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The contribution of smart applications in natural resources preservation

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A B S T R A C T

Technology has now infiltrated all areas of our daily lives. The use of mobile devices has increased dramatically around the world, and they have become devices for all uses. Applications have been developed that are called "smart applications", because they can respond to real conditions, process complex situations and act instantly. They facilitate the daily lives of citizens and promote energy saving. A multitude of "smart applications" have been developed with which citizens can calculate their ecological footprint and adapt their behavior with the aim of reducing it. These applications use data analysis, artificial intelligence and IoT technologies to provide personalized recommendations, actively contributing to the reduction of greenhouse gas emissions. This research is an approach to document and describe smart applications in the global market. The use of such applications can be a sustainable alternative in terms of saving valuable environmental resources and capital, while simultaneously reducing the total annual greenhouse gas emissions and environmental impacts.

1. Introduction

In recent years, the reckless use of natural resources has led to the acceleration of climate change. The rapid increase in greenhouse gas concentrations has led in the depletion of natural resources (Helm, 2008 ; Amiri et al, 2024). Individuals and organizations consume large amounts of natural resources daily (Gerard et al, 2018 ; Alvarado et al, 2021). The exponential population growth (Berck et al, 2012), has resulted in the impacts of human activities becoming apparent earlier than expected (Singh et al, 2012). The reduction of our planet's natural reserves is now irreversible and the predictions of the scientific community for the future of our planet's ecosystems are alarming (Gabric, 2023).

The global community is now aware of the situation and green practices for sustainability are being implemented. For this reason, and over time, as the human impact on the environment is constantly increasing, several efforts have been made at global level to mitigate the negative impact (Greyson, 2007 ; Rainville, 2017). The first international agreement that aimed to reduce greenhouse gas emissions and consequently mitigate climate change and conserve natural resource was the Kyoto Protocol (Dumanski, 2004). The protocol set binding targets and timetables for participating countries to lower their emissions (Gupta, 2016). In addition, eco-labels and energy efficiency standards have been introduced and adopted in many countries, serving as effective tools for addressing environmental challenges (Rainville, 2017; Gallastegui, 2002).

An important tool for measuring human impacts on the environment is the ecological footprint (Haberl et al, 2004 ; Cordero et al, 2008). By calculating the ecological footprint, individuals can calculate the amount of natural resources consumed even at a personal level (Pandey et al, 2011; Belčáková et al, 2017). The ecological footprint is measured in global hectares (gha), which represent

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the ratio of the total amount of a resource consumed to the global average biological productivity of the land required to generate it (Monfreda et al., 2004; Pandey et al., 2011).

The ecological footprint essentially concerns the area that is necessary for the production of the resources consumed to satisfy the needs of an individual, a city, a region, as well as the assimilation of the waste generated by the above activities (Barrett et al, 2005; Rees et al, 2008; Pandey et al, 2011). The most important components of the ecological footprint are the energy, carbon and water footprint (Rees et al, 2008).

The energy footprint refers to all the land areas necessary to capture carbon dioxide emissions (Fang et al, 2013). The carbon footprint refers to the area of land required to absorb all the carbon dioxide produced by humanity during its lifetime (Zhao et al, 2005 ; Pandey et al, 2011). The carbon footprint includes the six greenhouse gases, namely carbon dioxide, methane, nitrous oxide, hydrochlorofluorocarbons, perfluorocarbons and sulfur hexafluoride. The unit of measurement of the carbon footprint is the greenhouse carbon dioxide equivalent (Aroonsrimorakot et al, 2013 ; Pan et al, 2024).

Water is the most important natural resource in the world, because it is a key factor for the maintenance of life and development. Climate change poses enormous risks to the security and maintenance of sufficient water. The hydrological cycle has now been affected by changing hydrological data. The water footprint refers to the amount of water necessary to produce the products and services consumed by people worldwide (Hoekstra et al, 2007 ; Hu et al, 2024).

It is a fact that greenhouse gas emissions from human activities cannot be avoided. The most important greenhouse gas is carbon dioxide. When an individual's total carbon dioxide emissions are largely offset by actions to absorb it, it is called carbon neutrality. Carbon neutrality is an important measure for conserving natural resources and achieving sustainable development (You et al, 2024).

Nowadays, people are increasingly interested in protecting the environment. There is a gradual change in their behavior regarding the consumption of products and services (Alvarado et al, 2021). They are now turning to environmentally friendly products, thus supporting the creation of a sustainable environment (Chamorro et al, 2006).

