Instruments for Environmental Management: A Focus on Sustainable Innovation

Wilson Pereira Barbosa Filho

Federal University of Minas Gerais, Pos-Graduate Program in Nuclear Sciences and Techniques, Belo Horizonte (MG), Brazil
wilson.ferreira@meioambiente.mg.gov.br

Abílio César Soares de Azevedo

State Environmental Foundation, Belo Horizonte (MG), Brazil
abilio.azevedo@meioambiente.mg.gov.br

Wemerson Rocha Ferreira

Federal University of Minas Gerais, Pos-Graduate Program in Nuclear Sciences and Techniques, Belo Horizonte (MG), Brazil
wemerson.ferreira@meioambiente.mg.gov.br

Antônio Henrique dos Santos

Fundação Estadual do Meio Ambiente, Belo Horizonte (MG), Brasil
antonio.santos@meioambiente.mg.gov.br

Lívia Maria Leite da Silva

Pontifical Catholic University of Minas Gerais, Pos-Graduate Program in Electrical Engineering, Belo Horizonte (MG), Brazil.
liviamarialsilva@hotmail.com

ABSTRACT: The current environmental issue has increasingly demanded, initiatives aimed at finding solutions that can provide a balance between the evolving needs of society and the maintenance and preservation of the environment. In this sense, the instruments for environmental management emerge and are designed to help strategies and decision-making process. For as such instruments can become effective in the pursuit of sustainable development, it is necessary that they be based on a holistic view of all aspects of society, combining economic prospects, political and sociocultural to environmental balance. Thus, this article aims to propose sustainable technological innovation as an environmental management instrument, which can be a potentiating tool of the integration between management tools already established as well as new. This mechanism seeks to attract environmentally friendly solutions both in the development process, with improvements in environmental performance, as the products, adapting them to new market niches.

Key-words: *sustainable innovation, environmental management, management instruments, public policy, sustainable development.*

1. INTRODUCTION

Discussions on environmental policies increasingly converge on issues related to technological change. Social activities are often affected by the characteristics and directions of technological change, and partly, environmental policy interventions can create constraints and incentives that have significant effects on technological development in process. For Freeman (1996) and Ruttan (1996), innovation and diffusion represents the way to the adequacy of technological and social demands with environmental conditions, and for such, a holistic view of the ecosystem conditions and technological sets is necessary.

The construction of innovative technological policies currently represents one of the main challenge for environmentalism, forcing him to abandon a defensive and restrictive stance, front of to the broad possibilities of political and social restructuring in the contemporary world. It is necessary to seek to understand innovation as a complex compatibility formula of a technological system while technical and social environment. According to this notion, it's necessary leave the Cartesian view of technological discussion, in other words, not just replace a power source for another or add a palliative device on certain machines, it is necessary to develop a comprehensive view at building a technical, economic environmental paradigm that modifies the social behavior, consumption patterns, the way of life, so that the technology is considered in a holistic view. It is up to environmentalism, among other contemporary sectors, redeem the innovation of the interior of large corporations and government agencies, and disseminate it to all the social groups, creating conditions for the establishment of plural and efficient environments. The improvement of sustainable organization models, the development of sustainable technologies, management innovations for sustainable development will have more space in future studies.

2. SUSTAINABLE TECHNOLOGICAL INNOVATION - SYSTEMIC VISION

2.1 Dimensions

The concept of innovation is quite varied, depending mainly of its application. Briefly, there are those who believe that innovation is the successful exploitation of new ideas. Among the various possibilities to innovate, those relating to product or process innovations are known as technological innovations. Other types of innovations can relate to new markets, new business models, new processes and organizational methods or even new sources of supplies. The word innovate, of the Latin: "*Innovare*", means making new, renew, while innovation is relating to the act of innovate. In the early twentieth century, the studies of Joseph Schumpeter had a major impact in debate on technological and economic developments. According to Schumpeter (1982), entrepreneurial behavior, coupled with the introduction and expansion of technological and organizational innovations in enterprises is a key factor in the changes in the economic and long-term development. According to Feenberg (1999), the choice or rejection of certain technologies can not be based on purely economic criteria, but in the compatibilization involving behavior and interest of the groups and strategic sectors. Over the past decades, the development of systems theory has provided a basis for integration of knowledge aimed dynamic interactions through interconnected elements. Thus the determinism which is present in the economic debate on the logic and on the innovation models must be replaced by a systemic approach that does not address only economic choices. In this sense, the economic interests accompany, but do not determine the direction of innovation. In accordance with Latour (1994), the technical project and the social context tend to merge as a strategic action where the innovator monitors the social context and adapt to it, or will not achieve important innovations. According Barbieri (2007) to introduce the term sustainability to technological innovation implies being efficient in economic terms, to respect the environmental carrying capacity and be instrument of social justice, promoting social inclusion, protection of minorities and vulnerable groups etc. Is not enough innovate, but innovate considering the three dimensions of sustainability:

