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EXPERIMENTAL RESEARCH ON THE DEVELOPMENT OF A SALE SYSTEM (VENDING MACHINE), INDEPENDENT OF ENERGY, OF COLD AND HOT PRODUCTS

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Abstract: *This paper presents considerations regarding the realization of the experimental model of a sale system (vending machine), independent of energy, of cold and hot products. In the current context, in which desiderata such as: reducing energy consumption and reducing physical interaction, in the field of sales between customer and seller, are particularly important, the present paper presents the experimental research platform realized in order to test an innovative system of storage and delivery of cold or hot products, system powered by electricity obtained from renewable sources. This paper presents the tests performed and the results obtained regarding the sustainability of the proposed innovative system.*

Keywords: *Renewable sources, vending machine, energy efficiency, environment*

1. Introduction

In the current geopolitical context in which the aim is to reduce energy consumption and use renewable energies, the creation of an automatic energy-independent sales system is particularly current. Vending machines are becoming more and more present in today's trade because they limit the contact between the trader and the customer. The COVID 19 pandemic has generated among traders an increased interest in autonomous vending machines, machines that limit contact between people and the spread of viruses in case of epidemics. In order to place a vending machine near the customer (near the home, workplace, playground, etc.), a problem is the connection to the electricity system. The creation of an energy-independent machine solves this problem and generates an increase in sales of this kind.

Fig. 1. Source https://solarstik.com/energy-storage-feature/

There have been several attempts regarding the supply of vending machines from renewable sources. The solutions presented by other manufacturers and which are in the spirit of our system are presented as a reference as follows:
Coca Cola has created a freestanding vending machine that runs entirely on solar power. This off grid machine is self-contained and fully functional. It is also very easy to install and easy to ship, thanks to its compact solar panels and internal batteries. The machine can turn out to be a great asset in open areas like promenades, boardwalks, beaches, ballparks, college campuses, amusement parks and even military bases. All that it needs is the sun to function. What if there is no sun? The machine simply stores surplus energy in its batteries, powering the machine for at least five days on this stored energy [10].
Disney's ESPN Wide World of Sports Complex deploys two Renewable Equipped Vending (REV) Machines following a successful initial deployment of six prototype REVs at SeaWorld in Orlando, Florida. The solar-powered machines are selling beverages at the following locations within Sea World: Shamu's Happy Harbor, Key West; Terrace Garden, Pacific Point Preserve; and Aquatica, SeaWorld's Waterpark.[14]

Fig. 2. Source https://www.springwise.com/solar_powered_vending_machines/

Fig. 3. Source: Media-Cdn.TimesFreePress

Springwise has also come up with its own unique plan to design a vending machine powered by solar energy. The machine incorporates a strong refrigeration system that can keep the foods and drinks inside it cool for hours. It is fitted with solar panels at the top to absorb the sun's rays. The

electricity thus generated is used to power the vending machine as well as recharge a battery that would keep the machine running at night and on cloudy/rainy days. An inbuilt wind turbine can substitute for solar energy in areas where the sun does not come out too often. [10]
Another company called Solar Vending has developed an entirely off-grid vending machine that uses solar power to power its refrigeration and vending mechanisms. The off-grid ability would allow the machine to be placed even in remote locations like in the middle of a golf course.
A number of companies have started developing solar powered vending machines to keep beverages in the most sustainable manner. Utilizing only the sun's energy for operation, these machines will be a blessing for people living or travelling remote, off-grid locations. [10]

Fig. 4. Source http://innovativevendingsolutions.com/case-studies/td-solar-powered/

In the age of Coronavirus, as more consumers rely on vending machines to get their food and beverages, solar–powered vending machines only enhances the value of vending machines. Consumers can have confidence in knowing that regardless of what's happening with the power grid, as long as the vending machine is solar–powered, it's always going to be working.
Vending owners who own solar–powered vending machines can also have confidence that their devices are offering consumers real value while they are also doing their part to lower their carbon footprint by owning an environmentally friendly vending machine.[15]
The energy independence of the sales system ensures the creation of a green product with a low impact on the environment and also allows its placement in areas where electricity cannot be provided from other sources.
Taking into account the existing models, we developed an autonomous vending-machine type equipment that would allow the analysis of the operation of a system for selling cold and/or hot products that would be powered with the help of solar panels. In order to study the problems that arise in the case of the creation of such equipment, we designed and created an experimental model made on a real scale. The trading of products with the help of automatic systems allows getting closer to the customer. The customer does not have to travel long distances, with the help of means of transport that emit CO2, to procure certain products. Also, trading with the help of vending machines allows them to be fed at night, when fuel consumption for transporting goods from the warehouse to the point of sale is reduced and the impact of CO2 emissions is lower.

