Systematization of an Ecoefficiency Model as Applied to a University Campus

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Abstract– ***According to recent regulations, public organizations are encouraged to report current levels of resource consumption including fuels, water, electricity, paper, and others.***

Nevertheless, one of the key barriers for increasing adoption of ecoefficiency and cleaner production programs is the lack of successful studies among local organizations. In the light of the above concern, systematization of best practices and most common retrofits could help accelerate the pace of implementing further concrete actions.

The methodology that was carried out for the present work focuses on ecoefficiency in the public sector, local guidelines for ecoefficiency, most frequent ecoefficiency measures, and systematization for decision-making purposes

There are several ecoefficiency measures that have been frequently recommended for electricity, fuel, water, and office supplies usage optimization.

A model is proposed in order to capture interactions among ecoefficiency strategies, resources optimization, and feasibility for decision-making purposes.

It is concluded that an organization might be interested in implementing a recommended ecoefficiency strategy (best practice, retrofit, innovation) in order to achieve resource optimization (electricity, fuels, water, and office supplies) but feasibility will depend on several considerations (economic benefit, cost implementation, and payback period) for decision-making purposes.

Keywords-- ***Ecoefficiency / Cleaner Production / Environmental Management / Public Institutions.***

I. INTRODUCTION

This work was carried out by the research group named "Energy and Sustainable Development", with the participation of students and professors from the Environmental Engineering Department at the National University of Engineering, located in Lima-Peru, during the year 2020.

A. Introduction

The research group "Energy and Sustainable Development" has previously worked on elaboration of a methodology for implementation of a cleaner production on a university campus (2018), integral application of cleaner production on a university campus (2019), and analytical model of ecoefficiency based on life-cycle analysis (2019).

The Environmental Engineering Department at the National University of Engineering is very interested in contributing to sustainable development. A particular area of potential contribution is related to ecoefficiency and cleaner production promotion for public organizations.

According to recent regulations, public organizations are encouraged to report current levels of supplies consumption including fuels, water, electricity, paper and others.

Nevertheless, one of the key barriers for increasing adoption of ecoefficiency and cleaner production programs is the lack of successful studies among local organizations. In the light of the above concern, systematization of best practices and most common retrofits could help accelerate the pace of implementing further concrete actions.

B. Background

In Ref. [01], there is a need for a transition from unsustainable linear business models to a more sustainable circular approach, called the circular economy. To promote this need, a deeper understanding of which issues hinder organizations' transition to the circular economy and which ones catalyze it is needed. A systematic literature review was performed on the business implementation of the circular economy and 69 articles covering the topic were found. The review identifies different types of catalyst, obstacles and ambivalent factors influencing circular economy implementation in business. This study contributes to research on circular economy implementation at business organizations by providing understanding on the role of these factors in supporting or hindering the change. This study also opens discussion on ambivalent factors that in certain contexts can act as a catalyst to and in others as a hindrance to circular economy. This understanding further enables identification of the origins of these different types of factors, especially concerning their intraorganizational or interorganizational role. The study further identifies gaps to be studied in future research.

In Ref. [02], Cleaner Production (CP) method has fetched improvements to large energy intensive industries, which have the principal, technical knowledge and the organizational capacity for applying new and innovative techniques. Cleaner production enabled organizations to picture the idea of ecological manageability practically speaking and to put stock in the likelihood of creating more with less, other than diminishing natural expenses. Be that as it may, in spite of the fact that cleaner generation has just been acknowledged and is progressively connected, it isn't a standard technique for overseeing ecological perspectives. In this article, a brief review about a cleaner production is presented. As well, the

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various methodologies adopted for CP and quality tools which are used to reduce the resources have been discussed. The barriers encountered by the CP and strategies to overcome these barriers is also discussed.

