

## Prospective of the need for a heuristic model for the improvement of home electricity consumption in favor of an energy transition in Mexico

## Prospectiva de la necesidad de un modelo heurístico para el mejoramiento del consumo eléctrico domiciliario en pro a una transición energética en México

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### Abstract

Environmental problems have shown that as the days go by, the estimated negative scenarios are closer to being achieved. Despite this, in Mexico there are few programs that are directed or implemented in response to this need, and those that do exist do not have a systemic vision that ensures sustainability for the different factors that have a correlation with the system. On this premise, the research was carried out from a descriptive theoretical study method that allowed to visualize the background of this sector in a global way and its subsequent territorial delimitation, which when encompassed from the approach of the Transdisciplinary Cyber System, the different types of the knowledge. All with the purpose of seeking the transition towards beings more aware of their environment and the impact of their actions, for which, using the Cyber-Systemic Planning-Action Process, the different tools available to solve the need under study and with this, the creation of the adaptive methodology to the context and the model for environmental awareness based on contextualization, with the aim that the student population reaches more significant knowledge in relation to their surrounding environment.

**Energy, Awareness, Education**

### Resumen

Los problemas ambientales han demostrado que con el paso de los días se está más cerca de alcanzar los panoramas negativos estimados. A pesar de ello en México son escasos los programas que van dirigidos o que se implementen ante esta necesidad, y los que existen no tienen una visión sistémica que asegure la sostenibilidad para los diferentes factores que tienen correlación con el sistema. Sobre esta premisa la investigación se llevó a cabo desde un método de estudio teórico descriptivo que permitiera visualizar el trasfondo de este sector de manera global y su posterior delimitación territorial, que al abarcarlo desde el enfoque de la Ciber Sistema Transdisciplinar admitió conjuntar los diferentes tipos del conocimiento. Todo con el propósito de buscar la transición hacia seres más conscientes de su entorno y el impacto de sus acciones, para lo cual empleando el Proceso Ciber-Sistémico de Planeación-Acción se contrapusieron las diferentes herramientas que se disponen para solucionar la necesidad en estudio y con ello la creación de la metodología adaptativa al contexto y el modelo para la concientización ambiental basado en la contextualización, con el objetivo de que la población estudiantil alcance saberes más significativos en relación a su medio circundante.

**Energía, Concientización, Educación**

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## 1. Introduction

Among the main causes that have been studied to improve the correlation between the human being and the environment, is the search to minimize the ecological footprint; translated into treaties for the reduction of Greenhouse Gases (GHG). The drawback with this type of pollutant lies in the fact that it is caused by the increase of comfort in daily life, which means an increase in energy consumption per capita.

With this scenario in mind makes environmental experts wonder why Mexico being a country rich in favorable conditions for clean energy has not taken advantage of them. The first answer that usually accompanies this type of technology is the high cost of investment and the years of recovery, which enters a contrast between the different economist's approaches, since from a traditional point of view they are not profitable, but from an environmental vision it is shown that more is lost if this change is not sought, since everyone will be affected by the alteration of the natural conditions of ecosystems.

Paulette Dieterlen Struck, researcher at the Institute of Philosophical Research of the UNAM, sees as one of the main factors to achieve a real solution in the decrease of the ecological footprint, the change of socio-environmental awareness. Since; for some time humanity has been exercising an irrational consumption, where 75% of the products sold are not necessary (Gutiérrez, 2020), which requires the development of less selfish, fairer and more caring societies, which will have the task of decreasing by 7.6% global carbon emissions by 2020 and continue at that same rate each year for the next decade to keep global warming below 1.5° by the end of the century, according to the United Nations Environment Programme's 2019 Emissions Gap Report (Organización de las Naciones Unidas [ONU], 2020b).

It must be understood that for any of the energy alternatives to be a feasible option, a restructuring of the final consumer is first required, since he will stipulate how much should be produced and thus which solution is viable for both sectors; the economic and the environmental.

In this way it is reflected that the environmental system and its effects are intimately or connaturally related to cultural profiles of communities and societies. There is a lack of awareness and education programs on issues related to climate change (Vergara, 2015); since millions of people use electricity, but only a minimum of these know how it works, how much is spent by each appliance, how to reduce consumption, what is the impact it causes on the environment and what energy sources or alternatives are available (Olivares, 2018, p. 302).

The importance of considering this problem from the proposed approach is that even when given cheaper technological alternatives that have a lower environmental impact these will not have a real impact if the target audience is not aware of why it is important to opt for these solutions, since the energy sector is relatively strong, the average end consumer is only interested in supplying their consumption and that is competitive monetarily.

In view of this fact, the new generations are being targeted because it is to a certain degree normal for them to have a general understanding of global warming, since they were born when it was already present, so they have seen firsthand the changes in ecosystems, which has made them a little more sensitive and aware of this problem. Because of this, it is essential to teach people from an early age to understand what their role is if they want to change the unfavorable scenarios of this situation.

Due to the seriousness of the problem and that it is not so recent, numerous studies have been made for its solution from different perspectives; almost always very positive or negative, without contemplating what happens in that range of possibilities that have been left when opting for one or another approach. In virtue of this, an integral vision that contemplates the following objectives is proposed:

- Descriptive and critical research on energy consumption and its conscious use.

- Design of a methodology for the improvement of household energy consumption in consideration of the ecological footprint.
- Proposal of a flexible, dynamic and user- friendly system for the study of household energy consumption.

Its orientation to the domestic sector is aimed at a long-term solution to climate change, since this unresolved need demands that the population takes a more active role in this situation and is not a temporary change but becomes a lifestyle that improves their coexistence with the environment.

In addition, its viability is observed if the numbers related to the chosen sector are reviewed, since its demand represents 40% of the global primary energy and about 70% of the electrical energy consumed. Therefore, it is required to reduce its consumption and the formation of infrastructure of almost zero energy consumption. All for the formation of a base towards the transition of an energetically sustainable city where its value lies in the set of new processes and new human relations of how energy consumption is understood (Soto, 2019; Del Valle, 2017, p.51).

## 2. System context

By using a descriptive theoretical study method, the background of the energy sector was visualized in a global way and later segmented towards the market of the United Mexican States; with which the currents of the system and its connatural relation with the trident that establishes the human activities and that has an impact in its surroundings; the economy, the environment and the society were contemplated diametrically.

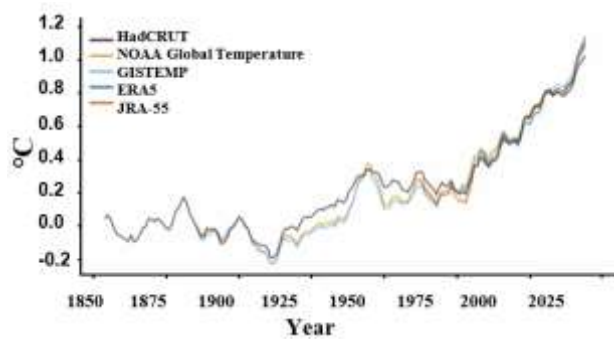
In the global energy market four major changes are considered, the rapid development and decreasing costs of clean technologies to generate electricity, the increasing use of this approaching the consumption of fuels associated with oil, the shift to a cleaner mix in the economy, and the resilience of gas and oil technologies (Correa, 2018 p.152). Certainly the problems of hydrocarbon scarcity and climate change have imposed the need to make a transition to renewable energies in the treaties postulated by the countries.