The experimental model

The proposed experimental model has dimensions similar to those of the sales system to be designed and built for commercialization.

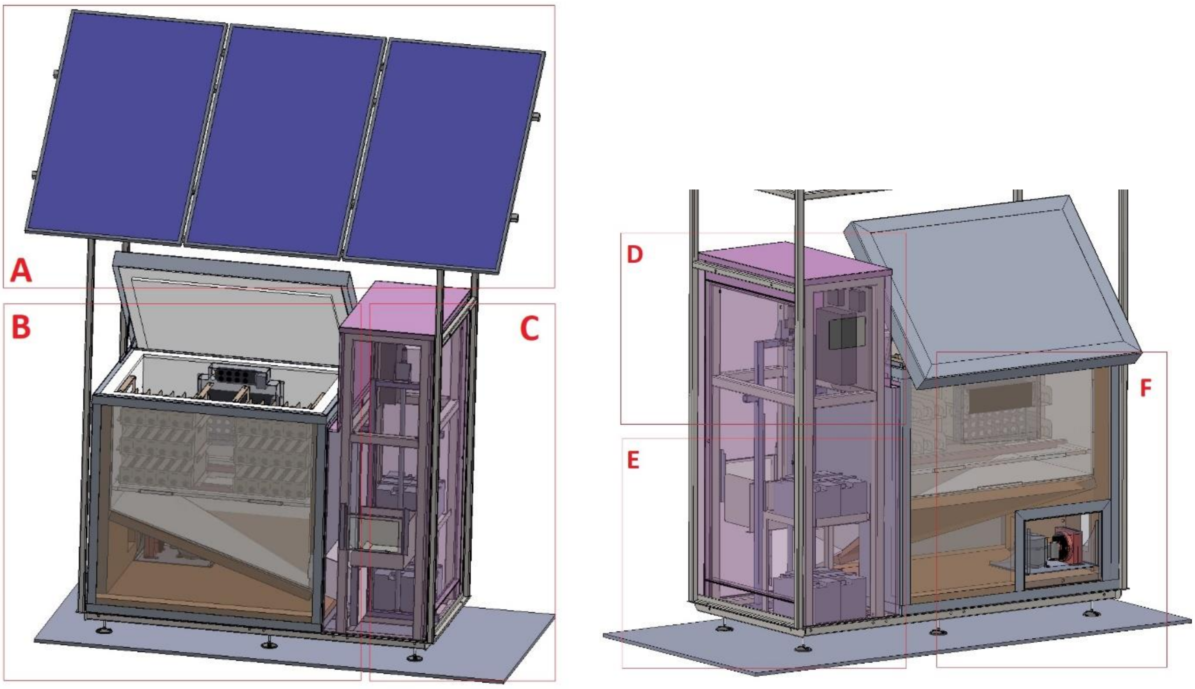

Fig. 5. Subsystems of the experimental model

Fig. 6. Experimental model

The experimental model designed and made has the following subsystems:

- Electricity production subsystem - A
- The thermally insulated enclosure subsystem - B;
- Product delivery subsystem - C;

- The command and control subsystem – D;
- The electricity storage subsystem – E;
- Refrigeration installation subsystem – F.

The efficient functioning of the entire system is determined by the structure and fulfillment of the functional roles of all the equipment components, as follows:

- the metallic structure of the experimental model ensures the support for the component elements;
- the subsystem - thermally insulated enclosure - is made of materials with low thermal transfer and represents the area where the products are stored for delivery.
- The products are fed on the upper part of the equipment and their delivery is carried out on the lower part; the product delivery function is ensured by a complex system consisting of two large components: the product tray in which the products are stored for delivery and the collection and transport system for delivery to the consumer;
- the refrigeration installation is the system that produces cold in a thermally insulated room;
- the production and storage of electricity is carried out by the system that uses photovoltaic panels for the conversion of solar energy into electricity which, through a management system, is either stored in accumulators or delivered to the consumers of the experimental model;
- the command and control functions are ensured by the electronic automation system that controls the thermal subsystem, the product delivery system, the communication of data received from the sensor systems, the remote control through an interface that the consumer accesses from a personal device.

