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# Power Control System Design for Monitoring Active and Standby Power Consumptions of PC Labs

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**ABSTRACT**

In this study, it was aimed to provide energy saving by informing the user about the power consumption instantly with the power control system (PCS) design and by cutting the energy of the devices in standby mode. The power consumptions of 39 PCs in Lab-1 and Lab-2 in Amasya University Engineering Faculty were examined through the designed system. Lab-1 contains older PCs while Lab-2 contains new generation PCs. The PCs used in the measurements made within the scope of the study were energized via PCS instead of a direct electrical socket. With this method, it has been tried to determine the electrical power consumptions in active work and standby work for calculate the annual electricity consumption and to reflect it on the invoices. The experimental method was carried out on the daily PC staying active for 2 hours and standby for 22 hours. According to the results, it is predicted that 56% lost standby power on an annual basis can be avoided with the use of PCS. The annual invoice cost of this lost power is calculated as 14.116,93 TL and 8.470,12 TL for Lab-1 and Lab-2 respectively. It is thought that the study will make an important contribution to researchers working on this subject.

# PC Laboratuvarların Aktif ve Bekleme Modunda Güç Tüketimlerinin İzlenmesi için Güç Kontrol Sistemi Tasarımı

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Akıllı priz

**ÖZ**

Bu çalışmada, güç kontrol sistemi (GKS) tasarımı ile kullanıcının anlık olarak güç tüketimi konusunda bilgilendirilmesi ve cihazların bekleme konumunda enerjisinin kesilmesi yoluyla enerji tasarrufu sağlanması amaçlanmıştır. Yapılan çalışmada Amasya Üniversitesi Mühendislik Fakültesindeki Lab-1 ve Lab-2 de bulunan 39 adet PC'lerin güç tüketimleri tasarlanan sistem üzerinden incelenmiştir. Lab-1'de eski nesil bilgisayarlar bulunurken Lab-2'de yeni nesil bilgisayarlar yer almaktadır. Çalışma kapsamında yapılan test ve ölçümlerde kullanılan bilgisayarlar doğrudan priz yerine GKS üzerinden enerjilendirilmiştir. Bu yöntemle aktif çalışma ve standby çalışmadaki elektriksel güç tüketimlerinin belirlenmesi, elektrik tüketimlerinin yıllık olarak hesaplanması ve faturalara yansıması ortaya konulmaya çalışılmıştır. Deney yöntemi günlük bir bilgisayarın 2 saat aktif çalışma ve 23 saat standby konumda kalması üzerine belirlenmiştir. Sonuçlara göre GKS kullanımı ile yıllık bazda %56 kayıp standby gücün önüne geçilebileceği öngörülmüştür. Bu kayıp gücün yıllık fatura bedeli Lab-1 ve Lab-2 için sırasıyla 14.116,93 TL ve 8.470,12 TL olarak hesaplanmıştır. Yapılan çalışmanın, bu konuda çalışma yapan araştırmacılara önemli katkı sunacağı düşünülmektedir.

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## Introduction

As a result of increasing human population and decreasing natural resources, studies on the most efficient use of electrical energy are gaining importance. With the increase in energy costs in recent days, the highest level of saving in energy consumed in all living spaces has become mandatory. The various programs from the US Department of Energy have revealed that buildings constitute a significant amount of total energy consumption (US Department of Energy 2019). Different foundations around the world, including India and China have carried out studies and implementations to reduce the consumption of energy in buildings (Government of India Ministry of Power, 2017; Ma et al., 2019). Today, it is known that there is an important electricity consumption with the computer, where people spend most of their time. It is predicted that efficient energy consumption in computers will contribute significantly to the total energy consumption of buildings (Wang et al., 2020).

According to a study in the literature, it has been reported that 62 percent of the 2009 electricity consumption was shared to office PCs, printer and local networks in India (Gelenbe and Caseau, 2015). Energy saving measures in computers are focused on the efficiency of computers, the use of energy-efficient components and the design of the buildings in which the computers are located. According to Pollard (2015), use of an Eco-Button on the computer derives the user with regular feedback on energy saved. This kind of system can display the actual savings in dollars.