- Economic dimension; concern for economic efficiency, revenue, and generating competitive advantages in the markets;
- Social dimension: concern about the social impact of innovations in human communities inside and outside the organization;
- Environmental dimension: concern for the environmental impacts from the use of natural resources and the emission of pollutants.

The concern in meet these dimensions makes the most demanding process and gives off greater technical effort, settling new tools and models for the management of innovation. According to Barbieri (2010) this is not only the task of companies that want to innovate, but teaching and research institutions, government agencies, standards organizations, civil society organizations in the form of knowledge network. In accordance to Capra (2002) while systems survive, their networks connect to other networks, which means that interacting, the knowledge is learned and organized, while new information is inserted in the environment. Thus, it is no longer possible to conceive of modern technology policy without thinking in terms of network researchers and integrated and interdisciplinary projects.

2.2 Characteristics of sustainable technological innovation

The term sustainable technology differs from environmental technology, both are geared to resolve problems while sustainable technology integrates the three components of sustainable development play a key role in the transition from the current production system to a more sustainable pattern, the environmental technology is not attentive to social and economic aspects. The added value of sustainable technology compared to environmental technology is mainly consider the short-term situation from a long-term perspective. According to Valenduc and Vendramin (1997), this approach has the following strengths:

- It enables a clearer identification in various branches of industry, in the relationship between sustainable technological innovation and structural changes to meet sustainable development;
- It allows a broader perspective of the importance of direct and indirect effects induced on jobs;
- It clarifies the relationship between the dynamics of technological innovation and the concept of qualitative growth;
- It interacts in the relationship between technological innovation and other instruments of sustainable development, such as environmental regulations, economic

instruments for environmental management, public policies and increased acceptability of changes.

The environmental technology shows many techniques, projects and small deployments of short-term operational solutions (Add-on) oriented to the problem, which often addresses only one component of sustainable development. These solutions often seem easier to program because it does not require radical changes in the production process. They seek to reduce the amount of matter and energy per unit produced, eliminate toxic substances and tend to increase the shelf life of products, however, may generate unemployment, harm communities or segments of society. Sustainable technology requires interdisciplinarity and shows an integrating context, which may posit further investment, however, generate better competitiveness and long-term cost savings. It is worth noting that the interdisciplinary approach is not just the dialogue between disciplines in the natural and social sciences but also between research and society. According to Barbieri et al. (2010), sustainable technology introduces products, production processes, management and business methods, new or improved with economic, social and environmental benefits. It is not only to reduce negative impacts, but to advance in net benefits. Therefore the condition of comparison between relevant alternatives is essential to the expected benefits. The evaluation of the consequences, within the three spheres of sustainability should be part of the innovation process.

3. ENVIRONMENTAL MANAGEMENT TOOLS

The environmental management approach can be considered from two points of view: the first involves an integrated approach that seeks to involve issues that interact in the natural environment or built; and the second covers public health, territorial planning and the interactions between different systems. According to Groenewegen & Vergragt (1991) apud Crazza (2003) the contributions of environmental management are grouped into three areas: production, innovation and strategic. In the productive area, the environmental management interferes in the control of respect to public regulations by the various operating divisions and implementing environmental actions. In the area of innovation, a environmental management provides a double technical assistance: on one side following the regulatory devices and ecotoxicological assessment of products and emissions and of the other contributing to the definition of product and technology development projects. And in the strategic area, environmental management generates assessments of the potential for development and on emerging environmental restrictions. In this context, it highlights the Green Strategy Oriented to Innovation, which according to Azzone, Bertele & Noci (1997) can be introduced in innovations in processes, environmental improvements for the company or in product innovations, creating new market requirements. The financial, technological and organizational resources are critical to the success of this strategy, as well as high environmental aware of employees and a constant search for environmentally friendly solutions through renewable or recyclable raw materials that do not harm the environment and that have low energy consumption. Still, as Boschetti & Bacarji (2010) when the theme is management, it is important to highlight the planning process and this, in the environmental area is revealed as an efficient instrumental resource to be used in environmental management. The environmental planning stands out on the need to develop projects that discussing instruments and that instituting mechanisms to minimize impacts on the environment coupled with the sustainability context.