The rapid development of Information and Communication Technologies can contribute to achieving sustainable development, making economic growth possible (Szilágyi et al,2022), while preserving the environment (Wu et al, 2018 ; Wang et al, 2024). With the use of technology, citizens can be informed at any time about events happening around the world through the internet (Sendecka, 2006). They are given the opportunity to access information immediately, without wasting time, resources and energy (Wang et al, 2024). Information and Communication Technologies have now become part of citizens everyday lives. They are used from food production to healthcare and smart homes (Andersen et al, 2021).

With the development of technology, there is also great growth in the field of mobile devices and mobile phones. There are greater storage capabilities and more methods of entertainment and information (Yan et al, 2013 ; Szilágyi et al, 2022). Mobile devices are a very important part of everyday life for citizens worldwide. They not only keep us connected but also perform daily tasks, making our daily live much easier (Wu et al, 2018). They have now turned into all-purpose devices (Machiry et al, 2013).

There is a variety of applications that users can download to their mobile phones (Harper, 2006). These applications can be educational and informative. By using smart applications related to education and information, citizens can access educational and informational material at any time from any place. This eliminates physical presence, saves time, and reduces travel costs and greenhouse gas emissions. Also, the fact that educational material and information are available in electronic form and not in paper form helps to preserve natural resources (Saleem et al, 2022).

There are also social media applications, entertainment applications, gaming applications and lifestyle applications. Some applications can guide citizens to follow an environmentally friendly lifestyle. These applications are called “Green or Ecological applications” (Deekshath et al, 2018).

Through green applications, citizens can receive information and develop new green behaviors that help them live a more sustainable lifestyle (Hoffman et al, 2022 ; Okonta, et al, 2024).

Also, there is the ability to communicate and connect with other people to donate goods they no longer need (Alsayed et al, 2022). Food waste significantly affects environmental pollution. Global food waste represents almost a third of all food. It is responsible for the total carbon footprint of global anthropogenic greenhouse gas emissions (Liegeard et al, 2020). Mobile phone applications enable food to be reused before it becomes waste. This reduces the volume of waste that burdens the natural environment (Hanson et al, 2022). So, by using such applications, people's environmental impacts can be calculated, less energy is consumed, fewer unnecessary products are used, citizens learn how to recycle, manage their waste, and reduce water consumption and their ecological footprint (Ullo et al, 2020; Okonta, et al, 2024).

Another important opportunity offered by digital applications is that citizens can monitor their activities and adjust their consumption habits in such a way that they can save energy and reduce their ecological footprint (Fazeli, 2014; Wolniak et al, 2023). The calculation of the ecological footprint takes into account an individual's activities and lifestyle, such as the consumption of products and services, the use of electricity, travel, etc. (Hoffmann et al, 2024).

Applications constantly provide information about alternative sustainable choices. Citizens can know, for example, to what extent the products they consume are impacting the environment. They can plan shared routes to save energy, be informed about alternative modes of transportation and activities with a reduced carbon footprint (Wolniak et al, 2023).

People can use green applications to control a variety of devices remotely. Many times citizens leave their home having forgotten to turn on a light, an air conditioner, a television, etc.. This result in all these hours they are away from home consuming energy and burdening the environment. Using applications from their mobile phone, they can activate/deactivate any device at any time (Tian et al, 2015). Also, there are water sensors that help to inform family members through applications about the amount of water they consume. They can program their devices to consume the minimum amount of water required (Tian et al, 2022). The purpose of this study is to record and analyze applications related to the calculation of the ecological footprint and the saving of natural resources.

2. Methodology

As mentioned earlier, the aim of the study is to record the applications that concern the ecological footprint and contribute to the saving of natural resources. It is interesting to see which of these applications have the most downloads and why citizens download them. It is also quite important to understand what features of the applications make them more attractive to citizens to download them on their device. The study highlights aspects of smart applications that can be improved to increase their global adoption.

To collect the research data, a search was carried out on digital application platforms. The platforms that were used are the App store and the Play store, which are accessible from mobile devices. The existence of a multitude of applications related to the ecological footprint made it difficult to select the most relevant and reliable applications. For this reason, specific criteria were used when selecting the applications. These criteria are the following:

1. The application must be available in English, so that it can be used by many users worldwide.

2. The applications recorded have either Android or iOS operating systems

After the above criteria were set, the characteristics of each application were recorded in a summary table. For each application were recorded the subject, the number of downloads, the platform on which it is available, the year of its release, the language in which it is available, and whether it is free or not. The keywords used when searching for applications are ¨Ecological footprint¨, ¨Energy saving¨ ¨Sustainability¨, ¨Carbon footprint¨, ¨Energy footprint¨, ¨Climate change¨ ¨Smart living¨, ¨Smart home¨ etc..