In order to build a new energy system that limits the worst consequences of climate change, however it has been slowed down by a lack of political capital due partially to the blockade of the United States of America, Saudi Arabia, Russia and Kuwait; which do not agree that if the Earth's temperature increases more than 1.5°C there may be an irreversible impact on the world (Lara, 2019, p.4).

Thus, finding a dilemma between changing the comfort of the current life or improve the quality of existence of not only living beings, but all those who interact with him. Proposing this way technological innovations that allow to diminish the environmental impact but that have a disadvantage, the high cost of investment and the years of recovery.

Generating an alarming panorama, since the curve of the Earth's temperature (figure 1) from the era of the industrial revolution (1760-1840) to the present tends to continue increasing, since, as the Jevons paradox expresses, the more efficient the equipment, the more use it will have, since steam engines not only allowed work to be done in less time and at a lower cost, but also allowed a greater number of products to be obtained which would cause another extra energy consumption, which is still contemplated in the current conditions of life, and which translates into generating a large percentage of pollutants and which, together with the accumulated damage caused by greenhouse gases, makes this problem more aggravating.

Note that the curves have a dispersion between 1920 and 1980 where the history of humanity suffered different geopolitical changes and was centralized in war activities, which again emphasizes the importance of humanity in this phenomenon and how only by exceptional situations and far from this area have caused the ecological footprint to be minimized.



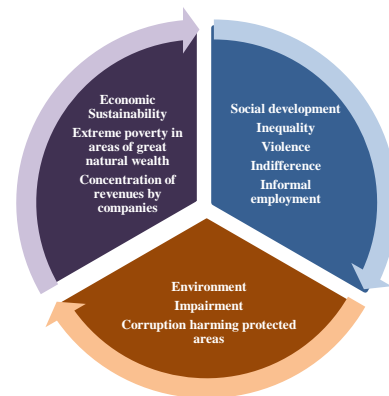
**Figure 1** Increase in the Earth's average temperature from 1850 to 2025

Source. Adapted from World Meteorological Organization [WMO] (2019)

In subsequent years the most relevant organizations in the study of the problem of global warming (NASA's GISTEMP, the JRA-55 project of Japan, the National Oceanic and Atmospheric Administration NOAA of the United States, the Copernicus ERA5 program of the European Commission and the monthly HadCrut data of the University of East Anglia in conjunction with the Hadley Centre of the United Kingdom); have shown that the changes on the planet are almost the same, with no great influence of the method and areas of study, so that by 2025 it can be predicted that the temperature will continue to increase by up to  $1.6^{\circ}$  compared to the period 1900-1925.

While it is known that the search for a transition from the current forms of energy generation to clean sources is necessary, there are many personal, economic, and social factors that do not allow it. Mexico has been characterized as an oil country, a pillar in its economy, however, the prospect of a shortage and changing prices have been shaping the need to restructure this sector. This does not mean that it can be done from one day to the next, since the necessary technologies to carry out this transformation are not usually produced in the country, besides, they do not currently guarantee energy security. For which and postulating the Mexican population as the main actor of the actions that allow decreasing the ecological impact, National Programs such as Green Mortgage, Sustainable Integrated Urban Developments (DUIS), and programs of international character that were adopted in Mexico, coordinated by Mexican institutions, which function as lines of financing to develop and acquire housing that use technology focused on saving and use of natural resources (Vallejo, 2016, p.102) were proposed.

The drawback is that, in the case of Mexico, there is no proven model or methodology to develop environmental infrastructure (Hernández, Hernández y Alcaraz, 2019, p.51).



**Figure 2** Problem of the most relevant aspects for Sustainable Development in Mexico

Source. Adapted from Hernández, Haro, Medina, Gutiérrez y Espinosa (2018)

Due to the unresolved needs of the GHG problem and the lack of programs proposed for its solution, activities oriented to satisfy the electricity requirements in Mexico were structured in a holistic way; having as first instance an administrative and logistic stage; for its later transportation, commercialization, and operation; however, this does not include the new energy efficiency models.

In conception to the previous disjunctive, the energy sector of the country should be directed towards a sustainable development approach, where the relationship between economic, social, and environmental systems is studied (figure 2); which in turn serve as the most relevant factors when thinking about raising awareness of the population in the efficient use of resources. Taking care that when trying to modify the current conditions, it is not deprotecting another sector or just producing a rebound effect, where the conflict is transferred to another area or another time.

This makes it essential to understand that it is not only the fact of the acceptance of the use of clean energy in the market; but to understand what this change will bring about, since modifying a system does not always mean that only benefits will be obtained. For the sector under study, one of the consequences will be that the separation of activities may cause underinvestment problems.

A producer who must make large investments in very specific assets, which cannot be easily reconverted for use in other activities, runs the risk that, once they have been made, consumers will not be willing to pay a price that allows the expected profitability to be obtained. At the same time, self-consumption does not include any taxes, these being those currently borne by essential areas of each country's economy (Molina, 2017, p.75; Alba, Aragones, Barquín y Moreda, 2017, p.41) Forcing to think about the preservation of security in sectors interrelated to energy, i.e. sustainable development must be sought to meet the requirements of electricity generation without unprotecting other needs, which makes foresee the integral and heuristic contemplation of the principles that underpin this position; which show that for a proposal to be valid from an ecological perspective, it is essential to visualize an equitable use of resources ratifying that the next generation have the same possibility to make use of these; where in an individual and participative way each individual has to ensure this fact and whoever does not comply must be responsible for the damage caused to the environment.

The conceptualization of sustainable development evokes different approaches that have been modified over time due to the evolution of the problem; falling into two perspectives one that tries to understand the three most important systems (economic, environmental, and social) in relation to the ecological footprint of human activities and a regulatory framework to solve the problems in a holistic manner where ethics and equity in the use of natural resources are preserved.

Requiring that actions are taken from a principle of responsibility, which avoids making the same mistakes by contemplating only the temporary benefits of human activities. Working with the cultural conditions of a society makes that connaturally it is studied from an ideological background; having to understand their actions and what is required to be modified. What makes us think about the principle of responsibility of Jonas (table 1) for the change that is being sought in the energy sector (which can be described by the will of sense of life of Frankl).

That even when it shows that both are directed to the search for decent living conditions, the first seeks to overcome hedonism and utilitarianism to adopt a style of consumption more moderate, ethical and moral, without falling into the radical ecological anthropocentrism, since the needs of the other sectors must be reviewed. For his part Frankl, recalls the current conditions with which the processes are managed and the irresponsible narcissism of the waste of resources without contemplating their present and future fellows.

