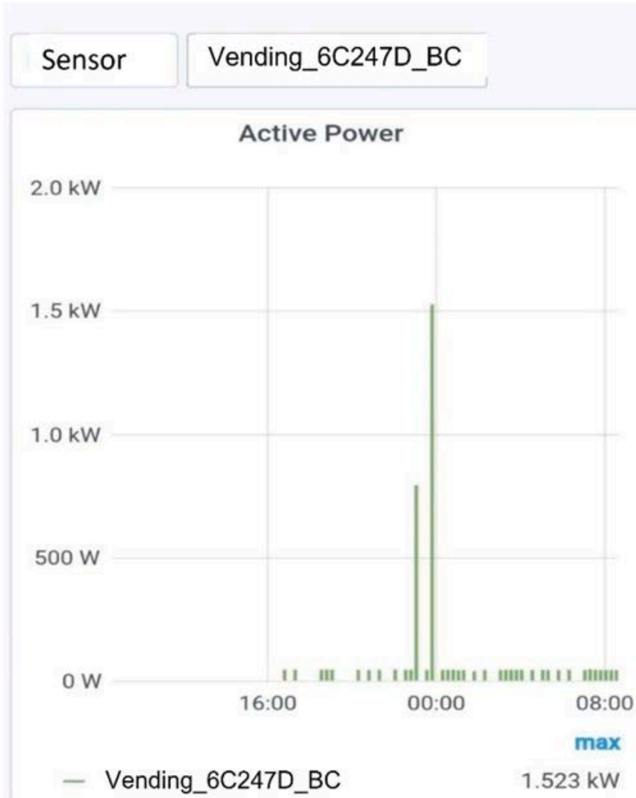


**Fig. 6.** Example of energy consumption when a coffee is purchased.

with the decrease in temperatures for the climate zone, particularly from October to March, with the lowest consumption recorded in January. The calculated average monthly consumption for the hot drinks vending machines stands at 107.29 kWh. In practical terms, it can be concluded that the average monthly consumption for a hot drinks vending machine is approximately 100 kWh.

## 4. Discussion

As previously mentioned, the average monthly consumptions for these vending machine types were as follows: snack refrigerated (250 kWh), cold drinks (200 kWh), and hot drinks (100 kWh). Fig. 11 illustrates the distribution of energy consumption by month, categorized by vending machine type. It is evident that snack refrigerated vending machines exhibit the highest energy consumption, accounting for 40% of the total. Following closely, cold drink vending machines represent 35% of the energy consumption, while hot drink vending machines show the lowest energy usage, at 25%.

In a study involving 263 vending machines at Texas A&M University (USA), it was observed that each machine consumed an average of 9.72 kWh per day or 291.6 kWh per month (Ritter and Hugghins, 2000). These results significantly exceed the findings of our study. Conversely, a separate study on vending machines within a Mexican university building (Martinez-Patiño et al., 2018) reported energy consumption levels that closely align with our results. Specifically, cold drinks consumed 7.50 kW/h per day (225 kWh per month), hot drinks (coffee) consumed 4.50 kW/h per day (135 kWh per month), and refrigerated snacks consumed 7.80 kW/h per day (234 kWh per month).

It is evident from the analyzed data that different types of vending machines exhibit varying levels of energy consumption (Menezes et al., 2013). Several factors contribute to these differences, including the need for chilled snack vending machines to maintain consistent snack temperatures, while hot beverage vending machines require less energy, primarily for beverage heating rather than temperature maintenance. Moreover, vending machine size, design, usage frequency, and the specific products they offer can also play a significant role in influencing energy consumption.

Fig. 12 displays the monthly energy consumption categorized by vending machine type. It is evident that during the colder seasons, the sale of cold drinks and refrigerated snacks decreases, whereas the energy consumption of hot drinks machines rises for the same period. These energy consumption trends align seamlessly with weather-related consumption patterns for beverages and snacks. Additionally, it is noticeable that during summer holidays, as well as the Christmas and year-end holiday seasons, the collective consumption of all vending machines experiences a decline. In 2022, the price of electricity in the wholesale market in Spain experienced a significant surge, nearly doubling compared to 2021, rising from 111 euros per megawatt-hour (MWh) to