Then, in Table 2, the characteristics which recorded for each application are compared. In this way, we can see if a characteristic is present in all applications. Also, users can understand which application best suits their needs. Finally, three applications are presented, which have several downloads and very good ratings from users on both platforms.

3. Results

A total of 31 applications were recorded. These are Irecycle, Ecosia, Geco Air, Emporia Energy, Power Concumption Analyzer, Loss of the night, Trashly: Recycling Made Easy, SmartLife-Smartliving, Oroeco, Sustainable Development Goals(SDG), Go Green Challenge, Olio, Recycle Coach, JouleBug, Home Wizard Climate, We Don't Have Time, Climate Change, Waterprint Calculator, Zify:Carpool, Rideshare and Commute, Green Choice :Grocery Shopping, Klima-live carbon neutral, Carbon Footprint & CO_2 Tracker for travel and food, Earth Hero:Climate Change, Footprint App, Earth Project, CO2IN-World for our children, Environment Challenge , Personal Carbon Footprint, Carbon Donut:act on climate, Ecobee, Reduce food waste, Bikemap.

The applications we recorded relate to the Energy Footprint, Energy Saving, the Carbon Footprint, the Sustainability, the Environmental Protection, the Water Footprint, the Recycling, the Reforestation, the Pollutant Control, the Food Saving, the Smart Living, the Light Pollution, the Bicycle Routes and the Energy Saving. The largest percentage of applications recorded concern Energy Footprint, Carbon Footprint and Sustainability with a percentages of 19%, 13% and 13% respectively (Figure 1).