Jonas Principle of Responsibility	Frankl's Meaning of Life
The imperative for the permanence of humanity is justified in dignified conditions.	Meaning of life: life is potentially meaningful, striving for a life worth "living".
Freedom is guaranteed by uncertainty, it moves away from totalitarianism and the dictatorship of the market.	It advocates freedom of will that allows you to overcome various conditioning. It is irresponsible choices to imitate what others do.
The responsibility of human life on Earth, without falling into contemplative environmentalism and radical anthropocentrism.	Will of meaning; capacity to be responsible, recognition of the other, sacrifices, seeking the good for the other.
Hedonism and utilitarianism must be overcome, a moderate lifestyle must be adopted.	The will to pleasure and power is insufficient; it leads to hedonistic narcissism and ignorance of the "other", whose actions have no present and future consequences.

**Table 1** Convergence factors between the Principle of Responsibility and the Will to Meaning

Source. Adapted from Diaz (2017)

### 3. Territorial delimitation in conception of the relevance of education and economy

Usually, education is a sector that relegates the study of climate change, since in the first instance it is not seen as a natural relationship. However, as the problem of climate change is an old one, the new generations have become more aware of this issue, and it is visible both in their daily context and in the literature, they study from lower to higher grades. Therefore, it is a segment of the population that should continue to be directed to have a reflective thinking and act against the ecological footprint caused by human activities.

In Mexico for the year 2015, the country reported an educational level higher than 9.1 grades of schooling on average, which means a little more than high school completed (Instituto Nacional de Estadística y Geografía [INEGI], 2015). For 2019 the enrollment data increased reaching a demand of 36,635,816 students where 69.6% is in basic education, 14.3% at higher secondary level and 10.8% at the higher level (Dirección General de planeación, Programación y Estadística Educativa [DGPPyEE], 2019), having the lowest number of young people in the southeast region, while in Baja California Sur, Sinaloa, Nuevo León, San Luis Potosí, Yucatán, and the central zone has a population (in the educational age) of about 97% in school (PrepaUP, 2020).

For its part contemplating the national economic level for the year 2014 the United Nations Children's Fund (UNICEF) (2014), postulated that 1 in 2 children and adolescents in Mexico live in poverty; of these, 20% are in extreme poverty, such data comes from the study of poverty measurement that considers how many people live with lower incomes to ensure their welfare and that their social rights are not respected. More recently the National Council for the Evaluation of Social Development Policy (CONEVAL) in 2019 shows how last year the percentage of poverty decreased, the downside is that the number of people has increased considerably, as 48.8% of the population have incomes below the poverty line and 16.8% are in extreme poverty, which translates into 61.1 million and 21 million people, respectively. While it is true that the southeast region of the country suffers the most backwardness, the entity with the largest number of individuals in poverty is the State of Mexico, with 7.5 million in this condition and the fifth with extreme poverty with 865,748 inhabitants (Lopez, 2019).

One might think that due to the above the choice of study would move away from the State of Mexico because of its economic lack, but from an integral approach makes it an area with great potential to carry out a pragmatic change in the efficient use of energy, since its educational level is one of the highest in the country and lacking resources a reduction in electricity consumption will mean an economic saving in the home which is one of the objectives set by the proposal in this research.

A motivator. At the same time the infrastructure of the RTN ensures that the service will be available to most of its population. Now, if we start from the perspective of shared ecological responsibility, the neighboring states will potentiate the State of Mexico; since by maintaining similar or superior conditions and a continuous interrelation, they can, in a particular and joint way, look for alternatives to increase the benefits obtained. Therefore, there will be local and network publicity, which will be an incentive to increase the participation of the proposed system; gradually implementing actions that go from the simple to the complex to achieve long-term objectives; in favor of a more harmonious life with the environment.

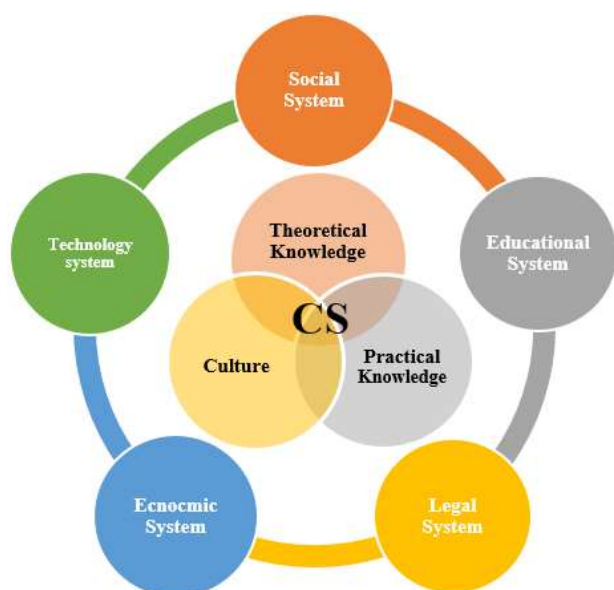
Due to the facts mentioned above and the factors that influence the problem under study, the area proposed for the present work is the Metropolitan Zone of the Valley of Mexico (figure 3).



**Figure 3** Territorial delimitation of the Metropolitan Zone of the Valley of Mexico  
Source. Prepared by the authors

#### 4. Approach to the problem under study

To prevent proposals for an unresolved need of the system under study from bringing more disadvantages than solutions in the long term, it is necessary to establish limits and approaches with which it will be necessary to contemplate it to avoid subjectivity in its approach as much as possible.



**Figure 4** Systemic theoretical framework  
Source. Prepared by the authors

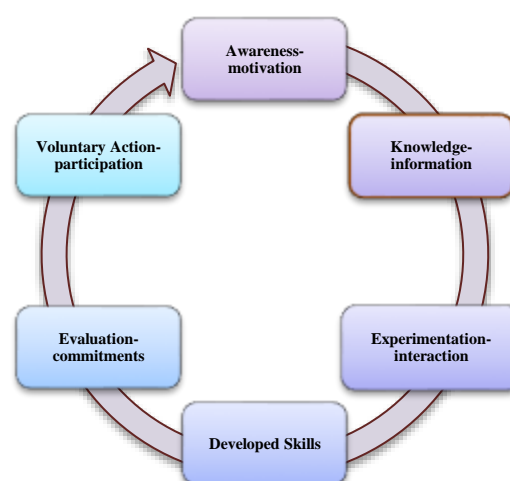
Therefore, the research was structured based on the systems (figure 4) that are related to the problem and the approach of the Transdisciplinary Cyber-Systemic (CST), allowing the integration of thought, action, and tools for the development of a systemic theoretical framework, which in turn served to diagnose the most appropriate methodology to address the situation and to improve the current situation.