The initial and final stages of the product's route inside the equipment are as follows: the product to be delivered to the consumer is loaded (by lifting the thermally insulated cover by tilting and inserting the trays with previously loaded products) in the upper area of the thermally insulated enclosure. The unloading of the product is carried out with the help of a spiral system, with which the product tray is equipped, in the collecting funnel of the thermally insulated enclosure that directs the mechanism for taking and delivering the products to the tray (see figure no. 1).

Fig. 7. Thermally insulated enclosure

The product is then lifted to the area where the product is picked up by the consumer, this area being equipped with a manually operated door.

The product delivery experimental model is energy independent and is designed in such a way as to use as efficiently as possible the electricity produced with the help of photovoltaic panels.
The main objective of this work is to analyze the consumption of the cold production installation in the thermally insulated premises, so that, in the following, it is presented how to achieve it.
In the design stage and later, in the manufacturing stage of the subsystem of the thermally insulated enclosure, the use of materials that have a heat transfer coefficient as low as possible was taken into account.
Thus, a new composite material (consisting of three different materials) was chosen for the construction of the enclosure, both for the product storage tank and for the tilting cover of the enclosure. On the inside, a Komacel expanded PVC [17] type plastic material was used, on the middle part we used a high-performance insulating material of the Termoconfort type [18], and on the outside, a material resistant to the weather and exposure to solar radiation, Bond PE type [16], was used.

Fig. 8. Realization of a thermally insulated enclosure

The use of these materials was aimed at ensuring the highest possible energy efficiency, but also the possibility of recycling the materials in the post-use stage. The realization of the experimental model on a natural scale allowed the validation of the technology and the manufacturing costs of the energy-efficient vending machine that will be produced in series.

Fig. 9. Refrigeration installation subsystem

The application of these manufacturing technologies allows obtaining superior energy performances but also reduced manufacturing costs by using existing materials and technologies.
The following equipment was used for the cold production installation: Evaporator coil; Evaporator fan motor (electrical power 36 W) Condenser coil; Condenser fan motor (electrical power 38 W) Hermetical single speed compresor (cooling capacity 523 W, condensing temperature 45 C Evaporating temperature -10 C [19]). Refrigerant installation uses R290 as a refrigerant.
The experimental model is equipped with a complex system of sensors whose values are collected and sent continuously via the Internet to a server. The collected data are stored in the server so that they can later be analyzed either in real mode through an Internet browser, or to be downloaded in the form of a database. The data stored on the server are: temperatures on three levels in the thermally insulated enclosure; ambient temperature; consumption for the refrigeration system [W]; consumption for the product heating system [W]; consumption for the interphase product transport system [W]; data provided by the photovoltaic system through the MPPT solar charge controller (Baterry [mV]; Baterry injected current [mA]; Solar voltage [mV]; Solar power [W]; etc).

