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Pairing simple domestic needs with products' reusability applications

Pareo de necesidades domésticas simples con aplicaciones de reutilización de productos

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Resumen

El largo y complejo proceso de degradación de los polímeros sintéticos presenta grandes desafíos ecológicos en todo el planeta. Podemos ver impactos directos día a día en la acumulación excesiva de plásticos que muchas veces terminan en su incineración, lo que a su vez contribuye a la contaminación y deterioro del medio ambiente. Aunque varios gobiernos alrededor del mundo han venido desarrollando programas que promueven alternativas a la reducción de residuos a través del reciclaje, la realidad es que estos programas muchas veces no son efectivos ya que no son acordes a las necesidades y accesibilidad de los consumidores. Una alternativa que puede estar más al alcance de los individuos es la de reutilización de productos.

Es posible reutilizar una amplia variedad de productos hechos con materiales como vidrio, papel, plástico, y metales entre otros. Para promover la reutilización, este manuscrito presenta una tríada de ideas para reutilizar varios productos con el fin de abordar problemas simples reales tales como mitigar las altas temperaturas en interiores, iluminar estéticamente jardines y pasillos en una casa, o bien dar soporte físico a macetas o sillas.

Palabras clave: reutilización de productos, bajo costo.

Abstract

The long and complex process of degradation of synthetic polymers presents important ecological challenges throughout the planet. We can see direct impacts in the excessive accumulation of plastics that often end up in their incineration, which in turn contributes to pollution and the deterioration of the environment. Although several governments worldwide have been developing programs that promote alternatives to waste reduction through recycling, the reality is that these programs are often ineffective since they are not consistent with the needs and accessibility of consumers. Product reutilization could be a more plausible alternative for individuals.

A wide variety of products made out of glass, paper, plastic, and metals can be used domestically. To promote reutilization, this manuscript presents a triad of ideas to give creative and functional use to reutilized products by using them to approach real problems like mitigating high indoor temperatures and providing aesthetic solutions for gardening and home decoration, among others.

Index terms: product reutilization, low-cost domestic reutilization.

I. INTRODUCTION

According to the United Nations Organization, by 2050, more plastic per volume will be in the oceans than fish [1]. This is not surprising since, for instance, it is estimated that a million plastic bottles are sold every minute in the world [2]. Currently, most plastic production is destined for food packaging and the manufacturing industry, which in turn means that 42% of plastic is "single-use plastics". These plastics, in most cases, are discarded in landfills for incineration or in bodies of water. They can take hundreds of years to decompose while accumulating the already known harmful and ecological hazards. The challenges in managing single-use plastics waste are recognized in [3] and are generalizable to all domestic garbage [4].

The reality is that waste has a direct relationship with all human activity. Therefore, although it is important to think of great engineering and societal solution, it is critical to generate and redesign a new and complete life cycle for materials such as plastic and glass (for example) so that these can cover new needs in the short and long term in a manner that is convenient to everyone. The concept of circular economy embodies these objectives [5], [6] and recognizes the multifaceted effort it requires [7], [8] along with its limitations [9], [10], [11] and challenges [12].

Since households are inherently part of the waste generation problem, it has been proposed that they can also be part of the solution [13]. This work describes and reproduces a series of simple ideas in product reutilization aimed at repurposing plastics, glass, and cables to solve domestic problems. The intention is to demonstrate the feasibility of reutilization in typical households according to three driving forces recognized along the life cycle of a product: demand, economic incentive, and convenience.

Figure 1 shows a model proposed here to explain the motivations and responsibilities in the life cycle of a product from its conceptualization to its disposal. It is shown that for a product to exist, there must be an unmet need in society -demand-. From this need, it is usually the engineering task to translate it into a concatenation of manufacturing elements to cover it. This implies translating the condition into the requirements of an engineering design. Subsequently, engineering will take this design through the development, prototyping, and production scale-up phases to manufacture the resulting product in quantities appropriate to meet demand. This step is practically tied to the generating need and the ability to specify a solution on an adequate scale to deliver it to the consumers through a supply chain. Once the consumer purchases this product, it is not unrealistic to say that engineering ignores everything that happens afterward. This part of the process will repeat itself whenever there is an economic profit in satisfying a need and will stop when the opposite occurs.