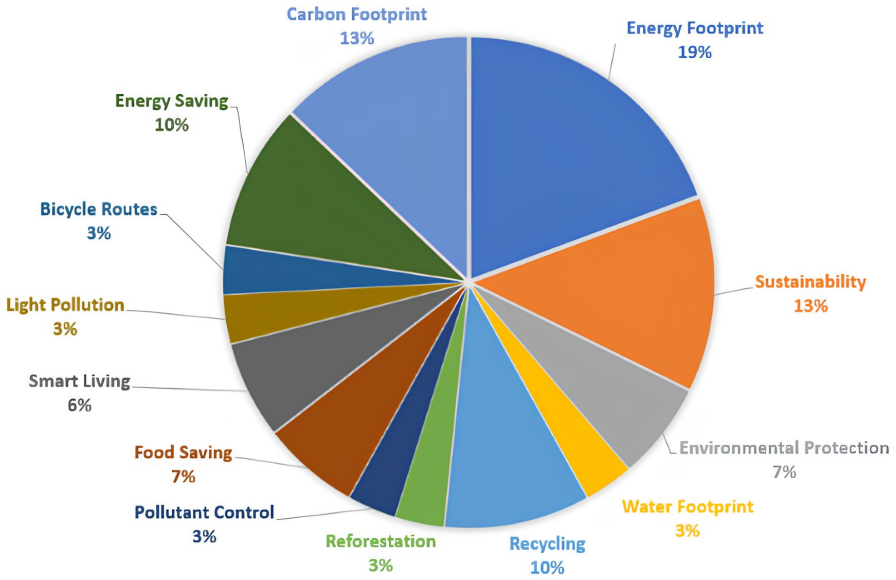


Figure 1. Objectives of applications

Table 1a. Applications with their characteristics

APPLICATION NAME	OBJECT OF APPLICATION	NUMBER OF DOWNLOADS	PLATFORM (App store, Play store)	YEAR OF RELEASE
Power Concumption Analyzer	Energy Saving	10000+	Play store	2012
Ecosia	Reforestation	10000000+	App store, Play store	2013
Loss of the night	Environmental Protection	50000+	Play store	2013
Bikemap	Bicycle Routes	5000000+	App store, Play store	2013
JouleBug	Sustainability	50000+	App store, Play store	2014
Ecobee	Smart Living	1000000	App store, Play store	2014
Oroeco	Carbon Footprint	50000+	App store, Play store	2015
Olio	Pollutant Control	1000000+	App store, Play store	2015
Recycle Coach	Recycling	100000+	App store, Play store	2016
Geco Air	Environmental Protection	10000+	App store, Play store	2017
Go Green Challenge	Environmental Protection	10000+	App store, Play store	2017
Green Choice	Food Saving	5000+	App store, Play store	2017
Waterprint Calculator	Water Footprint	10000+	App store	2018
Footprint App	Carbon Footprint	5000+	Play store	2018
Environment Challenge	Environmental Protection	100000+	App store	2018
Irecycle	Recycling	5000+	App store, Play store	2019
Emporia Energy	Energy Saving	10000+	App store, Play store	2019
Recycling Made Easy	Pollutant Control	10000+	Play store	2019
HomeWizard Climate	Smart Living	50000+	App store, Play store	2019
WeDontHaveTime Climate Change	Energy Footprint	10000+	App store, Play store	2019
Zify:Carpool, Rideshare and Commute	Carbon Footprint	5000+	App store	2019
Carbon Footprint & CO2 Tracker for travel and food	Energy Footprint	10000+	App store, Play store	2019
Earth Hero: Climate Change	Energy Footprint	10000+	App store, Play store	2019
Personal Carbon Footprint	Carbon Footprint	10000+	App store	2019
Sustainable Development Goals(SDG)	Sustainability	10000+	App store, Play store	2020
CO2IN: World for our children	Energy Footprint	1000+	App store	2020
Carbon Donut: act on climate	Energy Footprint	10000+	App store, Play store	2020
Reduce food waste	Food Saving	5000+	App store	2020
Smart Life- Smart living	Smart Living	10000000+	App store, Play store	2022
Klima-live carbon neutral	Carbon Footprint	10000+	App store, Play store	2022
Earth Project	Sustainability	5000+	App store	2023

In Table 1a, the applications are classified based on their year of release. It appears that the development of applications enabling citizens to calculate their ecological footprint on a global scale has primarily emerged within the last decade. Over time, the number of applications has increased. Great growth has been observed from 2019 onwards. This increase can be attributed to the growing environmental awareness that has emerged in recent years, driven by the significant changes observed in the natural environment. More and more applications are being created that concern environmental protection and the number of objects they focus on is gradually increasing. Also, Table 1a shows the object of each application, the number of downloads and the platform on which it is available.

Table 1b. Applications with their characteristics

APPLICATION NAME	APPLICATION LANGUAGE	COST
Power Concumption Analyzer	English	Free
Ecosia	English and more	Free
Loss of the night	English	Free
Bikemap	English and more	Free
JouleBug	English and more	Free
Ecobee	English and more	Free
Oroeco	English and more	Free
Olio	English, Spanish	Free
Recycle Coach	English	Free
Geco Air	English, French	Free
Go Green Challenge	English	Free
Green Choice	English	Free
Waterprint Calculator	English	Free
Footprint App	English	Free
Environment Challenge	English	Free
Irecycle	English	Free
Emporia Energy	English	Free
Recycling Made Easy	English	Free
HomeWizard Climate	English and more	Free
WeDontHaveTime Climate Change	English	Free
Zify:Carpool, Rideshare and Commute	English	Free
Carbon Footprint & CO2 Tracker for travel and food	English	Free
Earth Hero: Climate Change	English	Free
Personal Carbon Footprint	English	Free
Sustainable Development Goals(SDG)	English	Free
CO2IN: World for our children	English	Free
Carbon Donut: act on climate	English	Free
Reduce food waste	English	Free
Smart Life- Smart living	English and more	Free
Klima-live carbon neutral	English	Free
Earth Project	English	Free

In Table 1b we can see whether each application is available only in English or in other languages. Where we see the phrase ‘and more’, the application is available in over ten different languages. Also, in the last column of the table we see whether the application is free or not.

From Tables 1a and 1b is observed that applications that are available in more than one language have a greater number of downloads. This happens because when an application is available in a language that is familiar to the citizens makes it easier for them to use it daily and effectively.