### Social system

As is well known, the abnormal increase in the average temperature of the planet is due to the concentration of greenhouse gases in the atmosphere, which are produced by anthropogenic action (Intergovernmental Panel on Climate Change, 2008), which causes a negative impact on the lives of people, ecosystems, and the economy. In recent years, this has resulted in the detonation of diseases that threaten human beings because of their own actions, as it is recorded that man has modified approximately 80% of the earth's surface (Santana, 2020). Within this perspective it is undoubtedly the fact that today's society is more directed towards an anthropocentric interaction through a hedonistic consumption of resources for their own welfare and only a small amount is aware that this excessive spending generates not only individual impacts, but there is an interwoven relationship in subsystems and systems that interact with society, and which are the main actors for a possible solution in the medium and long term.

Demanding the generation of a society that is more aware of its actions and the impact they will have on its environment. This change is not immediate, since it requires contemplating both intrinsic and extrinsic factors of the person, for which phases are proposed through which the individual must pass to achieve this environmental awareness and that also lasts over time. Figure 5 shows a cyclical model that starts from the affective dimension with the sensitization and motivation of the individual so that he/she is interested in continuing with the following stages, then the cognitive dimension that will give him/her the necessary tools to formulate his/her own beliefs and solutions to the problem;

This will be joined to the active dimension by experiencing and interacting first hand with this problem; in this way a reflective feedback of the capacities that have been obtained throughout the process is obtained and that at the end a disposition is formed to want to participate in these activities and contribute improvements to the situation under study (conative dimension).



**Figure 5** Phases of Environmental Awareness through which a person passes  
Source. Adapted from Laso, Ruiz y Marbán (2019)

### Educational system

Education serves as an instrument of social transformation, which is a viable way to generate favorable changes in the face of environmental conflicts, not only creating awareness, but also facilitating the training space for people intrinsically aware of environmental damage and the possibilities of solving problems in this regard (Fuentealba y Soto, 2016, p. 449).

It is an indispensable task, aimed at both young generations and adults, to widen the bases of a well-informed public opinion and of an individual and collective conduct inspired by the sense of their responsibility regarding the protection and improvement of the environment in all its human dimension (Román y Cuesta, 2016, p.26).



**Figure 6** Components of Environmental Education  
Source. Adapted from U.S. Environmental Protection Agency [EPA] (2019)

This connotes that environmental education has a higher level of complexity than environmental knowledge, since this teaching-learning process is based on a constructivist vision aimed at the integration of five fundamental components (figure 6) among them present knowledge and understanding; together with awareness and sensitization, and attributes that characterize the human (habits, attitudes and participation) with the objective that the individual learns to learn, learns to be, learns to do and learns to live together.

Therefore, a total change is needed in the perspective of the different systems that aim to find solutions to the problem of climate change, given that, as has been repeatedly mentioned, the human being, individually and socially, is the key to changing the alarming scenarios of global warming, since it must be remembered that he himself is the generator of this ecological footprint. Being imminent the incorporation of the population to the plans and governmental programs to generate individuals with better knowledge on the subject and that can participate proactively.

### Legal system

Mexico is in an exceptionally privileged country in biological terms, where destructive environmental public policies are applied, which have serious repercussions on the health of Mexicans and the environment, this reality is caused by the weak national legislation, exemplified by (Santana, 2020):

- The alarming reduction of the environmental budget. Such as the 75% cut in the operating expenses of the Natural Protected Areas Commission (CONANP), which makes it impossible for the government to fulfill its function of protecting nature, controlling pollution, and operating sustainable rural development projects.
- The Federal Government's refusal to update Mexico's Climate Change Strategy and Regulations, and the withdrawal of support, incentives, and budget to achieve the transition to renewable energy production.
- Lack of a long-term vision to meet the needs of present and future generations by implementing projects that may undermine the protection of forests and ecosystems.

This demonstrates the need for a more proactive society in the face of environmental problems, since even when their representatives do not support the application of programs and plans that on paper are ideal, the same population can force a change in the way they are directed, since they are the final actors of these projections.

### Economic system

The ecological economy considered as the science of sustainability management, is born by the importance of making organizations aware of the impact on the environment, nature and climate effects, which would generate higher costs in the way of marketing (Delgado y Mariela, 2017, p.15-18), thus promoting and seeking the transformation of production, distribution and consumption systems, considering the finiteness of the resources that are exploited and the urgency of turning around the economy-environment relationship (Cuadra, Véliz, Sandoval y Castro, 2017).



Due to the approach that was given to the economic ecology was classified in the circular or cyclical models where the process continues to maintain the trend that the company acquires and transforms the primary materials to provide a service or good and that is directed towards the final consumer, however, intermediate stages were included as the incorporation of recycling and the power to use the waste by another energy market in the company of renewable sources admits that the same organization that produced the market chain acquires this product.

This alternative ensures the minimization of the environmental impact of the activities carried out by human beings to obtain a monetary remuneration without having a considerable impact on the systems that are related to it, since it is based on the characteristics and conditions of this ecological approach, based on limits set by nature and therefore give a different value to the service or product in terms of the environmental impact it will generate, with the aim of maintaining a closed cycle so that waste is minimal and there is a constant investment in cleaner technologies, all in order to search for a low-carbon business.

That once again it is remarked that to opt for this option, the education and environmental awareness of the individual must be promoted, since he will be responsible for carrying out this task that completely changes the monetary meaning given to goods and services, since he will consider how much it will affect the environment and consequently the future conditions of the market.

### **Technological system**

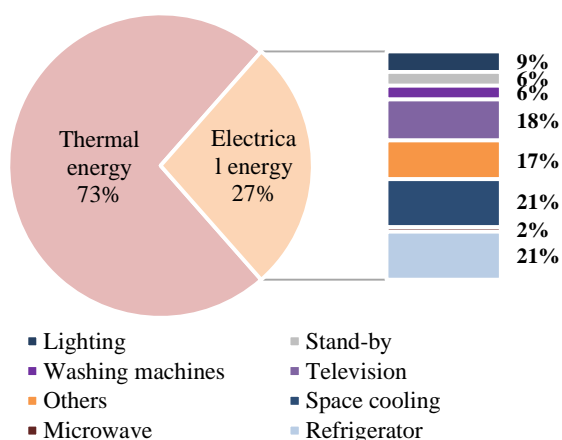
It is necessary to be clear with the point of why this investigation did not consider the benefits that renewable energies bring with them, since that is an undoubted fact if it is contrasted with the decrease in the environmental impact that it will generate if it is compared with the one caused by fossil fuels. However, it is not yet aimed at a market such as the national one, because it requires a considerable investment that, despite the fact that political proposals give support for its incorporation, this is still unfeasible for most of the population, requiring a social system of a defined size so that this cost can be cushioned;

Besides demanding that society itself has technical knowledge and basic planning for its self-management; which requires first of all a change in how citizens conceive the environmental issue so that they can be aware of the need to generate a more balanced lifestyle with their environment and impose a different value to goods and services in relation to the ecological footprint that will cause.