The consumer buys the product for the convenience of having a solution to the need if it is at a good price. Two additional essential forces join demand at this point: convenience -proximity, packaging- and economy -cost and status-. These forces will determine how long and in what quantity a product is used and ultimately play a final role in its disposal. Consumers will look for a convenient and cheap way to dispose of the product and generally do not have a sense of responsibility beyond this point.

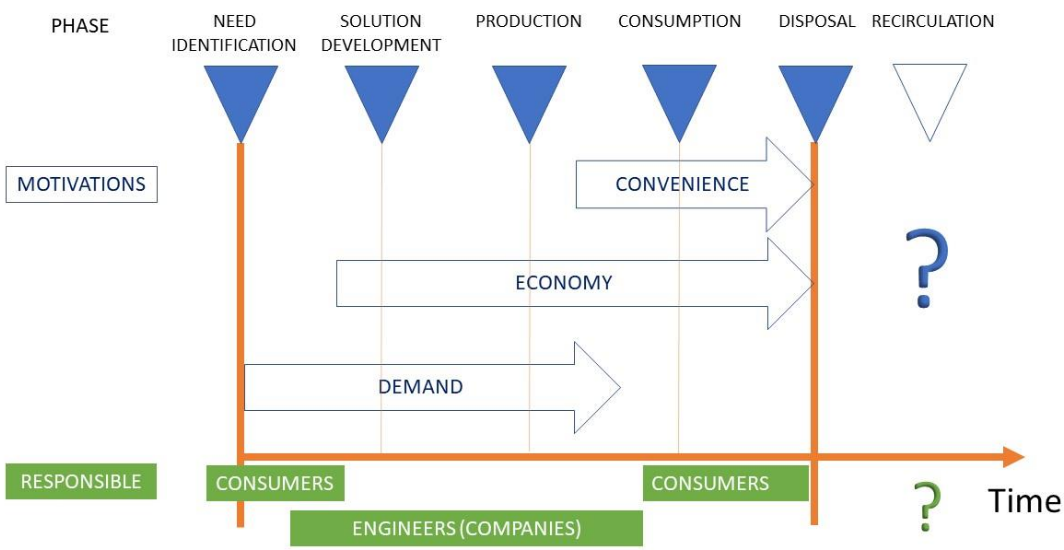


Fig. 1. A descriptive model of the motivations and responsibilities in the life cycle of a product.

When a product is discarded, we have great opportunities to recirculate its materials, components, and even packaging. However, the forces that moved the product are no longer there. There is no more economic profit, no convenience in making an additional effort to recirculate, and no demand. At this point, no one is also interested in taking responsibility for that product. Every product ends up, then, in waste. A subset of the three forces (demand, economy, and convenience) must be present in a product's "post-disposal" phase to recirculate products and materials. Historically, society and their governments place a lot of responsibility and blame on the consumer for generating waste, but engineering practitioners and companies need to take more responsibility for the recirculation of the products and materials they design. On the other hand, each government must also plan the recirculation of products and materials to be convenient and economically feasible.

II. REUTILIZATION PROJECTS

Project 1. Testing and Improving the Performance of an Invention from Asia: the Eco-Cooler

With global warming, temperatures are rising, and people are severely affected. This is especially true for those without access to commodities to mitigate the heat. With this in mind, a low-cost air conditioning artifact (called the Eco-Cooler) was invented in Asia [14]. It was created with reutilized materials to decrease the overall temperature in closed rooms. This work attempted first to replicate this device and its function, then probe the temperature change using the Eco-Cooler, and finally improve its cooling effect by trying out different prototypes with varied materials and dimensions.

Having a general idea of how the Eco-Cooler is built, it was decided that three initial prototypes would be assembled using three bottle types: water bottles, soda bottles, and wine bottles. Varying in diameter and material, our goal was to see if and how the difference between bottles affected temperature drop. A poster board was used as a platform to place the bottles. Fig. 1 shows the materials and tools used to construct the Eco Coolers.