The environmental management tools operate as an auxiliary tool in the planning process and in the theme of environmental management in order to integrate all activities strategically. Use environmental management tools is a better way to manage the demands and the creation of processes and environmentally friendly products in order to project the growth sustainably market.

To resolve environmental issues in recent decades, governments are using environmental management tools, with varying degrees of success. In the problems of industrial and urban pollution, called brown agenda, these instruments can be divided into two main: regulatory instruments, or instruments of command and control type (C&C); and market instruments, or economic instruments (EIs). According to Mendes & Seroa da Motta (1997) there are two types of economic instruments classification:

- Incentives that act in the form of awards - subsidized credit, tax breaks and other financial facilities for tax burden reduction effect; and
- Incentives that work in the form of price - these are all mechanisms that guide economic agents and enhance the environmental resources and services according to their scarcity and opportunity cost.

In Brazil, within the category of subsidies on less harmful products and technologies, highlight it the Incentive Program for Alternative Sources of Electric Energy (Programa de Incentivos às Fontes Alternativas de Energia Elétrica - PROINFA), created by Decree N°. 5.025/04. The goal was to promote the diversification of the Brazilian energy matrix, seeking alternatives to enhance security in the electric power supply, and allow the appreciation of the characteristics and regional and local potential.

New environmental instruments are gaining importance in the negotiation and the need to seek an effective "conciliation" between the parties, always anchored in the concept of "sustainable development" for the search for an integrative approach: integrate development with the sustainable use of resources, integrate command and control instruments traditionally applied to the environment with economic instruments, integrate public and private actors in environmental management, integrate the dynamics of local environmental issues with the global.

The environmental management instruments used in the public sector are: quality standards, environmental indicators, environmental impact assessment, evaluation methods and elaboration of studies (environmental impact study / environmental impact report, environmental control report and environmental control plan), strategic environmental zoning, command and control instruments , economic instruments, monitoring, ecolabels, environmental audit, integrated environmental assesment, strategic environmental assessment, among others. In the private sector: Assessment Program responsible, ISO 14000, environmental management system, environmental auditing, environmental performance evaluation, environmental indicators, life cycle analysis and others.

4. SUSTAINABLE TECHNOLOGICAL INNOVATION AS ENVIRONMENTAL MANAGEMENT INSTRUMENT

Given the increasing demand for environmental resources, not all existing technologies are long-term, adequate to ensure sustainable development. During the environmental licensing process should be a technology research process, seeking to assess the most appropriate. In this sense, this study proposes a new environmental management instrument that promote a comparison between technologies to meet the objectives of sustainable development. In conjunction with this instrument, it must make use of quality management tools to verify compliance with performance targets.

4.1 – Management instrument

The proposed instrument consists of three stages: creation of a knowledge network to expand the basis of the technical studies of the licensor; listing and definition of the parameters to be analyzed; and the use of a matrix analysis tool to aid decision making.

4.1.1 - Knowledge Network

The creation and development of a knowledge network is crucial to assist and expand the technical knowledge and institute systemic perspective on the licensing process. The systems thinking, as opposed to analytical thinking that is reductionist, believes that to know a subject is necessary to see it in context and understand the interrelationships between the parties, considering that the whole is not only the result of the sum of the parties, but rather, a result of the synergistic integration between the parties in constantly evolving. The network is scoped to promote environmental policies and the transfer of knowledge and technologies, including the encouragement of sustainable innovations, good practices of industrial production and diversification of energy matrix through renewable sources, in order to deal with the issues of innovations technological, energy management, environmental regulation and use of environmental resources in a context of sustainability. This network aims to encourage the expansion of knowledge of the technicians involved in environmental licensing, in terms of comparative analysis of technologies.