For this reason, it was decided to consider only that technology that most of society can acquire and/or manage at home, because it is a key sector for the reduction of GHG caused by human activity itself.

Within this approach has the advantage that homes are currently more energy efficient and coupled with the pandemic by Covid, now many people work in their homes, making the perfect time to monitor every action, every gesture, that can make a difference, a before and after (Yáñez, 2020a). Remembering that energy efficiency does not seek to reduce or stop performing certain activities to avoid energy consumption (Lizárraga, 2020), but seeks to optimize the use of energy resources without diminishing in any case the quality of life of whoever adopts measures of good energy use (Emol, 2017). In a timely manner this progress is complicated to analyze since it is an intangible consumption that represents the absence of energy consumption and that can only be estimated (SEGOB, 2020a), so it is essential to visualize all the agents that influence this activity and that allow giving feedback to modify or restructure the proposed actions, such as, for example, the decrease in the receipt of the service.

A clear example of this is that even when most of the current technological products have a better energy efficiency they still have consumption that can be minimized or avoided, for example, when analyzing graphic 1 it is noted that the expenditure generated by equipment on stand-by is a value of 6% which can be reduced by simply informing the population about what generates it and how to solve it, this being the easiest way, since it is enough to turn off and / or disconnect the devices; This may seem an insignificant contribution on an individual basis but it becomes relevant when considering society in general.



**Graphic 1** Mexico's National Energy Efficiency Monitoring Report 2018  
 Source: Adapted from SEGOB (2020a)

Undeniably the mere existence of human beings demands energy consumption, and as a result of their current lifestyle there are actions that cannot be minimized or eradicated, so we must take advantage of all available openings with which to support the reduction of the effects caused by global warming, actions that individually will be banal if combined with a larger number of individuals will make it closer to achieving a future benefit for humans and everything around him.

### 5. Methodology

Consequently, from the above diagnosis regarding the main components to generate a conscious energy consumption by the population arises the need to contemplate a methodology that is appropriate to the research in correspondence to the integration of the most relevant factors of the problem.

Therefore, for this purpose it is decided to use the Cyber-Systemic Action-Planning Process (PAP method) with reflective feedback, to diagnose the structure of the methodologies, to observe if they comply with the condition of linking or cybernetically feeding back the ontological and epistemological knowledge. Since linking theory and practice requires a participatory and iterative circular interaction that serves to obtain continuous learning by comparing the models of the systems with the concrete results under the dynamic conditions of the real world (Peón, 2015).

In conception of the above, the sections of the comparative table of methodologies (table 2) were filled in according to the steps and/or sub- steps that are related to the objectives of the PAP method, which are listed below: defining the boundaries of the system (D1), specifying the problem (D2), proposing the theoretical solution of the problem (D3), documenting the decisions of the planning process (A1), implementing the planned theoretical model (A2) and, operating the constructed system during its life cycle and improvement (A3); alluding to planning (D1,D2 and D3) and action (A1,A2 and A3) stages, respectively.

		Pap Method (D3-A3)				
Methodology		Jenkins	Checkland	Hall	MIO	Transdisciplinary
Planning	D1	1.2, 1.3, 1.4, 1.8	2,3	1,2	P1, P2, P4, P5	1.4, 2.1, 2.2, 3.2
	D2	1.1	1	4	P3, P6	1.1, 1.3, 3.1, 4.1
	D3	1.5, 1.6, 1.7, 2	4, 6	3,5	Phase 2	1.2, 1.5, 2.3, 2.4, 2.5, 2.6, 3.3, 3.4
Action	A1	3.1	5	6	S1, S2, S3	1.6, 3.5
	A2	3.2	7		S4, S5, S6, S7, S8 Phase IV y V	4.2
	A3	4			Phase VI	3.6,4.3,4.4,4.5,4.6

**Table 2** Comparative table of methodologies using the PAP method  
 Source. Prepared by the authors

The cybernetic method of Participative Action- Planning D3-A3, hides a potential masked by its graphic simplicity, since it allows the analysis of the methodologies from a systemic vision admitting diagnosing which of them can be adjusted in a better way to the project.

### Construction of the methodology

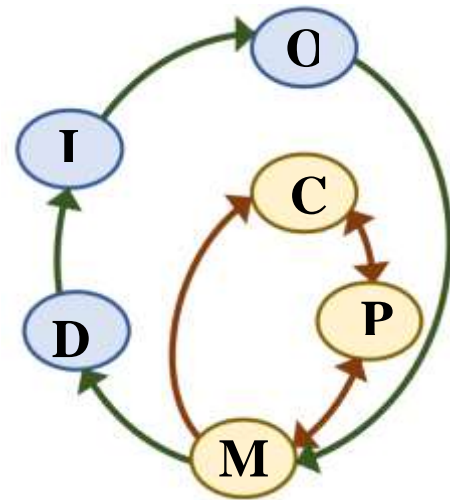
The advantage of carrying out the previous activity is that it makes it possible to create a flexible and dynamic methodology that allows the researcher to correlate his or her needs and interests in the study and modify it according to the scenarios that arise. The organization of the steps and sub-steps that are suggested to be followed in the face of the problem are shown below in a global manner.

## Methodology adaptive to the context

1. Context and state of the art (Cx)
  - C1) Definition and justification of the project. C2) Context and state of the art research.
  - C3) Bibliographic research of practical and/or theoretical solutions.
  - C4) Compilation of the most relevant factors of the system.
2. Problem (P)
  - P1) Define unmet needs.
  - P2) Problem formulation.
  - P3) Comprehensive hierarchical diagnosis of the situation of the relevant problems.
3. Modeling (M)
  - M1) System objectives.
  - M2) Definition of feasible desirable changes. M3) Document the rejected alternatives.
  - M4) Construction of the model.
  - M5) List the functions of the model.
  - M6) Compare the model theoretically with the objectives.
4. Documentation (D)
  - D1) Elaboration of the plan.
  - D2) Program development.
5. Implementation (I)
  - I1) Action to solve the problem or improve the situation.
  - I2) Diagnose the alternatives that can be adjusted from the implementation process.
6. Operation and Improvement (O)
  - O1) Evaluate and diagnose the impact of the proposal.
  - O2) Retrospective appreciation
  - O3) Improved operation
  - O4) Development of a growth and upgrading program.

Figure 7 shows the recommended relationships between the different stages of the methodology created. Starting with the justification, the delimitation of the boundary and the collection of information (context and state of the art) that will cement a deep knowledge of the system and its most relevant factors. Based on this, we proceed to the definition of the problem and the unresolved needs, to diagnose systemically and integrally the most relevant situations in conflict and prioritize them according to their importance (Problematic).

These two steps maintain constant feedback since the previous research will establish the limits and scope of the problem situation, but if this second stage finds factors that were not initially contemplated, it will require a new evaluation of the information obtained. This is essential since we have a dynamic system where its different actors maintain a broad relationship with their context.