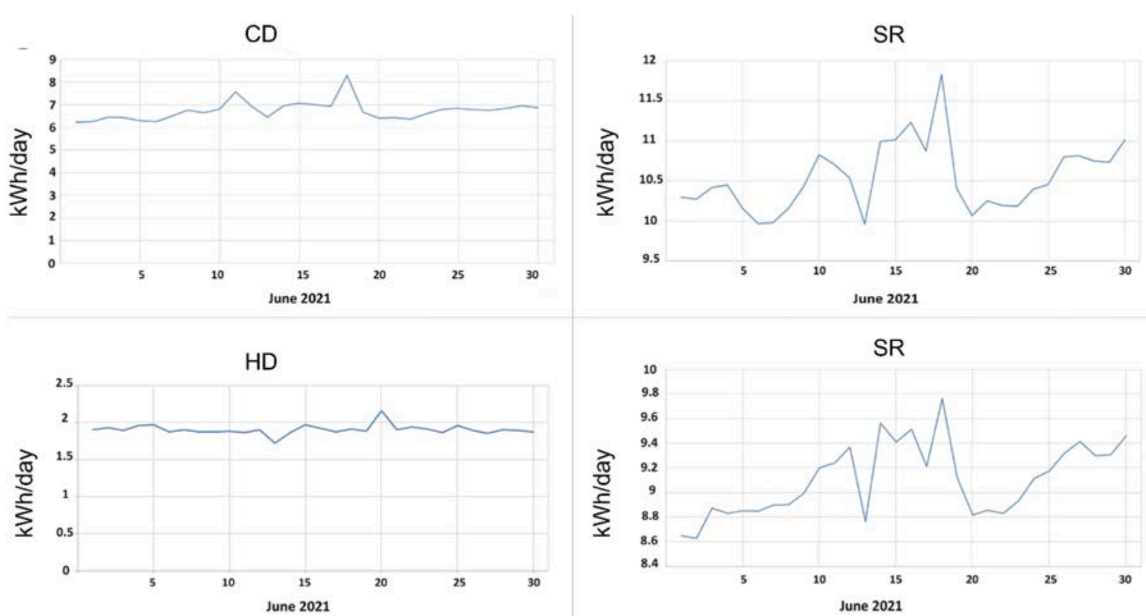


**Fig. 7.** Example of patterns of daily energy consumption of four vending machines for June 2021. Snack Refrigerated (SR), Hot Drink (HD), and Cold drink (CD).