4.1.2 - Indicators

The indicators or parameters to be used in the analysis may vary between the different technological innovations, being for product or process. This study suggests some, such as life cycle analysis, energy efficiency, renewable energy use, greenhouse gas emissions, noise pollution, self-sufficiency in relation to energy consumption, efficient use of environmental resources, water consumption, flexibility of uses, rehabilitation of the built environment, natural and technological risks, integration and social inclusion. The knowledge network is paramount to assist the definition of the parameters to be used in a multidisciplinary context.

4.1.3 - Support to decision-making

For the evaluation of technologies, product or process, must be performed the analysis of parameters or indicators associated, through the use of a decision-making support instrument. The instrument chosen was the method called Analytic Hierarchy Process (AHP) developed in the 1970s by Prof. Thomas Saaty, in the Wharton School of the

University of Pennsylvania. The AHP aims to support the analyst to choose and justify his choice and is based on mathematics and psychology. The central idea of this method is the study of systems in a comparison sequence in pairs that allows us to understand, how to make judgments in values that satisfy the wide optimization, according to multiple criteria. The use of the method is carried out in the decision making process, minimizing its flaws. Once the hierarchy is built, decision makers systematically evaluate its various elements, comparing them to each other in pairs. To making comparisons, they can use concrete data about the elements or can use their judgments about the relative significance or importance of the elements. The AHP converts the judgments into numerical values that can be processed and compared considering all extent of the problem. According Saaty (1980), it is considered the elements of a given hierarchical level, and then, it is determined the weights of the elements in relation to an element of the next higher level of the comparison matrix by pairs, by calculating the eigenvector. Thus, being *aij* the value obtained by comparison in pair of the element *i* with the element *j*, the matrix formed by these values is the matrix called *A*, where *A = (aij)*, and this matrix is a reciprocal matrix such that *aij =1/aij*, wherein, if the judgments were perfect in all comparisons would be possible to verify that *aij x ajk = aik*, for any *i, j, k*. For this procedure the matrix *A* should be consistent. However, it is sometimes observed some inconsistency in judgments, a fact which is admitted by the AHP. The nearer the value of $\lambda_{máx}$ is of *n*, the greater the consistency of judgments (Gomes et al., 2004). Saaty (1980) showed that, being *A*, the matrix of values, must be found the value that satisfies Equation 1:

$$A_w = \lambda_{máx} \times \omega \quad (1)$$

To obtain the eigenvector from Equation 1, one has Equation 2:

$$\lambda_{máx} = \frac{1}{n} \sum_{i=1}^{n} j_i \frac{(A\omega)i}{\omega i} \quad (2)$$

Still according with Saaty (1980), the matrix *A* is consistent if, and only if, $\lambda máx \geq n$. If the matrix *A* is consistent, the magnitude of the disturbance is calculated using the Consistency Index (CI), which must have a value of less than 0.1, through Equation 3:

$$I_c = (\lambda_{máx} - n)(n - 1) \quad (3)$$

Saaty (1980) proposes the calculation the Consistency Ratio (CR), which is the ratio of the Consistency Index (*CI*) by Randomic Index (*RI)*. This calculation provides as a result a new vector in which each element is divided by the corresponding element of eigenvector and the results are summed, then calculating the average.

$$R_c = \frac{IC}{IR} \quad (4)$$

The Randomic Index (RI) is a random index, calculated for square matrices of n order by the National Laboratory of Oak Ridge in USA. Table 1 shows some values.

Table 1 - Values of *RI* for square matrices of *n* order

Values of *RI*						
n	2	3	4	5	6	7
RI	0	0,58	0,9	1,12	1,24	1,32

Source: Gomes et al, p. 48, 2004.

Due the so-called psychological limit, according to which the human can, at most, judge correctly 7 ± 2 points, that is, a maximum nine points (parameters to be analyzed) to distinguish their differences, Saaty (1980) defined a Fundamental Scale which is presented in Table 2:

Table 2 – Fundamental Scale of Saaty (1980).