**Figure 7** Context-adaptive methodology  
Source. Prepared by the authors

When the previous condition is fulfilled, the actions to be taken are specified, for this purpose the objectives pursued by the system are outlined and the facts, alternatives and criteria that validate the satisfaction of what is proposed are established (modelling). Having a premature stage of documentation that establishes the rejected alternatives but that by its nature allows to think about its later implementation and a phase of continuous appreciation that allows not to lose sight of what is pursued theoretically; and that in turn shows if there is missing information or factors that have a considerable impact on the system. Because of this, this step maintains constant communication with the first and second step to update these aspects.

On the other hand, the steps corresponding to the action stage maintain a linear sequence to avoid the vices that are usually stigmatized to the systemic, since usually he wants to cover everything and does not proceed to carry it out in a practical way. Certainly, the sub-steps corresponding to this phase are designed to provide feedback on everything that was planned.

To do this, first the stipulated agreements that support the implementation of actions that improve the current situation are documented and alternatives that facilitate this process in future applications are foreseen. The final step is the operation and improvement of the system, which corresponds to the prospective of the system and the evaluation of the fulfillment of what was planned.

This last step is linked to the third one (modeling) so that it allows to evaluate if the model covers the objectives and the unresolved needs raised; or if what is not being fulfilled was discarded in the first instance or was not contemplated and the current proposal must be restructured.

### **Application**

As it can be noticed, the purpose of this research is to seek environmental awareness in the population, starting with the educational sector since they are in a process of integral development and have tools and knowledge that help them to correlate their actions and their impact on their environment in a more plausible way. In addition, it must be remembered that the problem is not temporary, so it is required that the new generations begin to be more sensitive about the issue if it is really required to reduce the expected situation.

Thus, in the search for the transition to a more environmentalist population, the need to make society aware of its impact on its environment becomes evident, in order to think about a real modification of the current energy sector in the country; which demands that the following changes be considered: gradual replacement of inefficient products, new consumption habits, education, information and advertising that influence the decision to purchase appliances and their use, transmission of information among a population more and better informed about environmental issues, and lasting lifestyles in search of sustainability.

The proposed change is not immediate, since it requires contemplating both intrinsic and extrinsic factors of the person, for which phases are proposed through which the individual must pass to achieve this environmental awareness and that also lasts over time.

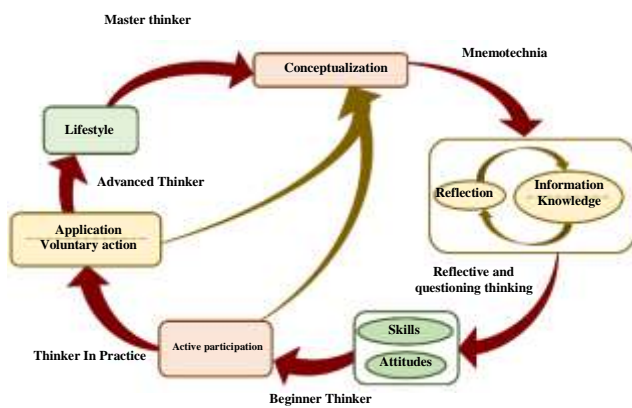
Starting from the affective dimension with the sensitization and motivation of the individual so that he/she has an interest in continuing with the following stages; subsequently the cognitive dimension is approached which gives him/her the necessary tools to formulate his/her own beliefs and solutions to the problem, in this way a reflective feedback of the capacities that have been obtained throughout the process is obtained and that at the end a disposition is formed for wanting to participate in these activities and to contribute improvements to the situation under study (conative dimension).

For the above, it is proposed to approach the problem under study from a model based on the phases of environmental awareness that a person goes through (awareness-motivation, knowledge-information, experimentation, interaction, developed capacities, valuation-commitment, voluntary action-participation), the components of environmental education (awareness and sensitization, knowledge and understanding, attitudes, skills, and participation), the ERCA model (Experience, Reflection, Conceptualization, and Application), and the six levels to be able to form the necessary skills to build critical thinking (reflective thinking, reflection, conceptualization, and application), knowledge and understanding, attitudes, skills, and participation).

Originating the model for environmental awareness based on contextualization (figure 8) which consists of 6 moments:

- Conceptualization
- Reflection - information / knowledge
- Skills-attitudes
- Active participation
- Applications-voluntary action
- Lifestyle.

Maintaining a circular base structure but including different stages of feedback focused on a heuristic process.



**Figure 8** Model for environmental awareness based on contextualization

Source. Prepared by the authors

The model is based on the conceptualization that considers the need for the basic foundations required for the student to have tools with which to contrast the knowledge acquired and their experiences, to reach a higher cognitive level. Although mnemonics are often stigmatized in the teaching process, memorizing also serves to think, to make decisions and thus to solve problems. This means that it is a systemic triad that leads to understanding the need to study not only isolated parts and processes, but also to solve problems (Equihua, 2017).

Therefore, an educational action oriented to transmit contents with the support of this technique must take into account: the pedagogical action has to respond with successful alternatives that facilitate the approach to the complicated reality, propose didactic alternatives to obtain knowledge, turn the classroom into a center of discussion and debate, and overcome the schemes that reproduce information by initiatives that stimulate creativity, criticality and innovation (Santiago, 2005, p.58). But only having tools and concepts is not enough since this only supposes the repetition on the part of the student, so it requires now to integrate it for the acquisition of information and to find the interrelation between the different types of knowledge that he has; always with the intention of maintaining a reflective vision. Subsequently, skills and attitudes must be founded so that the young person can present his conjectures and debate them, always supporting them logically and with values that maintain an environment in accordance with this process.

This can be seen as a stage where theoretical knowledge is developed and all the bases for making quality decisions that are pertinent to the present need. This leads to the proposition of questions where the young person continues to be guided to correlate their knowledge, but now in relation to practical aspects, leaving their passive role and taking an active one.

Evidently, to totally dominate an area of knowledge is impossible because day by day more information continues to emerge that is added to the great accumulation that we already have, so in the action stage there is a bifurcation in each of the subsequent moments; well, to improve in a subject it requires practice as every skill that the human being learns. In this way first it is understood that the level reached is that of a beginner thinker where he begins to shape his understanding of the problem in an environment controlled by a third party, for its subsequent application, but from a specific problem that the same thinker has shaped and voluntarily wishes to solve or improve the current scenario. At the end of this long and complex process

it is expected that the actor manages a high level of awareness and understands how their actions will have a negative or positive effect on the environment and take a stance on it; it is their lifestyle. As mentioned at the beginning, no matter how many years of study there will always be something new to learn, which will allow the process to be holistic and heuristic to the present needs and that will result in the need to take on the role of student, but now with a set of new knowledge and tools to address this scenario.

## 6. Implementation of the project "My impact on the environment"

In conception of what was shown, it was decided to implement a pilot test in the Escuela Nacional Colegio de Ciencias y Humanidades (ENCCCH) Plante Vallejo; located in Av. 100 Metros corner Fortuna, Magdalena de las Salinas, Gustavo A. Madero, Mexico City. Which complies with its student population is between the territorial delimitation.