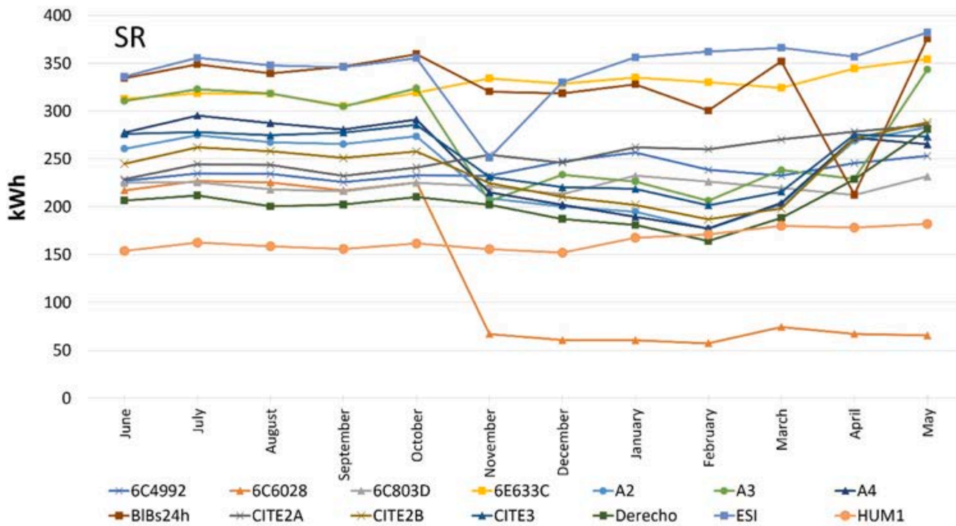


**Fig. 8.** Energy consumption (kWh) for vending machines of Snack Refrigerated (SR) from June 2021 to May 2022.

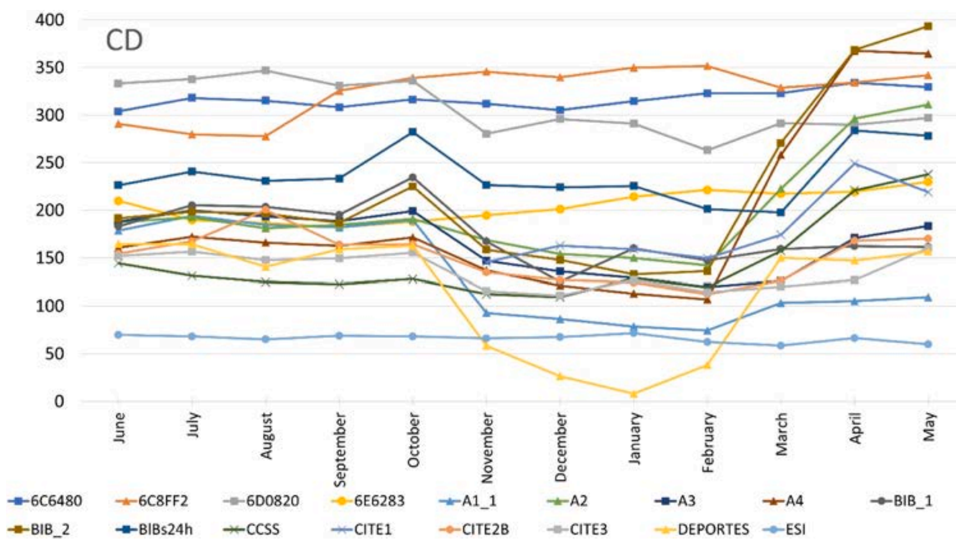


**Fig. 9.** Energy consumption (kWh) for vending machines of cold drinks (CD) from June 2021 to May 2022.

210 euros per MWh. The situation at the university was even more challenging, with the cost per megawatt-hour now reaching 300 euros, which is three times higher than the previous year's rate. To provide a recent illustration, the total energy consumption of vending machines at the University of Almeria in April 2023 amounted to 15,812 kWh, and in May, it reached 16,702 kWh. At the prevailing energy prices, this translates to approximately 4500 euros per month.

A few recommendations for ways to potentially save energy in vending machines at a university in southern Spain with a semi-hot climate:

- Use energy-efficient vending machines (Harnanan and Zaremba, 2015): Look for vending machines that are Energy Star certified or have other certifications indicating energy efficiency. These machines may use less energy to operate and could potentially save on energy costs over time.

- Use LED lighting (Montoya et al., 2017): LED lighting is more energy efficient than traditional incandescent bulbs and can help reduce energy consumption in vending machines.

- Use sensors to control lighting and temperature (Hafer, 2017): Installing sensors that can detect when the vending machine is in use and adjust the lighting and temperature accordingly can help save energy.

-Turn off vending machines when not in use (Deru, 2003; Brown et al., 2012): If possible, turn off vending machines when they are not in use to reduce energy consumption.

- Insulate vending machines (Madigan et al., 2015): Adding insulation to vending machines can help maintain a consistent temperature, which can reduce the energy needed to cool or heat the machine.

- Use energy-efficient vending machine products (Lewis et al., 2006): Consider using vending machine products that have low energy consumption requirements, such as LED display screens or low-power refrigeration systems.

- Regular maintenance (Harnanan and Zaremba, 2015): Regular maintenance of vending machines can help ensure that they are running efficiently and consuming less energy. This can include cleaning the machine and checking for any issues that may be causing the machine to use more energy than necessary.

Plug-in sensors provide data on an hourly basis, offering a clear overview of vending machine energy consumption. One of the mismanagement issues identified through this monitoring is that all vending machines remain operational during the night and holidays. While employing a low-cost sensor network to monitor vending machine