FUNDAMENTAL SCALE OF SAATY		
1	Equally important	The two alternatives contribute equally to the goal
3	Small importance of one over the other	Experience and judgment favor one activity over another
5	Great or essential importance	Experience and judgment strongly favor one activity over another
7	Importance too large or demonstrated	An activity is very strongly favored over the other. It could be demonstrated in practice.
9	Absolute importance	The evidence favors one activity over another, with the highest level of security
2, 4, 6, 8	Intermediate values	When it searched for a compromise condition between two settings

Source: Gomes et al, p. 48, 2004.

The Classic AHP method utilized considers many imponderables or unmatched aspects among themselves, therefore, the values assigned to the comparison should be listed subjectively using a multidisciplinary team. This method calculates the value of the impact of the j alternative in relation to i, where results represent numerical values of the verbal assignments given by decisor in each comparison of alternatives. It used the Equation 5, which corresponds to the number of alternatives or compared elements.

$$\sum_{i=1}^{n} \bar{v}_i\left(A_j\right) = 1 \qquad j = 1, \dots, n \tag{5}$$

Each part of this sum consists of:

$$\bar{v}_i\left(A_j\right) = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \qquad j = 1, \dots, n \tag{6}$$

This causes the priority vector of the alternative *i* with respect to the criterion *Ck*, is:

$$\bar{v}_k(A_i) = \sum_{j=1}^{n} \bar{v}_i \frac{(A_j)}{n} \qquad i = 1, \dots, n \tag{7}$$

According to Saaty (1980), after obtaining the vector of priorities or impact of the alternatives under each criterion *Ck*, it is necessary to continue with the level of the criteria. It is adopted then again, the verbal scale for the classification in pairs of the criteria, which are normalized in according the equation:

$$\bar{w}_i\left(C_j\right) = \frac{C_{ij}}{\sum_{i=1}^{m} C_{ij}} \qquad j = 1, \dots, m \tag{8}$$

Which corresponds to the number of criteria of the same level. The main vector is given by:

$$\bar{w}(C_i) = \sum_{j=1}^{m} \bar{w}_i \frac{(C_j)}{m} \qquad i = 1, \dots, m \tag{9}$$

Finally, a process of aggregation allow to generate the final values of the alternatives, ordering them by Equation 10, where *n* is the number of alternatives:

$$\bar{f}\left(A_j\right) = \sum_{i=1}^{m} \bar{w}(C_i) \times v_i\left(A_j\right) \qquad j = 1, \dots, n \tag{10}$$

4.2 - Performance goals

For the environmental management instrument proposed has excellence is required that the managers seek to evaluate the performance targets over time, and its use in assessments of the decision making. These goals are long term and based on the best environmental performance. Therefore, it is essential the use of a quality management tool to assess the instrument's efficiency, in addition to the talents and skills of the professionals involved. The tool chosen was the *PDCA* (Plan-Do-Check-Adjust), which consists of an iterative method of four-step management, used for the control and continuous improvement of processes and products. The basis of this tool is in the repetition. It is applied successively in the processes aiming to improve continuously. In this context, planning, standardization and documentation are important practices as accurate measurements. The PDCA cycle has as the initial stage the planning of the action then everything was planned is executed, generating subsequently the need for constant checking of these actions implemented. Based on this analysis and comparison of actions with what was planned, the manager then begins to implement measures to correct the failures that arose in the process or product.

5. CONCLUSION

As seen, sustainable innovation does not follow a linear path, but it is an interactive process between different actors and involves continuous feedback loops between the different stages. An innovation policy must be linked to sustainable development so that they can influence each other over time, to tackle the barriers to technology diffusion and trade-offs between the economy, society and the environment. Given the increasing demand for environmental resources, not all existing technologies are long-term, adequate to ensure sustainable development. During the environmental licensing process should be a technological research process seeking to assess the most appropriate technology. In this sense, this study presented a new environmental management instrument that causes the comparison between technologies to meet the objectives of sustainable development. This instrument consists of three stages: creation of a knowledge network to expand the basis of technical studies of the licenser, listing and definition of parameters to be analyzed and the use of a matrix analysis tool to aid decision making. Finally, pointed it the use of quality management tools to verify compliance with the performance targets. This environmental management instrument can be a potentiating tool of the integration between management tools already established as well as new. Such mechanism seeks to attract environmentally friendly solutions both in the development process with improvements in environmental performance, as in the products, adapting them to new market niches.

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