Fig. 2. Materials and tools used to build the Eco Coolers.

Assembly Process for the Eco Cooler

The bottles in the coolers should all be placed on the board at the same distance. Here, the separation distance constraint comes from the soda bottles since they are the largest in diameter. All the bottles of the same type were cut at the same length to limit added variation. The designated size was 4.72 inches for the soda bottles and 4.53 inches for the water bottles. For the exit, the diameters were 2.56 inches for the water bottles and 3.74 inches for the soda bottles. For the entry opening, the diameters were 2.17 inches – 2.36 inches for the water bottles and 3.54 – 3.74 inches for the soda bottles.

A knife and scissors were used to cut the plastic bottles at the desired length. This was quite simple to do since plastic is easy to work with it. However, cutting the glass bottles was more time-consuming and required more equipment (Fig. 2). Using a glass cutter, an initial indentation was made. Then, heat is applied to the bottle along the indentation (Fig. 3). Finally, the bottle is submerged in ice-cold water until it becomes loose, and both parts separate (Fig. 3). As the cooler's base, a poster board was used for the plastic bottles and a sturdier foam board for the wine bottles. Small incisions in the shape of a 't' were made on the board to facilitate inserting each bottle in place.

The larger-diameter soda bottles were used for the first cooler. The bottles were placed next to each other, leaving any space in between, forming a 3x3 square (Fig. 4). The distance between the centers of the soda bottles was measured and used for the other coolers to keep the same positions fixed (Fig. 4). he installation of the Eco Coolers seemed safer with the plastic bottles overall, as can be appreciated in Fig. 5. The decision with this first installation experience was to hold the glass bottle Eco Cooler for later for safety purposes.

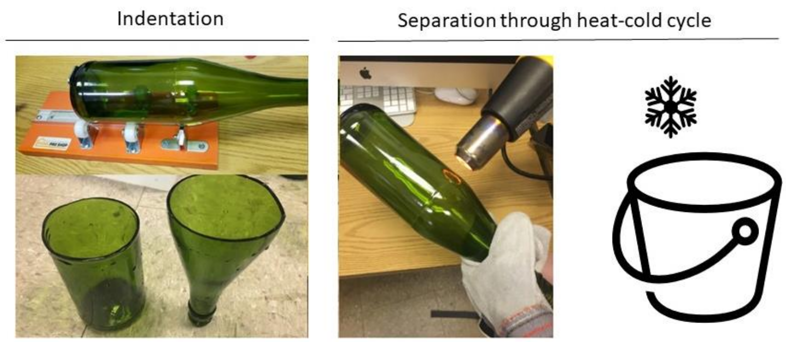


Fig. 3. Cutting process for glass bottles.

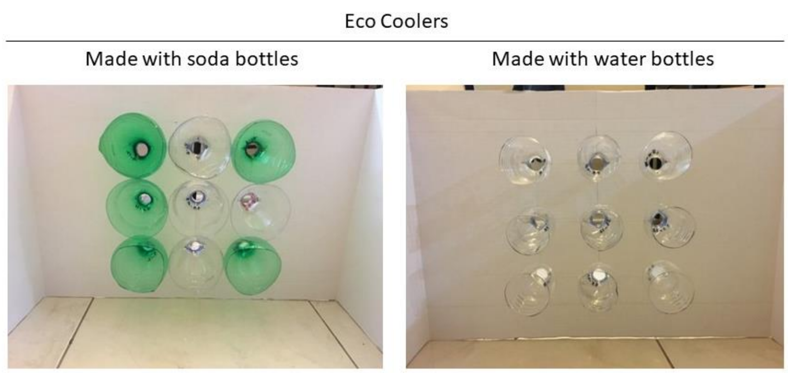


Fig. 4. Eco Coolers made with soda bottles and with water bottles.

Fig. 5. Installation of the Eco Coolers seen from inside and outside of the room.