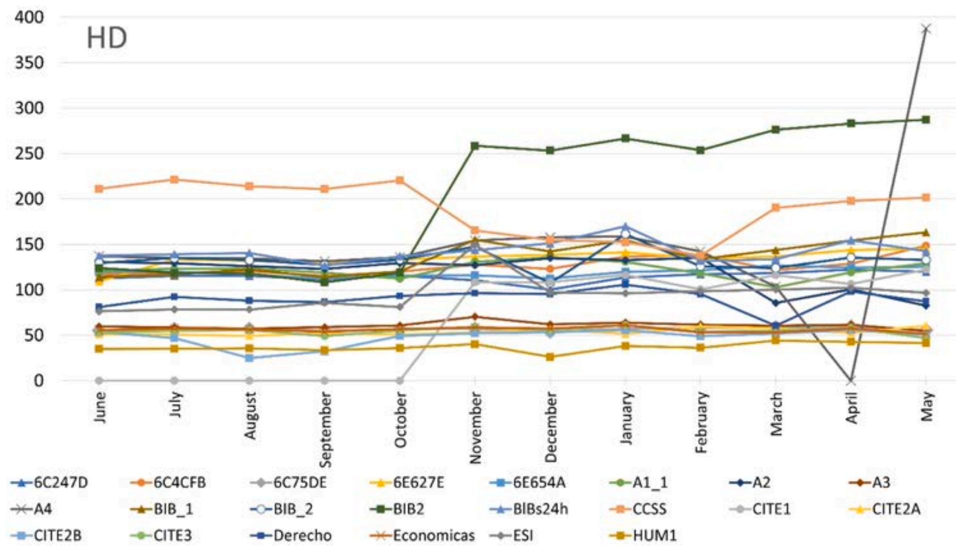


**Fig. 10.** Energy consumption (kWh) for vending machines of cold drinks (HD) from June 2021 to May 2022.

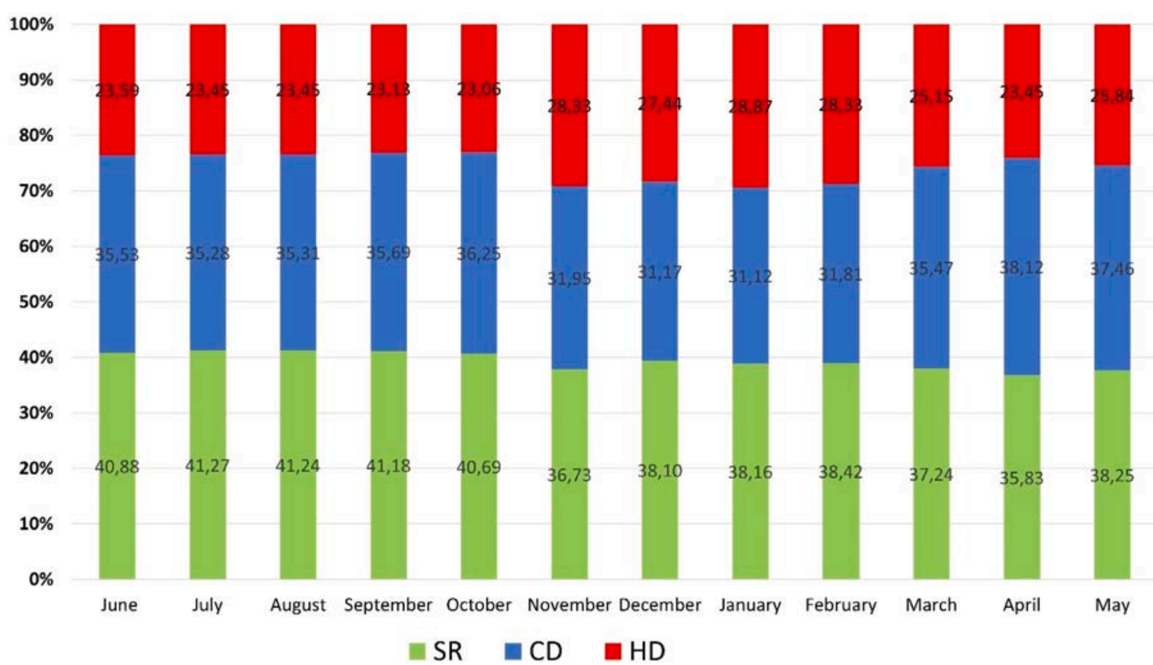


**Fig. 11.** Energy consumption percentage distribution according to vending machine type.

energy usage offers numerous advantages, there are also potential drawbacks to consider, including:

- The sensors and other equipment required for a low-cost sensor network may be subject to wear and tear, and they may need to be replaced or repaired over time (Sazonov et al., 2004). One potential drawback of using a low-cost sensor network to monitor the energy usage of vending machines is that the sensors and other equipment required for the network may be subject to wear and tear, or even theft. This is because the sensors are typically placed inside the vending machines, where they are exposed to a range of environmental conditions, including temperature fluctuations, humidity, and vibration. Over time, these conditions can cause the sensors and other equipment to degrade or malfunction, which can affect their ability to provide accurate and reliable data. As a result, it may be necessary to periodically replace or repair the sensors and other equipment to maintain the performance and accuracy of the sensor network. This can add to the overall cost and complexity of the network, and it may require specialized knowledge and expertize to properly maintain and troubleshoot the sensors and equipment.