Table 2. Comparison of characteristics

APPLICATIONS	PLATFORM (App store, Play store)		APPLICATION LANGUAGE	COST
	App store	Play store	More languages	Free
Power Concumption Analyzer	-	+	-	+
Ecosia	+	+	+	+
Loss of the night	-	+	-	+
Bikemap	+	+	+	+
JouleBug	+	+	+	+
Ecobee	+	+	+	+
Oroeco	+	+	+	+
Olio	+	+	+	+
Recycle Coach	+	+	-	-
Geco Air	+	+	+	+
Go Green Challenge	+	+	-	+
Green Choice	+	+	-	+
Waterprint Calculator	+	-	-	+
Footprint App	+	-	-	+
Environment Challenge	+	-	-	+
Irecycle	+	+	+	+
Emporia Energy	+	+	-	+
Recycling Made Easy	-	+	-	+
HomeWizard Climate	+	+	+	+
WeDontHaveTime Climate Change	+	+	-	+
Zify:Carpool, Rideshare and Commute	+	-	-	+
Carbon Footprint & CO2 Tracker for travel and food	+	+	+	+
Earth Hero: Climate Change	+	+	-	+
Personal Carbon Footprint	+	-	-	+
Sustainable Development Goals(SDG)	+	+	-	+
CO2IN: World for our children	+	+	-	+
Carbon Donut: act on climate	+	+	-	+
Reduce food waste	+	-	+	-
Smart Life- Smart living	+	+	-	+
Klima-live carbon neutral	+	+		+
Earth Project	+	-	-	+

Table 2 summarizes and compares the characteristics recorded by the applications. In the comparison of characteristics, whether the application is available in English was not used, because it was a criterion in their selection. A small part of the applications is also available in other languages. It can be seen from the table that all the applications recorded are available for free to the public. Finally, the largest percentage of the applications is available on both search platforms.

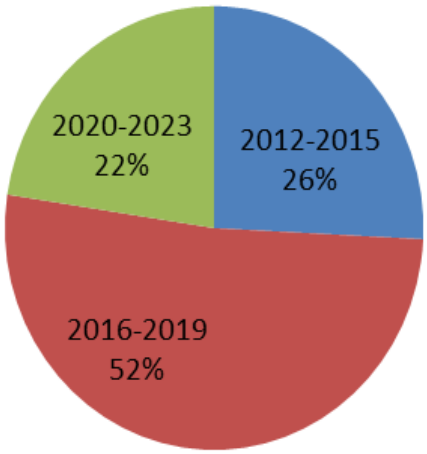


Figure 2. Rate of creation of new applications per four years

Figure 2 shows that 26% of applications were created in the four-year period 2012-2015. Great application development is observed in the four-year period 2016-2019. Specifically, 52% of the applications in the study were released in this period. This is due to the fact that there was interest in the early years of the creation of applications for the environment, the number of their objects increased and they attracted the interest of citizens. Finally, 22% of applications were released in the four-year period 2020-2023. Gradually, more and more applications are being added. However, in order for these applications to be successfully established in the global market, certain aspects must be improved, such as enhancing user experience, increasing accessibility for citizens, and maximizing their contribution to resource conservation. For this reason, the rate of application development has decreased, so that they can focus on improving the above elements.

Below some applications of the survey are analyzed. These applications concern smart living and carbon footprint.

ECOSIA

The Ecosia application has more than 10 million downloads. It is available on Android and iOS software. The application's rating on Google play is 4.5/5, while on the App store it is 4.7/5. The application is available in more than fifty languages and for free. Ecosia is a European search engine that donates 80% of its revenue to non-profit organizations for tree planting. Through the application, users have access to any website. With each search through Ecosia, one kilogram of carbon dioxide is removed from the atmosphere. When the user enters the application, the number of trees that have been planted is displayed. The user is also shown the company's monthly revenue and the percentage allocated to tree planting. Furthermore, the possibility of implementing environmentally friendly options is given. Below are some photos of the application environment.



Figure 3. Number of trees planted



Figure 4. Monthly ecosia income

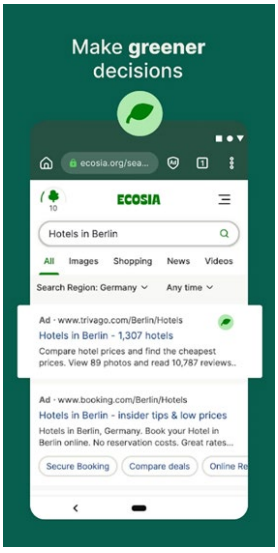


Figure 5. Environmental friendly options

ECOBEE

The ECOBEE application has more than 1 million downloads. It is available on Android software, as well as iOS software. The application's rating on Google play is 3.9/5, while on the App store it is 4.6/5. The application is available for free and is available in English. The application's purpose is the smart home. Users have access to detailed information about the use of the application and the placement of sensors regarding the monitoring of devices remotely. They can monitor the areas of their home and know what is happening in it at any time. The application offers complete control of the devices and the conditions prevailing in the home. There is also the possibility of saving energy by using sensors. Users can connect from their mobile phone and use sensors to control the kitchen, refrigerator, washing machine, etc.. Below are some photos of the application's environment.