Some network devices, such as televisions and PCs, are constantly left in standby in order to provide instantaneous data flow. On the other hand, some electronic devices are left plugged into the socket to provide ease of switching on and off, in case the device is used at any time. Leaving electrical appliances on standby leads to useless energy consumption. This means that these devices draw energy from the grid every minute of the day and consume a significant amount of lost energy if billions of devices are left on standby 24/7. In particular, there is a rapidly increasing energy demand due to billions of devices that are actively operated for only a few minutes or a few hours during the day. According to the report of the International Energy Agency (IEA), it has been concluded that the energy consumed by the devices in the "standby" mode is 10% of the total energy consumed. Consumers pay the cost of lost energy about standby, which they cannot actually use. The IEA has initiated the “1 Watt Stand-by” initiative in order to draw attention to the energy consumption in standby mode, which causes a significant amount of energy loss every year, and to minimize the standby energy loss with the awareness created on this issue (IEA, 2023). In a study, energy savings of up to 60% were achieved by preventing the use of lost energy drawn from the network in standby mode (Ghosh et al., 2013).

Today, it has been concluded that energy management systems a very important contribution in saving electrical energy (Hatipoğlu, 2014). For energy management systems used to increase energy efficiency in people's living spaces (home, office, restaurant, shopping mall, school, etc.); 4 main solutions proposal: measurement of energy consumption, control and switching, creation of a necessary network structure to access and manage measurements (Mrazovac et al., 2011).

The energy management systems using smart sockets are an important necessity that should be used in all energy-consuming areas. Smart sockets are one of the solutions created for the continuous monitoring and control of the energy consumption of electrical devices. In addition to providing instant energy consumption information to the user, smart sockets also prevent energy loss by cutting the energy drawn from the network when the devices are in standby mode (Veleva and Davcev, 2012; Amin and Wollenberg, 2005). In some studies, it is aimed to detect standby current and prevent standby power consumption by using smart sockets (Clement et al., 2007; Gerber et al., 2019; Shin et al, 2016; Kang et al., 2011; Kıral, 2014) in the literature.

Smart socket design consists of three separate stages: hardware design, creation of communication infrastructure and software development (Elmenreich and Egarter, 2012). Communication infrastructures are created by using different hardware systems such as Arduino Uno, Raspberry Pi and Beaglebone in order to communicate smart sockets with multimedia systems (Eliaçık, 2014). Smart socket designs with different features designed by researchers have been found in the literature (Morimoto et al., 2013; Horvat et al., 2013; Lentine et al., 2012). There are some applications that measure instantaneous power consumption and inform users about instantaneous power consumption via smartphone or social media in the literature (Jahn et al., 2010; Lopez-de Armentia et al., 2010). In addition, there are power control systems without communication feature in order to reduce the cost of the power control system (Seetharam et al., 2012).

It has been concluded that there is a 5% to 15% reduction in energy consumption with consumer awareness created by accessing instantaneous energy consumption information using smart sockets (Shajahan and Anand, 2013). It is known that the devices draw idle current from the mains in the standby mode, which means that the devices are plugged into the socket when they are in the off position. In some studies, in the literature, it has been stated that 10-50% of the electrical energy consumed in homes is caused by socket loads (Kıral, 2014). In a study in the literature, most of the 40 different smart devices, including smart lighting and camera doorbell, are more than 1 Watt while some consume more than 5 Watts of energy in standby mode (Wang et al., 2020).

In the literature, there are different studies to reduce the energy consumed by computers by using smart sockets. A designed system used the Internet of Things (IoT) to enable remote monitoring and control of the ambient temperature and energy consumption of computer rooms in colleges and Universities in China (Qu, 2022). Yar et al. (2021), was able to achieve less energy consumption with their system design using the Raspberry Pi (RPI). In a study in the literature, the consumption of electrical appliances was measured by a system using Zigbee. This system has a PLC based energy monitoring system (Han et al., 2014). Authors in (Baraka et al., 2013) designed a hybrid home energy management system consisting of Arduino and ZigBee.