- The sensor network may require ongoing maintenance and support, in order to ensure that it is functioning properly and providing accurate data (Mattern et al., 2010). Another potential drawback of using a low-cost sensor network to monitor the energy usage of vending machines is that the network may require ongoing maintenance and support to function properly and provide accurate data. This is because the sensors and other equipment in the network may be subject to wear and tear, as discussed above, and they may need to be regularly checked and maintained to ensure that they are functioning correctly. Additionally, the sensor network may be connected to the internet via a Wi-Fi network, which can be subject to interference or other issues that can affect the accuracy and reliability of the data being transmitted. As a result, it may be necessary to provide ongoing support and maintenance

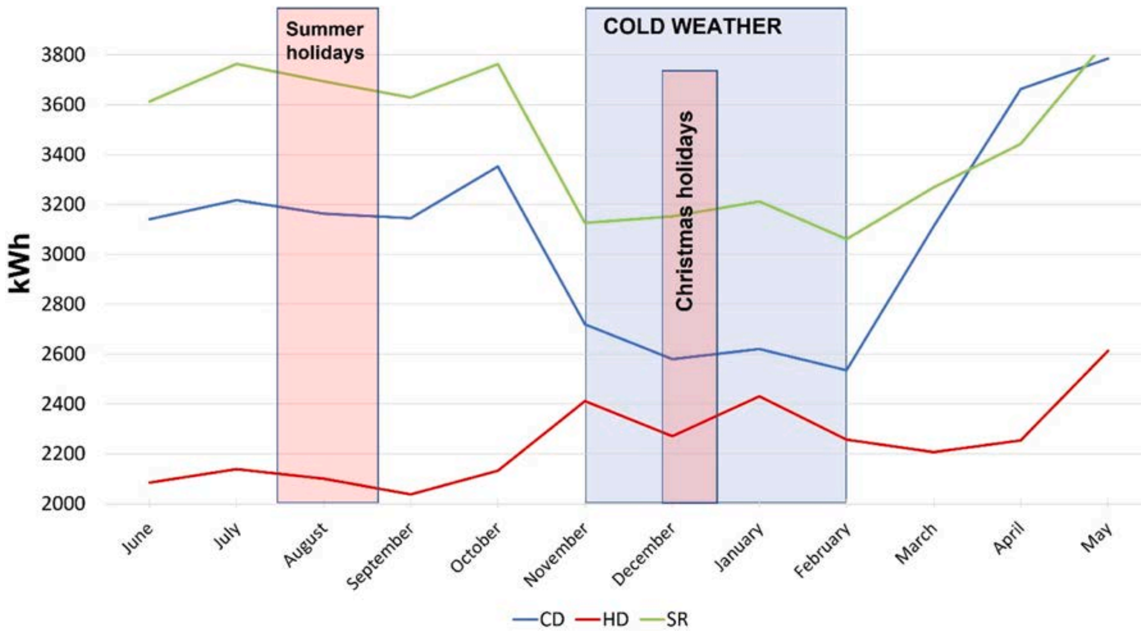


**Fig. 12.** Annual pattern of energy consumption of vending machines according to the type of product.

for the sensor network, to ensure that it is functioning properly and providing accurate and useful data. This can add to the overall cost and complexity of the network, and it may require specialized knowledge and expertize to properly maintain and troubleshoot the sensors and equipment.

- The use of a sensor network may require the installation of additional wiring or other infrastructure, which can be time-consuming and costly (Novas et al., 2017). Another potential drawback of using a low-cost sensor network to monitor the energy usage of vending machines is that the network may require the installation of additional wiring or other infrastructure, which can be time-consuming and costly. For the sensors to collect data on the energy usage of the vending machines, they must be connected to a central hub or gateway, which is typically located in a central location. To connect the sensors to the hub, it may be necessary to install additional wiring or other infrastructure, such as power outlets or communication channels. This can be a time-consuming and labor-intensive process, and it may require specialized knowledge and expertize to install the wiring and other infrastructure correctly. Additionally, the installation of additional wiring and infrastructure can add to the overall cost of the sensor network, making it more expensive to implement.

- The sensor network may generate a large amount of data, which can be difficult to manage and analyze (Cama et al., 2013). Another potential drawback of using a low-cost sensor network to monitor the energy usage of vending machines is that the network may generate a large amount of data, which can be difficult to manage and analyze (Solano et al., 2017). This is because the sensors in the network are constantly collecting data on the energy usage of the vending machines, and this data is transmitted to the central hub in real-time. As a result, the sensor network can generate a large amount of data, which may be difficult to manage and process efficiently. To make sense of this data, it may be necessary to use specialized software or tools to identify patterns and trends in energy use. This can be a time-consuming and complex process, and it may require specialized knowledge and expertize to properly manage and analyze the data. Additionally, the large amount of data generated by the sensor network can place a significant burden on the hardware and software infrastructure used to store and process the data, which can add to the overall cost and complexity of the network.