In Ref. [03], cleaner production is a lively concept in which new procedures and technologies constantly emerge introducing methods and practices to prevent damages to the environment. A broad range of cleaner production initiatives contribute to sustainable development not only through the efficient management of resources and energy, but also through the development of new and smart technologies, new ways of assisting policies development, and organizing supply chains, sectors and individual companies. The authors of this Virtual Special Issue sought to introduce first-hand knowledge and discussions identifying and highlighting the ways cleaner production can contribute to reach the United Nations sustainable development targets. The intent of the Virtual Special Issue is to provide an overview of the recent trends that cleaner production practitioners/researchers are following in the chase of the sustainable development goals, and in this context, this editorial was designed to summarize and underscore the link between cleaner production concepts and practices and the sustainable development goals.

In Ref. [04], as an integrated preventive environmental strategy, the development and diffusion of cleaner production (CP) concepts, tools and implementation have greatly improved the resource utilization efficiency and reduced pollution over the past thirty years. It has been proved that CP has contributed to the decoupling of economic growth and environmental impacts in most developed and industrialized countries. In the face of pressing challenges related to regional and global environmental problems, more and more developing and transition countries have been accelerating the low carbon, green and circular transformation. CP provide strategic and practical instruments for this transition considering the relevant economic, environmental as well as social needs in the short and long terms.

In Ref. [05], the literature on the circular economy at the micro-level has mainly focused on the analysis of the circular business model and implementation of different circular-related practices, but the process of adoption by businesses of the circular economy is still under investigation. In summary, it can be stated that circular economy-related activities are being introduced by businesses progressively, from a minor activity to a greater number of activities, but that these activities do not respond to the incremental closure of material loops within the circular economy framework. The applied indicators enhance the knowledge on the environmental management accounting applied to the CE for the reporting and the relations with stakeholders. In addition, the measurement of the introduction of the circular economy in different businesses is relevant for practitioners and for policy makers, in response to the institutional initiatives for the promotion of the circular economy at the territorial level.

In Ref. [06], the workshop focused on the role of the Advances in Cleaner Production Network to meet the United Nations Sustainable Development Goals. Challenges that emerged from the workshop involved the need for value-added communication and collaboration among members, and further progress in both theoretical and practical cleaner production approaches. Concerning the generation and sharing of new viewpoints, the main issue that emerged was the variety of positive connections that should be strengthened among potential collaborators. Improving and expanding the helpfulness of online sharing platforms and social media, mostly for managing discussion opportunities, was underlined for expanding the partnerships and in improving the networking.

In. Ref. [07], “Cleaner Production” (CP) is about less and more efficient energy and materials use and the substitution of more harmful products (for the environment and health) by less dangerous ones. CP was the reply of the industry to the call for sustainable development as launched by the WCED (1987) and further elaborated in Rio’s Agenda 21 (UN, 1992). During the past 25 years, the concept was put in practice. During this period, it changed in scope, methods, and application area. This provided a deeper socio-economic impact to an idea that was originally launched to awaken industry on its environmental responsibilities. This paper provides a review of essentials that contributed to the fundamental changes in CP during the most recent quarter of a century. It takes off with a review of CP definitions illustrating the changes of the content. Changes in scope are exemplified with the increasing importance of “Corporate Social Responsibility” (CSR). This includes that postmodern companies have not only responsibilities on their economic performance and the environment, but should also act on issues including human rights and resources, business ethics, and community involvement. The links between CP and green and circular economy are indicated. The CP approach is increasingly applied outside the industry. This widening of contents necessitates more and better-adapted methods supporting the measurement of the CP components. Indicators, assessment strategies, and green accounting are increasingly improved and used more specifically and frequently. This evolution is discussed in a context of a dilution of the original environmental targets in a wider, more societal scope and the transition towards a more responsible, proactive and reliable management of the sectors applying CP.

II. Methodology

The methodology that was carried out for the present work focuses on ecoefficiency in the public sector, local guidelines for ecoefficiency, most-frequent ecoefficiency measures, and systematization for decision-making purposes.

A. Ecoefficiency in the Public Sector

Local regulations include aspects related to ecoefficiency diagnostic and to ecoefficiency plans and corresponding follow-up and monitoring.

With regard to regulations associated with ecoefficiency diagnostic, the following applies:

- Supreme Decree 009-2009-MINAM that establishes ecoefficiency measures for the public sector.
- Supreme Decree 011-2010-MINAM that modifies a few articles of Supreme Decree 009-2009-MINAM.
- Internal norms for the public institutions that appear in the process of complying with the forementioned Supreme Decrees.
- Peruvian Technical Standard NTP-ISO 14045:2013 Environmental Management. Evaluation of the ecoefficiency of product system. Fundamentals, requirements, and guidelines.