In this study, energy management system was designed to remotely monitor and bill of energy consumption of two different computer laboratories (Lab-1 and Lab-2) and also cut off the energy while the computers are in the standby mode. It was aimed to reduce the effect of computer standby consumption on the monthly electricity bill of these computer laboratories. Unlike the existing studies in the literature, the energy consumption and invoice cost of new generation and old generation computers are given comparatively. In this study, only the effect of old and new generation computer parts and the energy consumed in standby on the total amount of energy consumption and the bill are considered.

## Material and Method

### Mathematical Approximation

The annual amount of electricity consumption of a computer is calculated by multiplying the electricity consumption per hour within the period over which it has been consume. It is given in Eq.1 as below. In this equation, *E*, *P* and *t* refer to the annual amount of electricity consumption calculated in kilowatt-hours (kWh), power units in watts and time over which the electricity consumption was consumed, respectively.

$$E= P*(t/1000) \qquad (1)$$

The annual amount of electricity consumption cost of a computer is calculated by multiplying the annual electric power consumption and unit price of electricity (*UP*). The electrical consumption has been made by considering the unit price of 3,42 TL/kWh (November 2022). Annual cost of energy (ACOE) can calculated by using Eq.2.

$$(ACOE) = E* UP \qquad (2)$$

### Hardware Design

Amasya University Faculty of Engineering has 2 computer laboratories, namely Lab-1 and Lab-2. Lab-1 contains older PCs while Lab-2 contains new generation PCs. There are 39 computers in each laboratory. Both laboratories have the same physical conditions.

It is known that the most power consuming components in a computer are the processor, motherboard and graphic card. The processor, motherboard and video card brand and model informations of the computers used in the laboratories are given in the Table-1.

**Table 1.** Brand and model information of the most power consuming components of computer

| | | Processor | Mother Board | Graphic Card |
|---|---|---|---|---|
| Laboratories Type | Lab-1 | Intel i5-6500 | AMD RX 570 | Asus GTX 750 |
| | Lab-2 | Intel i7-6500U | Asus Prime X570-Pro | Asus GTX 750 |

The technical specifications of the processors used in Lab-1 and Lab-2 are presented in Table 2.
The power consumption of Intel i7-6500U processor used in Lab-2 is 50 Watts lower than Intel i5-6500U used in Lab-1. Considering the power consumption of processors, it is expected that the power consumption of Lab-2 is lower than Lab-1.

**Table 2.** Technical specifications of processors used in Lab-1and Lab-2, respectively

| | | Intel i5-6500 | Intel i7-6500U |
|---|---|---|---|
| Technical Specifications | Total Cores | 4 | 2 |
| | Total Threads | 4 | 4 |
| | Max Turbo Frequency | 3.60 GHz | 3.10 GHz |
| | Processor Base Frequency | 3.20 GHz | 2.50 GHz |
| | Cache | 6 MB | 4 MB Intel |
| | Bus Speed | 8 GT/s | 4 GT/s |
| | Power Consumption | 65 W | 15 W |

Table 3 presents the technical specifications of the mother boards used in Lab-1 and Lab-2. According to this table, the hourly power consumption of the motherboard used in Lab 2 is 36 percent less than the motherboard used in Lab 1.

**Table 3.** Technical specifications of mother board used in Lab-1and Lab-2, respectively

| | | AMD RX 570 | Asus Prime X570-Pro |
|---|---|---|---|
| Technical Specification | Brand | Gigabyte | Gigabyte |
| | Weight | 998 g | 1250 g |
| | Dimensions | 23.1 cm ×12.2 cm | 30,5 cm ×24,4 cm |

| | | | |
|---|---|---|---|
| | Graphic coprocessor | AMD Radeon RX 570 | AMD Radeon X 570-pro |
| | Graphic RAM Type | GDDR5 | DDR4 |
| | Power consumption | 120 W (max) | 88 W (max) |

The new generation high resolution graphic card consumes more power to produce higher quality images. A better graphic card means less power consumption for work, school and daily use. Low power consumption is more important than high resolution for the graphics card to be used in computers used in undergraduate education laboratories. All of the computers which are used in Lab-1 and Lab-2 have Asus GTX 750 model graphic card in Amasya University Engineering Faculty.