- The sensor network may not be able to provide detailed information on the energy usage of all appliances and equipment, particularly if they are not directly connected to the sensors. Another potential drawback of using a low-cost sensor network to monitor the energy usage of vending machines is that the network may not be able to provide detailed information on the energy usage of all appliances and equipment, particularly if they are not directly connected to the sensors (Weng et al., 2011). For the sensors to collect data on the energy usage of a particular appliance or piece of equipment, the appliance or equipment must be directly connected to the sensors. This can be challenging in the case of vending machines because many of the components and systems inside the vending machines are not easily accessible, and they may not be directly connected to the sensors. As a result, the sensors may not be able to provide detailed information on the energy usage of all the components and systems inside the vending machines, which can limit the usefulness and effectiveness of the sensor network. To overcome this limitation, it may be necessary to install additional sensors or other equipment inside the vending machines, which can add to the overall cost and complexity of the network.

## 5. Conclusions

In conclusion, this energy monitoring study utilizing a cost-effective wireless sensor network has revealed several key findings. Firstly, it has demonstrated that such sensor networks can offer detailed and precise insights into the energy consumption of individual vending machines. This information proves invaluable in identifying usage patterns, pinpointing peak demand periods, and recognizing instances where vending machines operate less efficiently than desired. Furthermore, the study has showcased how this data can be harnessed to implement energy-saving strategies effectively, ultimately leading to a reduction in energy consumption and the promotion of energy efficiency. In the context of the case study, it has become evident that access to accurate electricity consumption data is a prerequisite for public contracts related to vending machine services. Low-cost energy sensors emerge as indispensable tools in this regard, facilitating informed decision-making processes and enabling organizations to optimize their energy use. The implementation of energy-efficient practices in public buildings can significantly contribute to sustainability goals, and this research underscores the pivotal role low-cost sensors play in making such initiatives feasible. The study emphasizes that vending machines, particularly those operating round-the-clock, can represent a substantial energy drain. However, by continuously monitoring their energy consumption, opportunities for energy reduction and improved efficiency can be identified. Integrating intelligent vending machine management systems, which adjust energy use based on hourly demand and minimize operation during off-peak hours, further enhances efficiency and sustainability efforts. These actions not only decrease the environmental footprint but also exemplify a commitment to responsible resource management, setting a compelling example of sustainable practices in public spaces. In essence, this research underscores the critical role of low-cost energy sensors in achieving energy savings, reducing environmental impact, and fostering responsible resource management in vending machine operations.

## CRediT authorship contribution statement

**Francisco Manzano-Agugliaro:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Mehdi Chihib:** Conceptualization, Methodology, Formal analysis, Resources, Data curation. **Mimoun Chourak:** Validation, Resources, Supervision. **José Antonio Martínez:** Methodology, Software, Visualization, Supervision, Project administration. **Antonio Zapata-Sierra:** Software, Validation, Formal analysis, Investigation, Data curation, Project administration, Funding acquisition. **Alfredo Alcayde:** Writing – original draft, Writing – review & editing, Funding acquisition.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## Appendix 1. Energy consumption (kWh) for vending machines of Snack Refrigerated (SR) from June 2021 to May 2022

| SR | June | July | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6C6028 | 217.3 | 227.0 | 225.6 | 217.3 | 225.5 | 67.0 | 60.7 | 60.5 | 57.5 | 74.5 | 67.2 | 65.6 |
| 6C4992 | 227.3 | 234.9 | 234.4 | 225.9 | 232.9 | 232.6 | 247.4 | 256.7 | 238.8 | 232.6 | 245.8 | 253.2 |
| 6C803D | 225.2 | 225.6 | 218.2 | 216.3 | 225.2 | 221.3 | 213.3 | 232.5 | 226.4 | 219.6 | 212.3 | 231.8 |
| 6E633C | 312.7 | 318.6 | 318.2 | 305.7 | 319.3 | 334.3 | 328.8 | 335.3 | 330.3 | 324.4 | 344.7 | 354.4 |
| A2 | 260.7 | 275.0 | 267.5 | 265.6 | 273.7 | 208.8 | 200.4 | 195.0 | 177.0 | 202.5 | 269.0 | 283.1 |
| A3 | 310.6 | 323.0 | 318.5 | 304.8 | 324.0 | 206.0 | 233.6 | 226.5 | 206.4 | 238.5 | 229.2 | 343.5 |
| A4 | 277.8 | 295.5 | 287.6 | 280.8 | 291.2 | 215.1 | 202.3 | 189.6 | 177.5 | 204.0 | 272.2 | 265.4 |
| BlBs24h | 334.6 | 349.0 | 339.5 | 346.6 | 359.6 | 320.5 | 318.7 | 328.1 | 300.6 | 352.1 | 213.0 | 376.0 |
| CITE2A | 228.9 | 244.7 | 243.8 | 232.4 | 241.1 | 254.5 | 246.2 | 262.4 | 260.3 | 270.4 | 278.6 | 285.6 |
| CITE2B | 245.1 | 262.2 | 258.2 | 251.2 | 257.8 | 224.9 | 210.6 | 202.1 | 187.0 | 198.3 | 271.5 | 288.2 |
| CITE3 | 276.3 | 278.0 | 274.9 | 277.7 | 285.6 | 231.3 | 220.6 | 218.7 | 201.6 | 215.9 | 275.4 | 273.4 |
| Derecho | 206.7 | 211.9 | 200.5 | 202.5 | 210.4 | 202.2 | 187.3 | 181.0 | 164.2 | 188.5 | 228.7 | 281.0 |
| ESI | 336.3 | 355.8 | 347.9 | 346.0 | 355.5 | 251.4 | 330.3 | 356.2 | 362.2 | 366.2 | 357.0 | 382.2 |
| HUM1 | 153.9 | 162.7 | 158.8 | 156.0 | 161.9 | 155.9 | 152.2 | 167.7 | 171.2 | 180.2 | 178.3 | 182.3 |