In addition, it seeks to potentiate the essence of its educational model which is based on four main axes: basic culture, academic organization by areas, the student as the subject of culture and main actor in their training, and the teacher as a guide in learning (Gaceta CCH, 2001), where innately by its constructivist approach aims to train the student integrally generating a critical thinking based on ethical and contextualized values (CCH, 1996).

This test was applied to a non-probabilistic sample with a total population of 240 students, corresponding to six fourth semester groups enrolled in Physics. Initially, in the period 2021- 1, the teaching process was implemented in the traditional way, from the perspective of the study program, except for the laboratory practices due to the SARS-CoV-2 pandemic. In the first instance so that the students could adapt to the new normality and to a subject that requires the incorporation of a more technical language for the understanding of the topics.

Therefore, addressing these issues from a traditional approach apart from generating the necessary tools to achieve the objectives proposed by the project will also serve to reflect on what impact it will have on the performance and learning achieved by students when implementing the proposed model.

At the end of the semester, with the most relevant factors in mind, the construction of the methodology and method, we began the creation of different digital environments aimed at informing and generating debates on topics of the mathematical physics area and its contextual application. These technological spaces were chosen because they were easy to access, free of charge and required few technological and network resources.

Thus, on February 15, 2021, access to the YouTube channel titled Fisccch was opened, aimed at addressing step by step the topics of the CCH Physics II program from a practical perspective based on previous learning and experiences. Simultaneously, to maintain communication and generate a repository of printed materials, different teams were created in Teams to maintain a more personal relationship and a continuous discussion of the elements reviewed in the course.

For the development of the necessary materials to meet the proposed objectives in search of environmental awareness, a form was made on the Microsoft Forms platform due to its compatibility with Teams, which allows only the desired student population to answer it. This previous activity has the purpose of visualizing the level of understanding that young people have of environmental problems and the importance of what they learned in Physics. It should be clarified that the questions proposed in this activity follow the essence of the project, that from a friendly language young people can define and explain the physical phenomena and ecological needs.

This form was applied to students who had already completed a semester of the subject from the approach proposed by the study program with adaptations to online teaching, the most relevant results obtained are the following:

- 40% of students do not consider that the subject of physics has any impact on their life.
- 52% mentioned that they do not know how to interpret an electricity bill and 60% indicated that they do not know the factors that are considered to charge them for this service.
- 26% do not recognize energy-saving equipment, a percentage that is repeated with the implementation of incandescent lamps in their homes.
- 82% mention that they try to save electricity, but 77% don't know what phantom consumption is.
- 72% know how electricity is generated, indicating 66% that this activity pollutes the environment, while only 3% do not believe it does, and the remaining 3% mention that they cannot decide on any of the answers.
- 55% know what renewable energies are, 42% indicate that they have heard of them, but do not know what they are and 3% have never heard of them.
- 45% consider that Mexico does implement renewable energies in its matrix, but only 26% believe that the country does support this type of projects.

- 98% and 96% indicate that they know or have heard of global warming and the greenhouse effect, respectively. But 32% do not know how to differentiate between these terms.
- 63% know someone who is interested in environmental issues, showing that for 70% it is essential to understand this type of problem, 15% believe that it is relevant but only from time to time and the rest mention that they are interested when they see, read, or hear about it in the media.
- 76% have seen the causes of the greenhouse effect in school mainly in biology and chemistry subjects. 21% have done it on their own and 3% mentioned that they had never heard of it.

This brought about the verification of the initial premise of the project; the current generations are more aware of the existence of environmental problems and are more sensitive to them because they were born when they were already present and have experienced them firsthand. However, most of the population are in the basic levels since they are still unable to explain it in a clear way, they confuse the concepts, they do not find the relationships between factors, they try to take care of their consumption, but they do not know how to do it in a correct way.

Reflecting that their intentions are good, but they lack tools and actions that support them in their perspective of the world. In this way it was noted that a foundation of concepts that allow young people to understand the phenomena present in their daily lives is required, as they showed that they had that practical experience but could not consciously capture it. Based on the above, we proceeded to create the necessary material to be able to approach the course from a contextualized vision. Zoom was used to record the videos by means of the electronic whiteboard (figure 9) and their subsequent processing and editing using the VEGAS Pro software.



**Figure 9** Creation of materials  
Source. Prepared by the authors

Thus, generating more than 40 videos with durations ranging from 30 to 80 min, hosted on the YouTube channel mentioned above (figure 10) and that to date totals more than 8000 views from both the study population and the general population, since at the request of the students their privacy was changed to public so that they could share it with their friends and acquaintances.



**Figure 10** Replenishment of the videos on the Fiscch YouTube channel  
Source. Prepared by the authors

In addition to the above, the students were invited to an extra course-workshop called "My impact on the environment", to study climate change in greater detail, its elements, correlations, effects, alternatives to improve the situation and what their role is in the face of this problem. The meetings began on March 4th and were held eight to fifteen days apart so that the young people did not have any setbacks with their academic activities.

We counted with the participation of 102 students who were encouraged to participate in scientific and outreach events that the National Autonomous University of Mexico (UNAM) opens each year; also, through a discussion group created on the Facebook page with the same name as the YouTube channel students proposed their conjectures to the concerns, they had about the issues seen and needs they noticed in their environment.

During this period, they were invited to create two materials as a team to publish in this social network and open it to the general public to share what they learned during this period; Therefore, on June 1, 2021, the population is given access to the activities developed by the students, where they explain in short videos global warming and its consequences from their perspective, and through infographics propose simple solutions that do not greatly affect the lifestyle of the person but that allow to improve the current situation of the environment; to turn it into an action that lasts for its simplicity.

## 7. Results

The following results were obtained when applying the themes of the Physics syllabus from the perspective of the model proposed in the project:

- Students were more active during class, reflecting and creating questions about everyday phenomena.
- Decreased the failure rate by 20% with respect to semester 2021-1.
- The acceptance form indicated that 94% found the subject of Physics to be interesting or useful in their daily lives.
- 94% of the students can correctly exemplify a practical application in relation to the career they want to study or an aspect they are interested in.
- An online repository of audiovisual materials that exemplifies the subject of Physics in a contextualized way, hosted on the YouTube channel named "Fiscch".
- Students can explain both colloquially and with physics concepts what global warming is, they can differentiate it from the greenhouse effect, but at the same time they understand its relationship and impact.
- Public Facebook group called "Fiscch" aimed at discussion and feedback of acquired knowledge. It currently hosts materials created by students explaining global warming and alternatives to improve it.
- A public diffusion considerably higher than initially expected by raising private environments, counting more than 8000 reproductions on YouTube and close to 1000 reactions on Facebook. Highlighting the fact that by making them public many aspects of the platform's history were reset.
- The continuity and acceptance of more than 100 students for the implementation of the Course-Workshop My Impact on the Environment.
- Incorporation of teachers from the experimental area to the course-workshop.
- Interest on the part of young people in science outreach events promoted by UNAM.
- Assessment of the projects that the young people proposed and registered for the different UNAM events and that mainly addressed environmental problems.
- Participation of students in the 10th meeting of the High School Meteorological Stations Program (PEMBU) and obtaining the first place.
- Participation in the XXIX University Contest Science Fair, obtaining the first, second and third place in different categories with the works entitled: "The temperature and the hot air balloon", "Everything you should know about vampires" and "Proposition of systems to improve environmental coexistence", advised by different teachers belonging to the course-workshop.
- Finalist in the Youth Program towards research in Natural Sciences and Mathematics of the Secretary of Learning Support Services, which made the young people were worthy to present their project "Environmental Coexistence in the CCH" in the 3rd Student Meeting of initiation to research.