The technical specifications of the graphics cards used in Lab-1 and Lab-2 are presented in Table 4. This type of graphic card consumes 60 W in one hour.

**Table 4.** Technical specifications of graphic card used in Lab-1and Lab-2, respectively

| | Asus GTX 750 | |
|---|---|---|
| **Technical Specifications** | Memory size | 2 GB |
| | Memory type | GDDR5 |
| | Memory speed | 2500 MHz |
| | Memory interface width | 86,4 GB/s |
| | GPU core | 640 |
| | Main frequency | 1020 MHz |
| | Power consumption | 60 W (max) |

The PCS prototype designed to monitor the power consumption of the PCs in Lab-1 and Lab-2 in Amasya University Engineering Faculty and to detect the standby position and cut the power of the devices is shown in Figure 1. There are 3 different current sensors (ACS712T ELC-5, ACS712T ELC-20 and ACS712T ELC-30) in order to adjust the sensitivity of the current drawn by different load(s) in the relevant circuit. The electrical data obtained instantaneously in this circuit can be monitored via mobile devices using the HC06 bluetooth modüle.

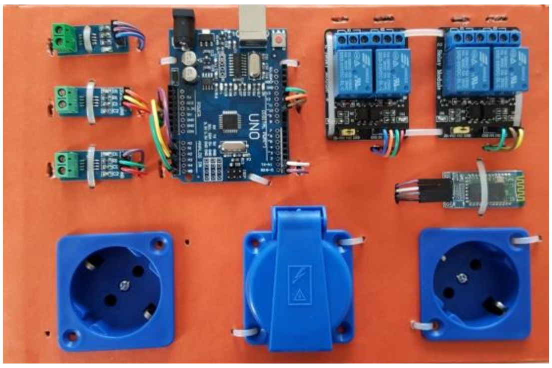


**Figure 1**. Top view of PCS prototype (1,2,3-Current sensor,
4-Arduino UNO, 5,6-AA Relay,7-Bluetooth Module, 8,9,10 Plug)

## Software Design

In PCS design, which is very important to establish the communication infrastructure, provides the basic communication between the hardware component and the system user. PCS communicates with PC via Arduino UNO and with mobile device via bluetooth module. The PC interface was designed in the Microsoft Visual Studio environment (Tomar et al., 2015). The PC interface where the PCS data can be viewed in Figure 2.