With regard to ecoefficiency plan and the corresponding follow-up and monitoring, the following applies:

- Supreme Decree 009-2009-MINAM that establishes ecoefficiency measures for the public sector.
- Supreme Decree 011-2010-MINAM that modifies a few articles of Supreme Decree 009-2009-MINAM.
- Ministry Resolution 021-2011-MINAM, that establishes percentages of recycled material in plastics, paper, and cardboard to be used by institutions of the public sector.
- Supreme Decree 004-2011-MINAM, referred to gradual application of percentage of recycled material in plastics, paper, and cardboard that the public sector should utilize and purchase.
- Law 27345. Promotion law for energy efficient use.
- Supreme Decree 053-2007-EM, regulations of the promotion law for energy efficient use.
- Law 29338, Hydrological Resources Law.
- Law 27314, General law for solid waste.
- Legislative Decree 1065 that modifies law 27314, solid waste law.
- Supreme Decree 057-2004-PCM that approves regulation of law 27314, solid waste law.
- Legislative Decree 1278, law for integral management of solid waste.
- Supreme Decree 001-2012-MINAM, national regulations for management and handling of electric and electronics equipment waste.
- Supreme Decree 007-2008-TR, that approves the Unified Text of the Law for competitiveness, formalization, and development promotion of micro and small enterprises and access to decent employment 021-2009-MEF.
- Law 28411, National System for Budgeting.
- Legislative Decree 1017, law for contracting with the state.
- Supreme Decree 008-2008-TR, regulations for micro and small enterprises law.
- Supreme Decree 028-2013-EM, that creates a program for massive conversion of vehicles to Compressed Natural Gas (CNG) and indicates measures for its massive use in vehicles from the public sector.

B. Local Guidelines for Ecoefficiency

Recently, the Ministry of Environment in Peru published basic guidelines in order to promote ecoefficiency measures in the public sector. Ref. [08].

A first step to considered is related to organization and responsibility assignment. The objective is to organize the work and development of an ecoefficiency plan within institutions of the public sector. In order to do that, it is important to consider the Supreme Decree 009-2009-MINAM and its amendment, approved by Supreme Decree 011-2011-MINAM, establishing that the Administrative General Office (OGA) in each public institution is responsible for implementing ecoefficiency measures. Prior to developing an ecoefficiency plan, it is suggested that the first activity to be carried out should be the conformation of a multidisciplinary team representing different areas of the public institution. Such team receives the name of Ecoefficiency Committee, which along with the OGA in each institution has the responsibility to carry out the Ecoefficiency Plan. According to the forementioned Supreme Decrees, the conformation of an Ecoefficiency Committee it is not a legal requirement. However, its role is important because it allows involving all of the areas in each institution, facilitating the articulated conduction of ecoefficiency measures.

A second step to considered is related to ecoefficiency diagnostic. The ecoefficiency diagnostic allows identification of the current situation within the public institution. Its development is of crucial importance because it is on the basis of this document that ecoefficiency measures will be determined in order to be implemented in the institution. After elaboration and approval of the ecoefficiency diagnostic, the public institution should always have updated environmental performance indicators. Also, in case of a new construction, change of location or any other project that may generate significant changes in the infrastructure and resource usage, the elaborated and approved diagnostic will have to be updated in order to incorporate new aspects. In general, the final version of the ecoefficiency diagnostic should contain at least the following: introduction, objectives, legal framework, baseline, description of current situation that leads to improvement opportunities, and conclusions. Baseline section should include consumption associated with electricity, fuels, water and office supplies, as well as solid waste and carbon dioxide generation.

A third step to be considered is related to an ecoefficiency plan. The ecoefficiency plan is defined as the document that contains the group of ecoefficiency measures identified as feasible in the opportunity diagnostic. Such a document should contain at least the following: introduction, objectives, legal framework, ecoefficiency measures, implementation strategies, action plan, activity schedule, and conclusions.