Temperature Change

To measure the effectiveness of the assembly, the designs of the Eco Coolers were placed inside a room with access to a window (Fig. 5). Four different settings were established: (1) Closed windows without Eco Cooler, (2) Open window without Eco Cooler, (3) Open window with the Eco Cooler with soda bottles, and (4) Open Window with the Eco Cooler with water bottles. Four sections in the room were selected for temperature measurement for each set, starting with Section 1 near the window and ending with Section 4, far from the window (two central points in between were Sections 2 and 3, respectively). For each combination setting section, the temperature was measured three times. The resulting temperature values are plotted in Fig. 6. The Analysis of Variance (ANOVA) associated with this experiment is shown in Fig. 7.

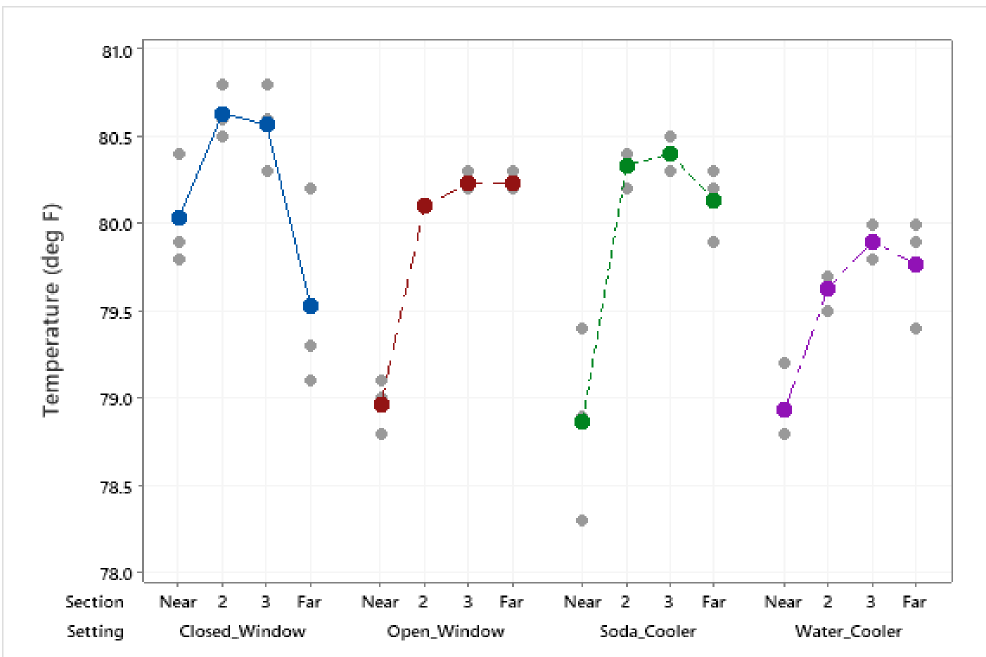
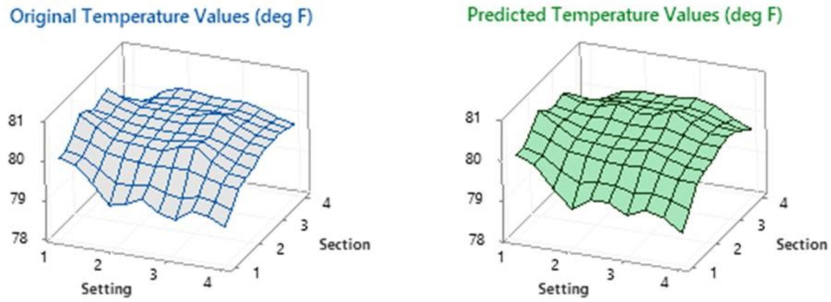


Fig. 6. Temperature measurements from the Eco Cooler experiment.



Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	8	13.8480	1.73100	23.05	0.000
Section	1	3.8810	3.88102	51.68	0.000
Setting	3	4.2049	1.40162	18.66	0.000
Section*Section	1	5.3333	5.33333	71.02	0.000
Section*Setting	3	3.0422	1.01406	13.50	0.000
Error	39	2.9287	0.07509		
Lack-of-Fit	7	0.7020	0.10029	1.44	0.224
Pure Error	32	2.2267	0.06958		
Total	47	16.7767			

Fig. 7. Statistical modeling and analysis of variance (low p-values in the last column indicate significant effects of the sources of variation in the first column).