Fig. 10. Data server interface experimental model

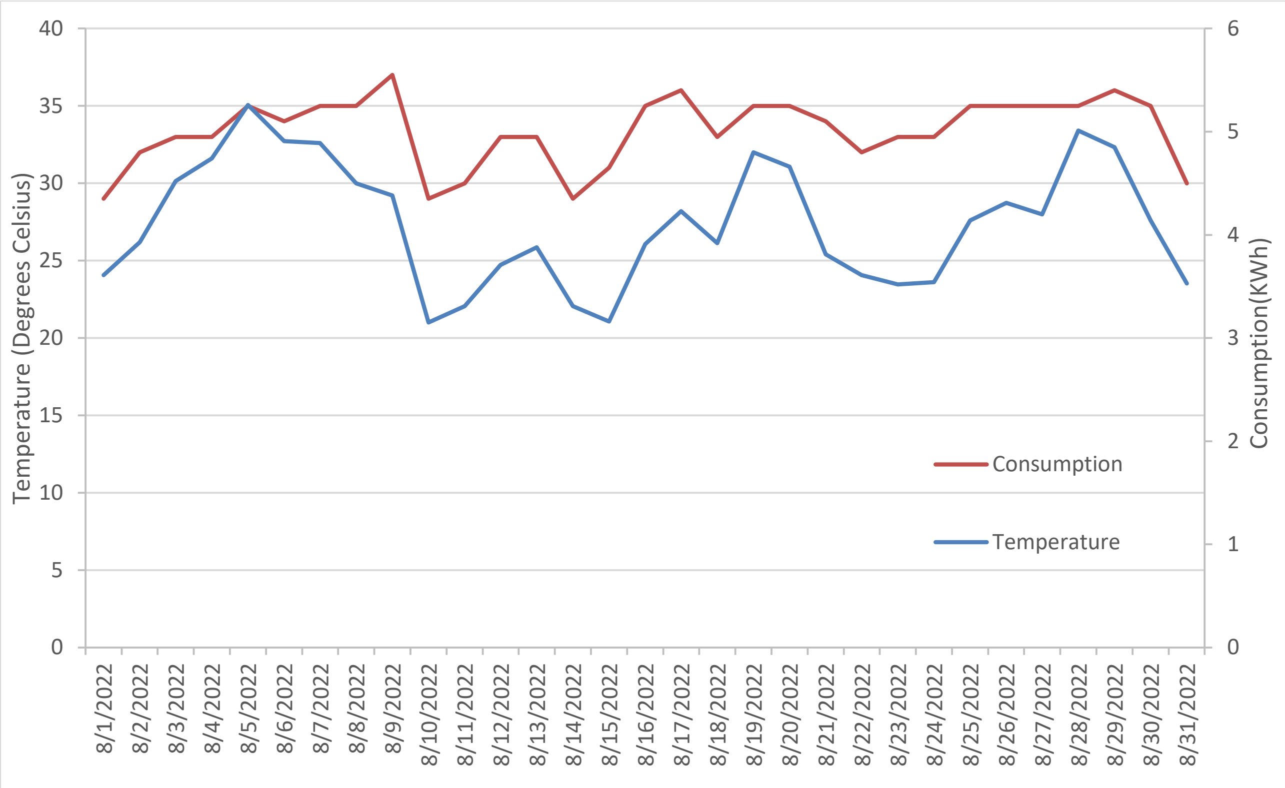
Temperature (Degrees Celsius)
Consumption(KWh)
Consumption
Temperature

Fig. 11.

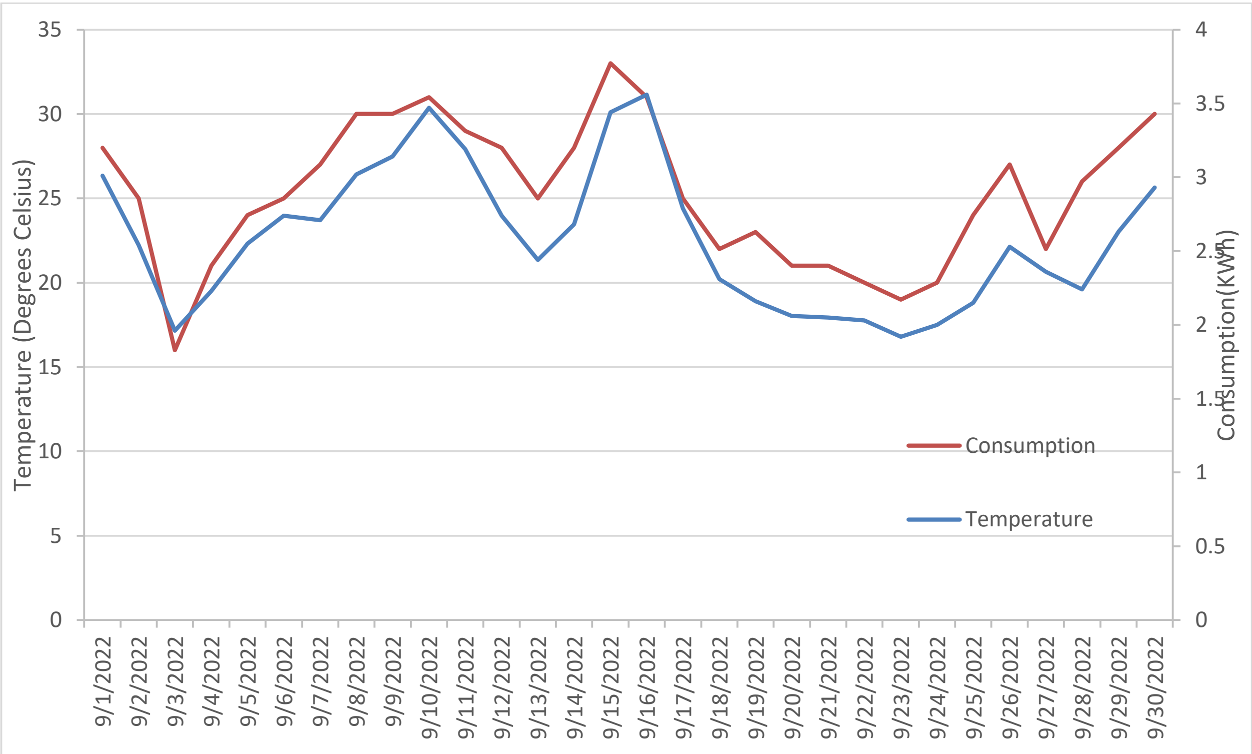
Temperature (Degrees Celsius)
Consumption(KWh)
Consumption
Temperature