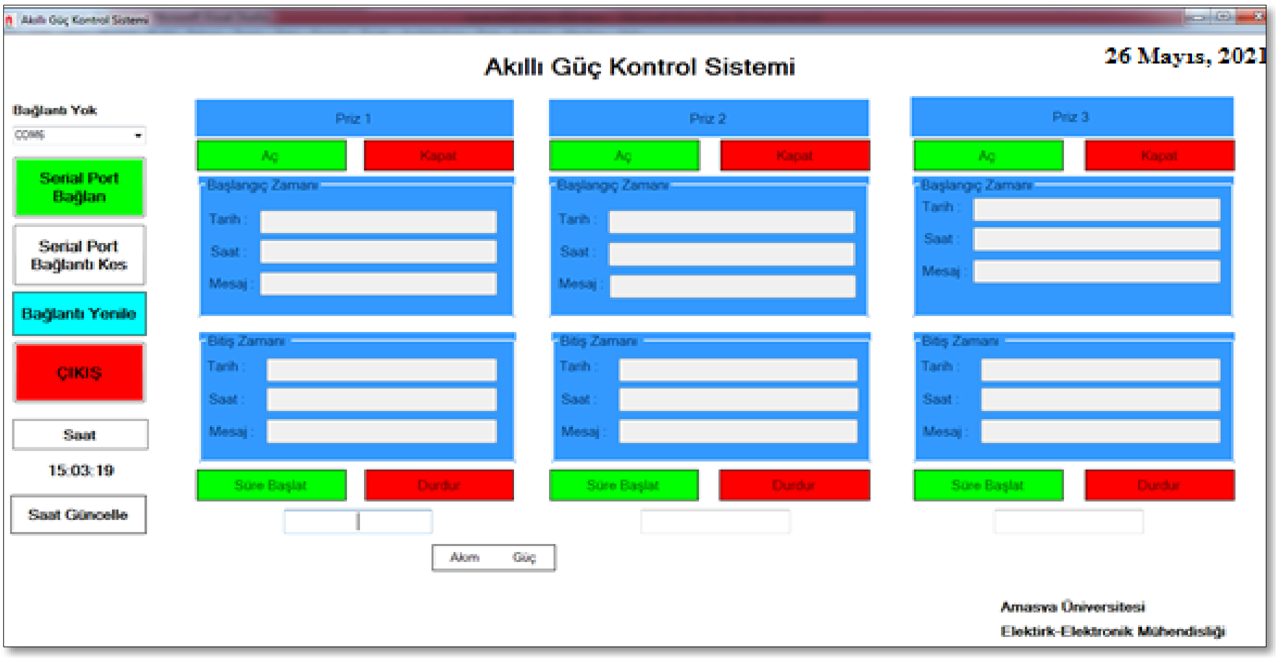



**Figure 2.** PCS User panel

Mobile devices have many applications such as control of smart devices, GPS, entertainment, internet, etc. In this study, an android-based application was implemented. Figure 3 (a) shows the power socket list and selection screen which the load group is connected. In Figure 3 (b), (c), (d) the control and monitoring screen of each outlet is shown.

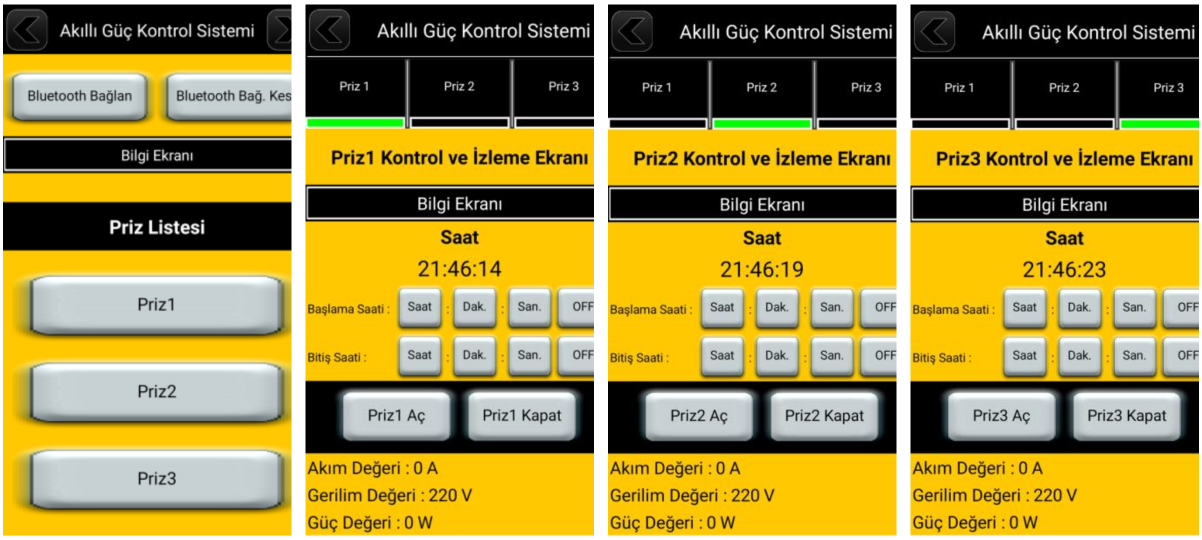
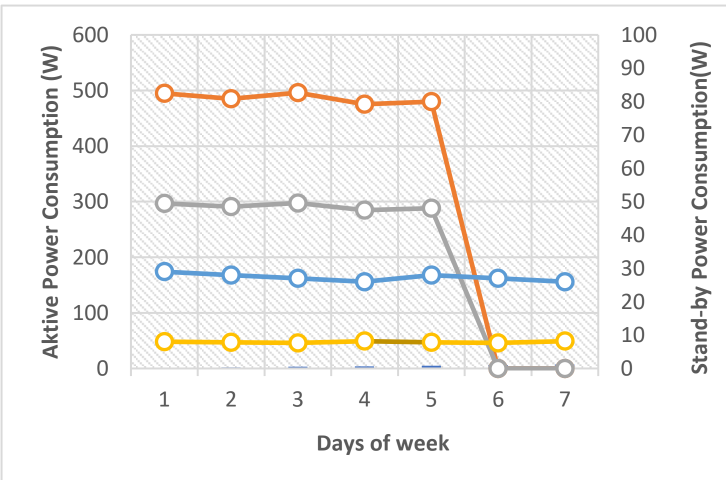