As shown in Fig. 7, lower temperatures seemed apparent when the Eco Cooler made with water bottles was used. It is also noticeable that, as expected, different room sections showed different temperature values. An ANOVA based on a regression model helped confirm statistically that the temperature measurements varied as a function of the type of setting and the section in the room. Because the regression model helped explain 82.54% of the total variation in temperature values -a fidelity that can be corroborated in the 3D plots in Fig. 7, it is possible to conclude that the lowest temperatures were achieved using the Eco Cooler built using water bottles. It was somewhat surprising that the Eco Cooler made with soda bottles did not show very different results from an open window, so clearly, dimensioning the vents is an important part of the Eco Cooler.

The fact that the results of this experiment favored the use of low-diameter and lightweight plastic water bottles discouraged the further testing of glass bottles, as it would require a more involved installation, and the possibility of breakage seemed an unnecessary hazard. To this end, the next section follows up on other simple, safer ways to reutilize glass bottles.

Project 2. Reutilization of Glass Bottles

Glass is a material ideally poised for recycling and reutilization. According to the Glass Packaging Institute, with information from state environmental agencies, the number of recycled glass containers was 3.1 million tons in 2018, for a recycling rate of 31.3 percent in the USA [15]. However, in terms of reutilization, it is quite common for people to keep already-used glass bottles for decoration purposes.

In order to have some local statistics available in this project, three businesses in the town of Mayaguez, Puerto Rico, were contacted to obtain data about the number of glass bottles they discarded. As shown in Fig. 8, the number of discarded bottles increased from Wednesday onwards, while Thursday showed the largest number of discarded units. This is because the population of this college town tends to go out and consume many types of drinks during this day, especially in the evening. Most students return to their hometowns on Friday, which explains the dip in this day in the graph. Consumption, an important stage of the timeline for a product's life (**Fig.1**), is an issue if post-disposal is not addressed.

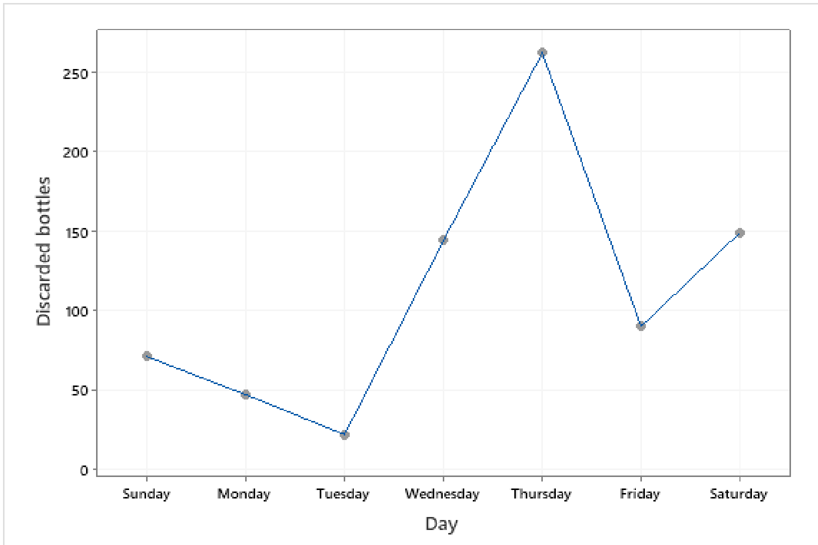


Figure 8. During a week, a number of discarded glass bottles from three businesses in the town of Mayaguez.

There are many benefits to glass reutilization, such as decreasing the volume of garbage in landfills [16]. On the other hand, glass maintains its qualities even if recycled. This work focused on the inherent appealing aesthetics of glass and its application to decorating home interiors and exteriors. A sample of possible uses and ideas is presented in Table 1. The most frequently required process to support glass reutilization is that of cutting the bottles, which was discussed earlier in this manuscript (Fig. 3). Figure 9 illustrates the reproduction of concepts to promote glass reutilization in domestic environments [17].