Figure 6. Smart application functions

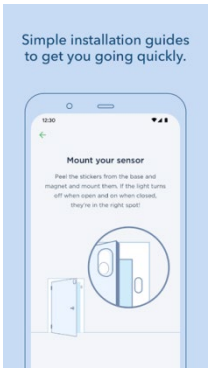


Figure 7. Operating instructions

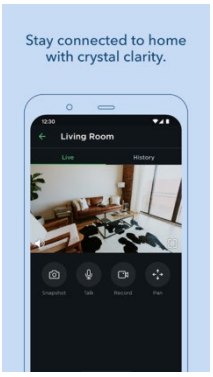


Figure 8. . Smart application functions

RECYCLE COACH

The Recycle Coach app has more than five hundred thousand downloads. It is available on Android and iOS. The app's rating on Google Play is 4.6/5, while on the App Store it is 4.8/5. The app is free and available in English. The app is about recycling. The app makes the recycling process easier than ever. The app offers calendars for scheduling recycling and maps where the user can see the locations

of recycling centers. The user also receives notifications from the app regarding the time they have set to take out the trash. There are also instructions regarding the categories of items that can be recycled. Below are some photos of the app's environment.

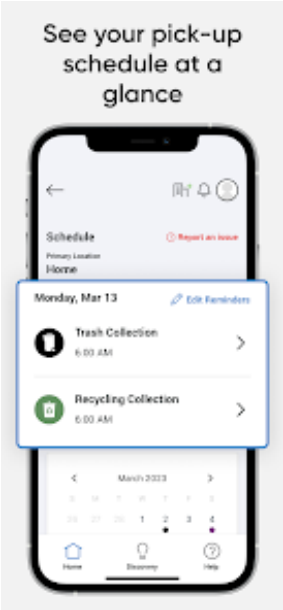


Figure 9. Recycling programme

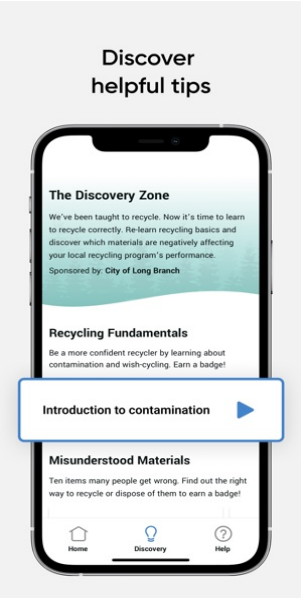


Figure 10. Recycling information

4. CONCLUSION

The environment is subject to continuous ecological degradation which is related to the irreversible reduction of our planet's natural reserves. Saving natural resources is a burning issue that concerns the global community. The responsibility for environmental protection falls on all countries and citizens worldwide. It is therefore imperative to minimize greenhouse gas emissions and properly manage natural resources (Dumanski, 2004). Citizens are now more aware of environmental issues and an environmental focus and orientation prevails. The impacts of climate change are multifaceted and require a holistic approach to address it. Technological developments contribute to the mitigation of climate change (Suprayitno et al, 2024).

People around the world have access to a variety of applications that they can use to conserve natural resources. There is no doubt that the development of smart applications contributes to mitigating climate change and achieving sustainable development goals.

The above results show that citizens are mainly interested in applications related to carbon footprint, energy footprint and energy saving. Through these applications they can save energy, time and money. This fact shows that citizens are now more aware and informed about environmental issues.

These results are quite encouraging if we take into account the overall picture of the global environmental crisis. There is no doubt that a coordinated effort should be made to inform about the existence of applications that contribute to the protection of the natural environment and the conservation of natural resources.

Through this research, applications are made known to the general public that citizens can use daily to calculate their ecological footprint and adjust their behavior. By observing the results, everyone can find the application that suits them and use it.

In addition, developers can enhance specific features of the applications that currently show limited performance or user engagement. For example, when an application is available in more than one language, it makes sense for it to be used by more people. By having aggregated results from various

applications, experts can see where an application is lagging behind, make improvements, and thus expand its use.

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