## Appendix 2. Energy consumption (kWh) for vending machines of cold drinks (CD) from June 2021 to May 2022

| CD | June | July | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CITE1 | | | | | | 145.5 | 162.9 | 159.2 | 149.7 | 174.2 | 249.2 | 219.0 |
| 6C6480 | 304.1 | 318.1 | 315.2 | 308.3 | 316.6 | 312.1 | 305.2 | 314.8 | 323.0 | 323.0 | 334.1 | 329.6 |
| 6C8FF2 | 290.9 | 279.7 | 277.9 | 325.7 | 339.3 | 345.7 | 339.9 | 349.9 | 351.8 | 328.9 | 334.4 | 342.0 |
| 6D0820 | 333.4 | 337.9 | 346.9 | 331.1 | 336.1 | 280.5 | 296.0 | 291.1 | 263.1 | 291.5 | 289.9 | 297.2 |
| 6E6283 | 209.9 | 189.9 | 186.7 | 182.2 | 188.0 | 194.8 | 201.2 | 214.3 | 221.4 | 217.5 | 219.5 | 229.9 |
| A1_1 | 178.7 | 194.2 | 184.7 | 182.0 | 189.8 | 92.8 | 86.5 | 78.6 | 74.5 | 103.2 | 105.2 | 109.3 |
| A2 | 187.7 | 192.8 | 181.3 | 184.8 | 191.1 | 168.6 | 154.2 | 150.0 | 142.3 | 222.7 | 296.4 | 311.2 |
| A3 | 188.1 | 199.9 | 193.6 | 188.6 | 199.1 | 147.1 | 135.9 | 129.3 | 120.0 | 126.0 | 170.9 | 183.5 |
| A4 | 160.6 | 172.3 | 166.1 | 162.6 | 171.5 | 137.0 | 121.4 | 113.1 | 107.0 | 258.3 | 367.7 | 364.5 |
| BIB_1 | 183.1 | 205.4 | 203.7 | 195.3 | 234.6 | 167.3 | 125.1 | 160.1 | 147.5 | 159.3 | 162.3 | 161.6 |
| BIB_2 | 191.7 | 198.3 | 196.6 | 186.9 | 225.2 | 158.7 | 147.9 | 132.8 | 136.2 | 270.9 | 368.7 | 393.4 |
| BlBs24h | 226.4 | 240.7 | 230.8 | 233.4 | 282.3 | 226.6 | 224.2 | 225.5 | 201.3 | 197.6 | 283.8 | 278.3 |
| CCSS | 144.4 | 131.4 | 124.9 | 122.8 | 128.0 | 112.5 | 109.3 | 128.7 | 119.4 | 157.5 | 221.1 | 237.9 |
| CITE2B | 154.6 | 167.6 | 200.5 | 163.9 | 164.4 | 135.0 | 127.1 | 124.4 | 112.2 | 126.4 | 168.0 | 170.3 |
| CITE3 | 152.1 | 156.7 | 147.8 | 149.6 | 155.6 | 115.6 | 110.9 | 127.0 | 114.3 | 120.2 | 126.9 | 160.2 |
| DEPORTES | 164.6 | 164.5 | 140.8 | 159.0 | 162.9 | 58.5 | 26.6 | 8.1 | 38.4 | 150.2 | 147.4 | 156.7 |
| ESI | 70.0 | 68.2 | 65.2 | 69.0 | 68.2 | 66.3 | 67.6 | 71.7 | 62.4 | 58.7 | 66.6 | 60.0 |