TABLE 1.
IDEA MATRIX

	Function complexity		
Shape	Simple	Medium	High
Cylinder	Plant pot	Lamp	Column
Cone	Dispenser	Spice Rack	Feeder
Ring (circlet)	Base	Organizer	
Joint	Vivarium		

Fig. 9. Illumination and decoration with segments of glass bottles.

The outdoor and indoor solar lights in Fig. 9 combine the bottom part of a transparent glass bottle -cut at different lengths- with inexpensive solar lead bulbs and a plastic base. If put together with other joints, a series of bottle segments can be structured into multiple shapes, as shown in the light ornament in the same figure. These ideas favor simplicity and safety, as more elaborate structures require a more detailed and careful consideration of stability and fitness for use.

Although it is debatable whether the rate at which glass bottles are consumed in a household can be translated efficiently into the simple ideas reproduced in this section, the aim here is to point to a solution for the need to light an outdoor hallway or a garden at home. Accumulating waste at home is a common phenomenon that can sometimes be subtle, such as keeping a large number of glass bottles or, in other cases, several unused electric cables, as described in the following project.

Project 3. Reutilization of cables

Most people own cables from old devices that are not used anymore. However, it is possible to reutilize them for different purposes. This project aims to create a configuration or a combination of cables using special knots feasibly and productively. Most of the wires gathered for this project were from phones and gaming console chargers. Most chargers contain small amounts of copper and cadmium, but the largest component is the plastic coating. Two different designs were reproduced: a potholder and a net to restore the sitting support in a chair. Fig. 10 shows the potholder, and Fig. 11 shows the chair support design.

The potholder assembly used two computer charger cables and a plastic pot. To evaluate the assembly, it was necessary to test it with a weight load. At the bottom of the pot, there are two holes through which a Japanese Square knot was made [18] (Fig. 10). In addition, to hold the pot, a Barrel Hitch knot was performed [19]. Finally, the pot was loaded with stones since it had more weight than soil and plants. In other words, if it resisted the weight of the stones, it was ready to contain soil for planting.

Fig. 10. Potholder Assembly.

In the second case, an unused chair and cables were used. Several strategies were implemented by trial and error to verify which one was the best option to build and whether it was the one that resisted more weight and was more comfortable. The knots that met the requirements were the Constrictor and the Ossel Hitch [20] (Fig. 11). Since the main goal was to create support, a cushion is further recommended to prevent discomfort.

Fig. 11. Chair Support Assembly

III. DISCUSSION

The model illustrated in Fig. 1 poses that, for product and material recirculation to occur, three driving forces must be present: (1) economics, (2) convenience, and (3) demand. These three reutilization projects discuss ideas where the three driving forces are present at a domestic scale. For example, the demand in the first project comes from the need to cool a room in a house. The Eco Cooler can help meet this need, using affordable reused products conveniently. As a result, operating expenses are nonexistent, and the initial capital investment is small. The second project meets the needs of illumination and decoration in a house by using discarded glass bottles. Again, affordability, convenience, and demand make up a modest recirculation loop. Finally, the third project uses a simple combination of well-proven knots in the reutilization of cables that meet all three driving forces. Importantly, all three projects require modest assembly skills and the basic use of tools that attest to their feasibility and convenience.

IV. CONCLUSION

This work focuses on the reutilization of materials in a domestic environment. Three different ideas are reproduced here to (i) reutilize plastic water bottles to build an Eco Cooler to help mitigate high indoor temperatures, (ii) reutilize glass bottles for illumination, and decorative purposes, and (iii) reutilize spare cables to form supporting assemblies for different household items. It is initially posed that for any significant material recirculation to happen, the associated activities must be in demand by society, economically attractive, convenient, and -if necessary- regulated by government policies. Because the scale of such an endeavor is too big and out of reach for the typical individual, it is imperative to motivate the association of simple needs and ingenious simple solutions at home to have the chance to make at least a modest contribution to recirculation. In future work, a formal quantification of environmental impact is proposed, along with the performance optimization of each reproduction in this manuscript.

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