**Figure 3.** (a) Power Plug list (a), Plug-1 (b), Plug-2 (c), Plug-3(d)

With the "Open" and "Close" buttons on the relevant interface, it is possible to make the sockets open or close instantly. At the bottom of the interface screen, there are instantaneous electrical data such as current, voltage and power.

## Results and Discussion

In this study, the power consumption of PCs in Lab-1 and Lab-2 in Amasya University Engineering Faculty were investigated. The total amount of energy consumed in standby mode and active operating mode has been calculated annually. Detailed invoice costs have been presented comparatively. First, the necessary calculations were made by measuring the active and standby power consumption values of a new generation and old generation PC for 7 days.




Orange: Old generation PC active mode power consumption.

Grey: New generation PC active mode power consumption.

Blue: Old generation PC standby mode power consumption.

Yellow: New generation PC standby mode power consumption.

**Figure 4.** Power consumption of new generation and old generation PC in active and standby mode.

Figure 4 shows the power consumption of the old generation and new generation PCs on different days in active and standby mode. The experimental method was carried out on the daily PC staying active for 2 hours and standby for 22 hours. In the measurements taken on the same day and time, the same operations were run on both PCs. 7-day measurements were made for two generations of PCs. According to the results obtained; With the use of new generation PCs, approximately 35% energy savings were achieved in active operating mode and in standby mode, approximately 40% energy savings were achieved. The power consumption of Lab-1 in standby mode was determined as 0,585 kW. The power consumption of Lab-2 in standby mode was determined as 0,351 kW. While the active power consumption of Lab-1 was 5,655 kW, the active power consumption of Lab-2 was determined as 3,413 kW. In active consumption, it has been determined that the new generation PCs consume approximately 40% less energy than the old generation PCs. Annual electrical energy consumption for Lab-1 4.127,76 kWh and Lab-2 2.476,66 kWh was calculated as in standby operation. In Figure 5, active and standby energy consumptions for Lab-1 and Lab-2 were included in the total energy consumption. In Table 2, the detailed invoice calculation of the labs has been made by considering the unit price of 3,42 TL/kWh (November 2022). Annual energy consumption costs of Lab-1 and Lab-2 in standby mode respectively were calculated as 14.116,93 TL and 8.470,12 TL. In active operation mode, the annual energy consumption costs of Lab-1 and Lab-2 respectively were calculated as 11.139,89 TL and 6.722,35 TL.