A fourth step to be considered is related to follow-up and monitoring of the ecoefficiency plan. In general terms, the monitoring of the ecoefficiency plan allows evaluating achieved improvements and make decisions for corrective purposes when certain measures failed to achieve the expected

outcome. Monitoring of performance indicators should be carried out according to criteria established in the ecoefficiency diagnostic. In this regard, it is important to consider that the impact of such measures is assessed by comparing indicator values obtained by monitoring with reference values quantified prior to the implementation of the ecoefficiency measures. Monitoring program results should be presented regularly to institution personnel in order to show the benefits achieved through implemented measures and to keep a high degree of interest in the ecoefficiency program.

C. Frequent ecoefficiency measures

There are several ecoefficiency measures that have been frequently recommended for electricity, fuel, water, and office supply consumption optimization.

Electricity

Lighting systems represent a significant share of electricity consumption on a university campus. It is estimated that electricity for lighting systems may be in the range of 30-40% of total electricity consumption. Common ecoefficiency measures include the following:

- Lamps should be turned off whenever they are not needed. (L1)
- Installation of occupancy sensors. (L2)
- Substitution of compact fluorescent lamps by LED lamps. (L3)
- Substitution of tube fluorescent lamps by LED tube lamps. (L4)
- Substitution of magnetic ballasts by electronic ballasts for tube fluorescent lamps. (L5)

Air conditioning systems also represent an important share of electricity consumption. It is estimated that electricity for air conditioning systems may be in the range of 20-30% of total electricity consumption, under local average temperatures. Common ecoefficiency measures include the following:

- Air conditioning units should be turned off whenever they are not needed. (AC1)
- Regulation of temperature set point. (AC2)
- Utilization of fans/ventilators to reduce the usage of air conditioning units. (AC3)
- Installation of variable speed control systems (AC4)
- Substitution of air conditioning systems by more efficient units. (AC5)

Fuels

Fuel consumption is associated with the use of vehicles and buses for official use inside and outside campus facilities. Small cars usually use gasoline while buses normally use diesel oil. Common ecoefficiency measures include the following:

- Considering other alternatives for short distance transportation. (F1)
- Avoid using transportation units with very few people on board. (F2)
- Utilize kit converters in order to switch from gasoline cars to Liquified Petroleum Gas (LPG) cars. (F3)
- Utilize kit converters in order to switch from gasoline cars to compressed natural gas (CNG) cars. (F4)
- Substitution of diesel oil buses by compressed natural gas (CNG) buses. (F5)

Water

Water consumption is associated with the use of restrooms, lavatories, showers, kitchenets, and the kind by local personnel on a daily basis. Common ecoefficiency measures include the following:

- Water consumption units should be turned off whenever they are not needed. (W1)
- Considering using less amount of water by modifying old-fashion habits. (W2)
- Installation of occupancy sensors. (W3)
- Fixing leakages. (W4)
- Substitution of water consumption units by more efficient units. (W5)

Office supplies

Office supplies usually include paper and ink for administrative procedures. Even though, there is a global trend to migrate to digital information procedures, there is still an important usage of printed matter which is perceived by some authorities as more “official” compared to digital documentation. Common ecoefficiency measures include the following:

- Considering alternatives for referring to a digital information whenever possible. (O1)
- Considering alternatives for reducing the quantity of pages required by the document. (O2)
- Avoid the need for printing multiple copies of the same document. (O3)
- Avoid photocopying printed documents that originally have a digital version. (O4)
- Avoid the need for stamping (ink) every single page of the documents. (O5)
- Use both sides of a sheet for printing purposes. (O6)
- Use blank side left from older printed documents. (O7)
- Considering use of less quality paper whenever possible. (O8)

D. Systematization for decision making

The forementioned common ecoefficiency measures could normally fall into best practices and retrofits categories; however, there may also be other additional measures that might be considered as technology innovations.

Best Practices

Ecoefficiency measures associated with operation and control aspects are usually considered as best practices. Modification of patterns of consumption and user's habits fall also into this category. In general, it is said the ecoefficiency measures that are considered as best practices should only require a very small amount of investment. In some cases, it is basically a change of attitude and the achievement of social-environmental awareness. Often, best practices can be accomplished by communication campaigns, internal workshops, posting signs, and distribution of flyers.