Fig. 12.

Following the tests carried out with the help of the experimental model, we collected more data regarding the operation of a system for the automatic sale of cold and hot products, an energy independent system. From the complex of multidisciplinary data, this paper presents, in summary, an analysis of the electricity consumption of the refrigeration system in correlation with the ambient temperature. The presented data were extracted from the database in which the experimental model of the energy independent sales system stores the values recorded from the sensors it is equipped with. The analysis is carried out for August and September 2022, in fig. 11 and fig. 12, being presented in the form of graphs, the daily consumption (KWh) of the cooling subsystem and the ambient temperature (degrees Celsius).
Analyzing the graphs presented previously, we notice that there is a direct dependence between the electricity consumption and the energy consumption of the refrigeration system that ensures the internal temperature of around 6 degrees Celsius in the premises where the products to be delivered are stored. In August, the average outside temperature was 33.38 degrees Celsius, and in September, an average temperature of 25.30 degrees Celsius was reached.
In the analyzed period, the system consumed a total of 127.44 kWh for the month of August 2022. The daily average consumption was 4.11 KWh. Considering the value mentioned in the electricity label [] of an electricity supplier from Romania, for the production of electricity in the year 2021, the level of CO2 emissions was 217.24 g/KWh. Using this value of CO2 emissions, in determining the level of emissions for the cooling system of the experimental model, we conclude that by using solar panels we can obtain a reduction in CO2 emissions of 0.027685 tons of CO2 in August 2022.
In September 2022, the experimental model consumed a total of 77.58 kWh. The average daily consumption was 2.50 KWh. Considering the value mentioned in the electricity label [12] of an electricity supplier from Romania, for the production of electricity in the year 20211, the level of CO2 emissions was 217.24 g/KWh. Using this value of CO2 emissions, in determining the level of emissions for the cooling system of the experimental model, we conclude that by using solar panels we can obtain a reduction in CO2 emissions of 0.016853 tons of CO2 in September 2022.

Conclusions

The realization of an experimental model on a real scale for an automatic sales system of cold and hot products allowed the performance of tests that, in the case of a complex system, would not be conclusive for a reduced-scale model.
Following the presented analysis, we can say that the use of renewable sources to power an automatic sales system leads to a significant reduction in CO2 emissions. The reduction of CO2 emissions has a beneficial effect on the environment, which recommends these systems for use in the urban environment or in protected geographical areas.
For the two months analyzed in terms of consumption, a total consumption of 205.22 KWh was recorded, which corresponds to an average consumption of a house for one month [9]. The total value of reduced CO2 emissions is 0.0445 tons, equivalent to a road of about 280 km traveled by a mid-range gasoline car, with an emission level of 160 grCO2/km. Considering the large number of vending machines currently existing in the urban environment and the future regarding the use of these systems, the reduction of energy consumption and CO2 emissions will be significant in the energy balance and in terms of environmental protection from urban areas.

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