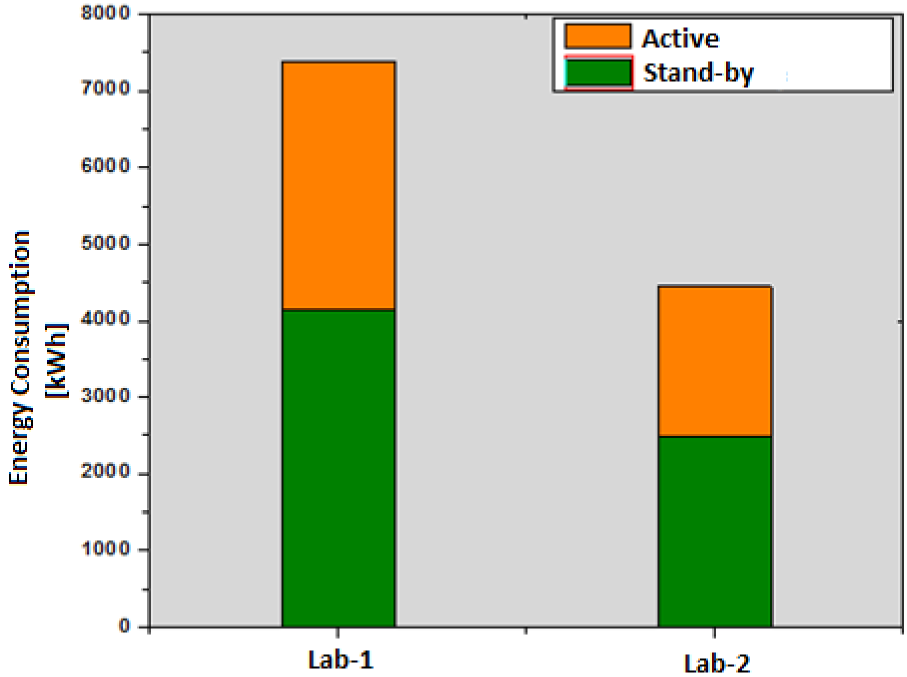



**Figure 5.** Comparison of annual power consumption of new gen. and old gen. PCs

**Table 2.** Annual standby and active mode energy consumption cost

| | | Power Consumption (kW) | Annual Use time (hour) | Annual Energy Consumption (kWh) | Annual Cost (TL) |
|---|---|---|---|---|---|
| Standby Mode | Lab-1 | 0,585 | 7056 | 4127,76 | 14.116,93 |
| | Lab-2 | 0,351 | 7056 | 2476,66 | 8.470,12 |
| Active Mode | Lab-1 | 5,655 | 576 | 3257,28 | 11.139,89 |
| | Lab-2 | 3,413 | 576 | 1965,60 | 6.722,35 |
| Active+ Standby Mode | Lab-1 | 6,240 | 7632 | 7385,56 | 25.258,61 |
| | Lab-2 | 3,764 | 7632 | 4442,26 | 15.192,52 |

## Conclusions

With the increase in energy costs day by day, the stand-by consumption of the devices used by users has become important. In order to determine the useless energy consumption of electrical devices that are waiting in stand-by mode, a study was carried out in Lab-1 and Lab-2 PC laboratories within the Faculty of Engineering of Amasya University. The experimental method was based on the fact that a daily the PC was active for an average of 2 hours and was in stand-by mode for 22 hours.

According to the obtained results, while the annual consumption power in standby mode, corresponding to a total of 7056 hours in old generation PCs, was 4127,76 kW and the active power consumption corresponding to 576 hours was measured as 3257,28 kW. In the new generation PCs, the annual consumption power was measured as 2476,65 kW and the active power consumption as 1965,6 kW in the standby mode according to the same hourly usage values in total. The total power consumption of old generation PCs in annual consumption was calculated as 7385 kW and new generation PCs as 4442 kW. As a result, it has been observed that the standby consumption in old generation PCs was 27% higher than active consumption on an annual basis, and 26% more in new generation PCs. According to the electrical energy unit prices of November 2022, the annual invoice cost of the lost power has been calculated as 14.116,93 TL and 8.470,12 TL for Lab-1 and Lab-2, respectively. It has been determined that the total consumption costs of the new generation PCs were lower than the old generation PCs. With the designed PCS, it was predicted that approximately 56% gain would be achieved in the invoice price.

**Statement of Conflict of Interest**

Authors have declared no conflict of interest.

**Authors' Contributions**

ME and MŞK designed the structure. MŞK grew the sample according to the specifications. ME fabricated the device, carried out the experiments work, the theoretical calculations, in collaboration with MŞK, and wrote up the article. ME and MŞK is the inventor of the original device and the overall supervisor of the project.

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