Retrofit Strategies

Ecoefficiency measures associated with replacement of existing units by more efficient ones are usually considered as retrofit strategies. Incorporation of auxiliary components, control devices, instrumentation equipment may also fall into this category. Often retrofit strategies require a feasibility study in order to validate technical aspects, including installation characteristics as well as operation and maintenance conditions, including spare parts. With regard to economic feasibility, cost implementation and expected cost savings should be carefully assessed. Classical indicators of economic feasibility include simple payback, net present value, and internal rate of return. Discount rates play a significant role on economic feasibility, and it depends on the organization's size, the user financial profile, and the complexity of the ecoefficiency measure to be financed. Acceptable payback period varies across countries, regions, and even withing organizations themselves. However, it is said that a period of 1-3 years may be considered as a reasonable payback time.

Innovation Strategies

Ecoefficiency measures associated with early adoption of very new technologies can be considered as innovation strategies. In some cases, there seems to be a confusion between a "normal" new equipment and a very new technology. The purchase of a "normal" new equipment should be considered just as a retrofit, if it belongs to an already well stablished technology. Therefore, we may not find quite a few cases of ecoefficiency measures involving innovations strategies but if they are feasible at all it could lead to significant impacts in both economic and environmental benefits. However, cost implementation is expected to be high and thus, payback period would be longer. There is also a potential risk that needs to be address when dealing with very new technologies.

E. Modelling of Ecoefficiency Strategies

There are interactions among ecoefficiency strategies, resource optimization, and feasibility aspects. Fig. 1 shows a proposed model in order to capture such interactions. An organization might be interested in implementing a recommended ecoefficiency strategy (best practice, retrofit, innovation) in order to achieve resource optimization (electricity, fuels, water, and office supplies) but feasibility will depend on several considerations (economic benefit, cost implementation, and payback period) for decision making purposes.

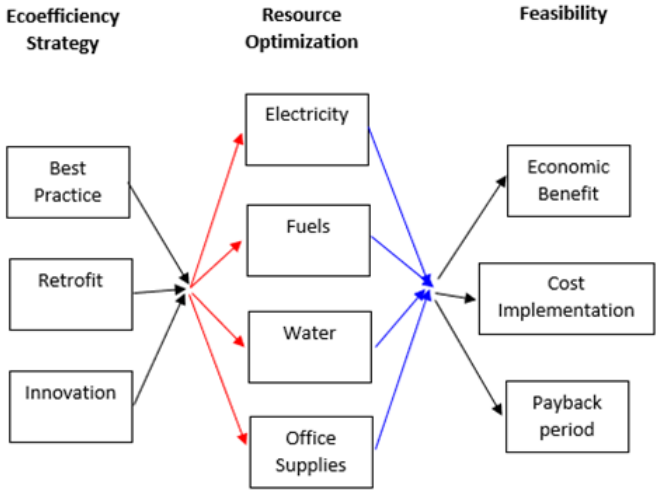

Fig. 1 Modelling of Ecoefficiency Strategies

III. Results

On the basis of the forementioned methodology, the following results are presented.

A. Ecoefficiency strategies for electricity consumption optimization

For illustration purposes, Table I shows an ecoefficiency strategies matrix for electricity consumption optimization, including categories for ecoefficiency measures, and reference ranking of expected economic benefits, cost implementation, and payback period.

TABLE I
Ecoefficiency Strategies Matrix (Electricity)

Electricity Lighting	Ecoefficiency Strategy	Economic Benefit	Cost Implementation	Payback Period
L1	Best Practice	Low	Low	Short
L2	Retrofit	Medium	Medium	Medium
L3	Retrofit	Medium	Medium	Medium
L4	Retrofit	Medium	High	Long
L5	Retrofit	Medium	Medium	Medium
Air Conditioning				
AC1	Best Practice	Low	Low	Short
AC2	Best Practice	Low	Low	Short
AC3	Retrofit	Low	Low	Medium
AC4	Retrofit	Medium	High	Long
AC5	Retrofit	High	High	Long

B. Ecoefficiency strategies for fuel consumption optimization

For illustration purposes, Table II shows an ecoefficiency strategies matrix for fuel consumption optimization, including categories for ecoefficiency measures, and reference ranking of expected economic benefits, cost implementation, and payback period.