## Appendix 3. Energy consumption (kWh) for vending machines of hot drinks (HD) from June 2021 to May 2022

| HD | June | July | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CITE1 | ND | ND | ND | ND | ND | 108.5 | 108.6 | 116.4 | 100.5 | 116.2 | 106.4 | 122.3 |
| 6C247D | 112.5 | 115.5 | 115.4 | 111.6 | 115.7 | 110.5 | 100.2 | 113.5 | 117.2 | 118.4 | 122.3 | 119.9 |
| 6C4CFB | 117.0 | 119.0 | 120.5 | 115.3 | 120.0 | 127.6 | 123.0 | 136.8 | 138.3 | 121.9 | 128.8 | 148.7 |
| 6C75DE | 55.4 | 56.9 | 56.9 | 55.1 | 56.9 | 57.2 | 54.3 | 57.3 | 58.2 | 58.5 | 59.6 | 55.6 |
| 6E627E | 109.3 | 133.2 | 132.1 | 129.7 | 133.4 | 136.8 | 138.5 | 141.2 | 134.8 | 136.8 | 143.9 | 145.1 |
| 6E654A | 119.7 | 120.1 | 117.1 | 112.4 | 115.6 | 115.9 | 112.5 | 119.8 | 121.7 | 126.8 | 124.4 | 125.5 |
| A1_1 | 120.9 | 123.2 | 123.5 | 119.1 | 112.2 | 130.7 | 136.0 | 130.9 | 118.2 | 102.9 | 119.2 | 129.2 |
| A2 | 130.7 | 129.3 | 126.1 | 123.1 | 129.4 | 127.3 | 135.0 | 132.7 | 135.3 | 85.7 | 100.5 | 82.7 |
| A3 | 59.7 | 58.6 | 57.2 | 59.0 | 60.8 | 70.4 | 62.0 | 64.0 | 61.6 | 60.7 | 61.6 | 54.8 |
| A4 | 137.0 | 135.1 | 134.6 | 131.4 | 135.8 | 154.3 | 157.9 | 158.8 | 142.3 | 103.7 | ND | 387.6 |
| BIB_1 | 114.1 | 116.9 | 122.6 | 114.0 | 120.3 | 155.1 | 142.2 | 154.7 | 133.8 | 143.8 | 154.4 | 163.2 |
| BIB_2 | 129.6 | 135.1 | 132.7 | 127.4 | 133.2 | 147.6 | 107.5 | 161.4 | 126.0 | 124.2 | 135.6 | 132.9 |
| BIB2 | 124.1 | 118.7 | 118.0 | 108.2 | 118.8 | 258.6 | 253.2 | 266.6 | 253.6 | 276.3 | 283.0 | 287.3 |
| BIBs24h | 137.7 | 139.2 | 140.5 | 126.7 | 137.0 | 143.6 | 151.3 | 170.0 | 131.8 | 134.0 | 154.6 | 142.4 |
| CCSS | 211.1 | 221.4 | 214.0 | 210.9 | 220.4 | 165.4 | 155.0 | 152.5 | 137.8 | 190.3 | 197.9 | 201.5 |
| CITE2A | 51.0 | 50.8 | 49.4 | 52.4 | 50.8 | 53.2 | 56.9 | 51.6 | 59.9 | 57.7 | 52.7 | 60.5 |
| CITE2B | 53.6 | 47.1 | 24.9 | 32.4 | 49.4 | 52.4 | 53.4 | 55.6 | 49.0 | 52.0 | 55.8 | 50.5 |
| CITE3 | 53.0 | 54.9 | 55.8 | 49.3 | 55.3 | 59.5 | 55.5 | 61.2 | 54.2 | 55.3 | 58.4 | 47.1 |
| Derecho | 81.1 | 92.3 | 88.0 | 86.6 | 93.3 | 96.3 | 95.3 | 105.6 | 95.4 | 60.6 | 98.2 | 87.3 |
| Economicas | 55.6 | 57.4 | 56.5 | 53.9 | 57.0 | 58.5 | 57.5 | 61.2 | 53.2 | 53.1 | 57.6 | 51.8 |
| ESI | 76.5 | 78.5 | 78.4 | 85.8 | 81.2 | 149.7 | 97.2 | 96.3 | 98.6 | 100.3 | 102.3 | 96.7 |
| HUM1 | 35.1 | 35.2 | 35.7 | 33.8 | 36.0 | 40.2 | 26.2 | 38.3 | 36.3 | 44.2 | 42.8 | 41.6 |

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