- The evaluating jury of the 3rd Student Meeting of Initiation to Research encouraged the young people to present this proposal to the authorities of the CCH Vallejo and the corresponding town hall so that they can jointly seek a greater good and the conscious use of the resources they have.

## 8. Conclusions

On an international level, various literary sources have emerged that from different visions address the unresolved needs that are present in the increase of the planet's temperature and that are intertwined in agreements to rectify the alarming panoramas due to the irreversible modifications of the ecosystems. But they remain as idealistic qualitative alternatives since they have no repercussion and do not play a relevant role in the solution of the problem.

The shared but differentiated responsibility is one of these alternatives to achieve that the human being looks for a better coexistence with the environment, since the one who damages, his environment will have to pay for these actions and support the one who does not do it, nevertheless, it continues being an idea directed to the conscience of each individual and for the hedonistic consumerism it is far from being a valid form to solve this conflict.

Particularly Latin American countries lack plans focused on providing their population with a solid environmental education, since they state in their programs that the most relevant element to combat climate change is the transition of their current power plants to renewable energies. Without foreseeing the negative consequences that this will have on their neighboring sectors; A clear example of this is what happened in Spain that when implementing large-scale solar collection technology did not foresee that this sector is the basis of the main activities of a nation either by creating products and services, or by charging for their use, which consider a tax charge that people to self-supply not pay and that caused havoc in different areas, bringing with it that the government had to take out a proposal to cushion this loss, around the world was known as "sun tax".

Which without background seems an idea that leads to authoritarianism and imposition of an owner to natural resources; But it is nothing more than an unforeseen consequence of a solution that imposes a rebound effect in the short term.

Unfortunately, sustainable development in Mexico is a distant prospect, since it is not a global priority, first, the ideas of its leaders must be consolidated and cemented, and the benefits they seek must be eradicated, since even when the population has good intentions, there is a lack of knowledge of this nature. Therefore, in order to reduce the risks in this aspect, a dynamic strategy is required since, as it has been shown, it is essential to make the population aware of these issues, which ideally should arise governmental environmental programs that have a continuous monitoring aimed at all sectors in relation to their contextual needs; but since this is not possible, the most appropriate idea is to take advantage of the knowledge acquired by the students of the country; since they already have the bases, they only need to be guided so that they have the tools to take action to mitigate this problem and transmit their perspective to their third parties. As it can be noticed, this option does not require a drastic modification in the current style of the educational sector since it would be a way for young people to develop their learning integrally by relating theory, practice, and culture; of course, requesting for it to train teachers.

In conception to the above it was required to identify and diagnose the main factors and systems in relation to the energy sector from systemic methods, which admit determining a long-term solution of the connatural problems that climate change brings with it. Thus, avoiding the dilemma between economic, social, and environmental processes that impact their environment due to human activities. Thus, allowing the design of a methodology for the improvement of household energy consumption in consideration of the ecological footprint, which was based on the approach of the Transdisciplinary Cyber Systemic, which brings together different types of knowledge; ontological, epistemological, and cultural.

Directing in this way the activities towards the environmental education of the population and mainly to those who are already in this training process; since it was found that the application of efficient technologies is necessary, but not urgent, since as suggested by the paradox of Jevons "more efficiency more use", which will bring a decrease in energy expenditure in a period expected but that will contribute equal or more to the one that currently has. Making imminent the need for a society more aware of its actions in favor of a more friendly relationship with the environment, which by leading to a change of thinking brings with it a complex system in relation to all the elements that establish the way of being of the individual.

Taking into account the above, the model for awareness raising based on contextualization considers a holistic, heuristic and flexible process; so as not to affect the person's current lifestyle to a great extent, but rather that with simple actions he will understand the importance of his actions in the present environmental problems; and also that he obtains a more egocentric benefit and motivates him to continue with these actions until he establishes the necessary skills and attitudes to overcome this individualistic feeling and move on to a more systemic one that leads him to understand his role in the system, to have an active participation and a more eco-environmental way of life.

The implementation of this proposal in the Colegio de Ciencias y Humanidad Plantel Vallejo, brought with it a great reflection since in addition to obtaining good results by implementing it in a particular area of knowledge from contextualized problems, showed that young people already had cemented this thought for wanting to contribute something to their environment although they did not know how or do not carry it in the best way; making it plausible that guiding these activities will generate better results in their comprehensive training and will support a deep foundation of cognitive skills necessary to properly establish critical thinking.

A favorable consequence of the project is that it was achieved that young people willingly enrolled in scientific outreach events to present their understanding of the reality of environmental problems and proposals for their possible minimization. Their conjectures were transmitted and were also well seen by the evaluators and the student population, so that they wanted to continue in this area, to learn more and better about this problem and to continue making proposals in their environment to solve the current needs.

On the other hand, the participating teachers understood the level that the students have of the problems of their environment, what is the acceptance of their subject and what significant knowledge was achieved; but at the same time they learned new aspects because depending on the conditions of each individual they had a different understanding of how to solve the problem and they found from browsers that every time they use them they plant a tree (Ecosia), to video games that through fables try to make young people understand the consequences of their actions on the environment.

As has been alluded to, environmental awareness is complex and its foundation will not be laid from one moment to the next; it will require the acquisition of knowledge and its maturation; Therefore, in order to improve the proposal, it is foreseen that this vision be included in a transdisciplinary way, incorporating experts in different areas who contribute their understanding, for the formation of plans and programs to be applied in the educational field, to be restructured and optimized in the search for the continued growth of the system by means of word-of-mouth publicity of the different actors and the benefits obtained in the short, medium and long term; always foreseeing in the first instance the context to which it will be applied.

Certainly, at some point it will be mandatory the acquisition and implementation of renewable sources and more efficient equipment in each of the nations because the current excessive lifestyle is not possible to maintain it; but it will require a society that understands why this transition was necessary and is measured in its consumption subjecting it to the ecological footprint that will generate in the present and future environment.

Remembering that there is no technology that is one hundred percent friendly to the planet and that the best way to reduce energy consumption is not using it; but not being able to comply with it will require the population to take prudent measures to ensure a future for future generations.

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