TABLE II
ECOEFFICIENCY STRATEGIES MATRIX (FUELS)

Fuels	Ecoefficiency	Economic	Cost	Payback
Transportation	Strategy	Benefit	Implementation	Period
F1	Best Practice	Low	Low	Short
F2	Best Practice	Low	Low	Short
F3	Retrofit	Medium	Medium	Medium
F4	Retrofit	Medium	Medium	Medium
F5	Retrofit	High	High	Long

C. Ecoefficiency strategies for water consumption optimization

For illustration purposes, Table III shows an ecoefficiency strategies matrix for water consumption optimization, including categories for ecoefficiency measures, and reference ranking of expected economic benefits, cost implementation, and payback period.

TABLE III
ECOEFFICIENCY STRATEGIES MATRIX (WATER)

Water	Ecoefficiency	Economic	Cost	Payback
Usage	Strategy	Benefit	Implementation	Period
W1	Best Practice	Low	Low	Short
W2	Best Practice	Low	Low	Short
W3	Retrofit	Medium	Medium	Medium
W4	Retrofit	Medium	Medium	Medium
W5	Retrofit	Medium	High	Long

D. Ecoefficiency measures for office supplies utilization

For illustration purposes, Table IV shows an ecoefficiency strategies matrix for office supplies optimization, including categories for ecoefficiency measures, and reference ranking of expected economic benefits, cost implementation, and payback period.

TABLE IV
ECOEFFICIENCY STRATEGIES MATRIX (OFFICE SUPPLIES)

Office	Ecoefficiency	Economic	Cost	Payback
Supplies	Strategy	Benefit	Implementation	Period
O1	Best Practice	High	Low	Short
O2	Best Practice	High	Low	Short
O3	Best Practice	High	Low	Short
O4	Best Practice	High	Low	Short
O5	Best Practice	Medium	Low	Short
O6	Best Practice	Medium	Low	Short
O7	Best Practice	Medium	Low	Short
O8	Retrofit	Medium	Medium	Medium

In the above tables, innovation strategies have not been shown since they are not common recommendations but in certain cases their implementation could become rather interesting. An example may be the introduction of electric cars. Another example may be the introduction of solar refrigeration units for space cooling.

IV. CONCLUSIONS

With regard to this work, the following preliminary conclusions can be outlined:

1. Common ecoefficiency measures for lighting include: lamps should be turned off whenever they are not needed, installation of occupancy sensors, substitution of compact fluorescent lamps by LED lamps, substitution of tube fluorescent lamps by LED tube lamps, and substitution of magnetic ballasts by electronic ballasts for tube fluorescent lamps.
2. Common ecoefficiency measures for air conditioning include: air conditioning units should be turned off whenever they are not needed, regulation of temperature set point, utilization of fans/ventilators to reduce the usage of air conditioning units, installation of variable speed control systems, and substitution of air conditioning systems by more efficient units.
3. Common ecoefficiency measures for water include: considering other alternatives for short distance transportation, avoid using transportation units with very few people on board, utilize kit converters in order to switch from gasoline cars to Liquified Petroleum Gas (LPG) cars, utilize kit converters in order to switch from gasoline cars to compressed natural gas (CNG) cars, and substitution of diesel oil buses by compressed natural gas (CNG) buses.
4. Common ecoefficiency measures for office supply include: considering alternatives for referring to a digital information whenever possible, considering alternatives for reducing the quantity of pages required by the document, avoid the need for printing multiple copies of the same document, avoid photocopying printed documents that originally have a digital version, avoid the need for stamping (ink) every single page of the documents, use both sides of a sheet for printing purposes, use blank side left from older printed documents, and considering use of less quality paper whenever possible.
5. A model is proposed in order capture interactions among ecoefficiency strategies, resources optimization, and feasibility for decision making purposes.

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