Business organisational response to environmental challenges : innovation[1]

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Abstract

Environmental issues constitute a significant driver of innovation in business companies. The paper starts from the historical perspective by identifying which have been the factors and significant steps in technological innovation that have been related to increasing environmental awareness in recent history. Then we analyse the dimensions of technological innovation as related to environmental pressures, i.e., the speed of generation and diffusion of technology, the intensity of the innovation process, and the pervasiveness of technological change. Environmental challenges can be taken, in various ways, as the central focus on which business strategies can be elaborated, which is reviewed next. Finally we examine various forms of environment-friendly innovations, and present a few examples, at three different levels, i.e., the process, the product, and the system. It is concluded that in many instances, technological innovation induced by environmental issues not only yields advantages from an ecological standpoint, but also from an economic and strategic point of view.

Outline

1. The changing relationship between technology and the environment
2. The key role played by technology in fostering sustainable development
3. Dimensions of technological innovation
   3.1. The speed of generation and diffusion of technology
   3.2. The intensity of the innovation process
   3.3. The pervasiveness of technological change
4. Environmental protection as the driving force behind the innovation process
5. Environment as a strategic company variable
6. The company and the forms of environment-friendly innovations
   6.1. Process innovation
   6.2. Product innovation
   6.3. System innovation
7. Acknowledgements
8. References

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1. The changing relationship between technology and the environment

Since environmental issues first emerged in the 60s, technological change has represented one of the fundamental issues related to the debate regarding the possibility of reconciling economic development with the protection of natural resources. If, on the one hand, it seems obvious that technology is of the utmost importance in making the industrial system and companies more competitive, on the other hand, this variable is directly or indirectly responsible for many of today's environmental problems. Phenomena of environmental degradation on a global and local scale such as the greenhouse effect, the ozone depletion, acid rain, the eutrophication of water basins and waterways all stem from the large-scale diffusion of modern technological solutions (new production processes and products).

The problem of pollution is not, however, a characteristic of our century. The earliest records of water pollution date back to the ancient land of Mesopotamia ruled by Hammurabi. In imperial Rome lead, which had excellent properties and could be easily worked, was widely used in architecture, in the construction of aqueducts and in preserving food. This gave rise to serious forms of lead poisoning. Moreover, the historians of the Middle Ages speak of the serious urban degradation characterized by appalling sanitation in which the amount of organic waste threatened the health of the population.

Beginning with the Industrial Revolution, however, the concept of pollution radically changes. The rapid succession of inventions and innovations in agriculture, the manufacturing sector and the metal and mechanical industry lead to new production methods and the spread of new kinds of products. In this context, technology, in addition to being the key variable fostering economic growth at unheard of rates, contributes to completely changing the relationship between man and his natural environment. Consequently, on the one hand, man frees himself from the limitations of nature, which, for the first time in history, becomes subordinate to his wishes as a result of his inventions. However, on the other hand, the ensuing environmental degradation becomes the direct by-product of the industrialization process and, at the same time, the natural environment comes to be regarded as an unlimited resource.

This phase, characterized by widespread confidence in scientific and technological progress, continues for more than two centuries up to the early 1970s. Then, for the first time, the problems related to the degradation of the ecosystem and the scarcity of resources take on global proportions and begin to clearly emerge in all the industrialized countries. Among the first, Rachel Carson (1962) reports on the misdeeds of pesticide overuse, likely to bring about a "Silent Spring".

The turning point in the debate between environmentalists and economists regarding the possible compatibility between economic growth objectives and the protection of the planet is represented by the publication of the report *The limits to growth* in 1972 by the Club of Rome[2]. The document, which contains a detailed report by a group of MIT researchers concerning the relationship between economic growth and the environment, indicates that the

[2] The catastrophic conclusions of this work, which have not unfolded as predicted, have led D.H Meadows and his collaborators to publish a second report which revises the theoretical framework and the observations made in the light of the profound technological, economic and social changes of the last 20 years (see Meadows et al. 1972; Meadows et al 1992).

growth rate of some variables (population, industrialization, consumption of natural resources, food production and pollution) was considered a serious risk factor which in a few decades would, at best, bring man to reach his limits of growth.

In the last few years a succession of events has led to the consolidation of the concept of "environmental crisis" and the emergence of the "environmental issue" as a global phenomenon[3]. As the clash between the economy and the environment increases, confidence in the technological variable decreases. In fact, many environmental activists accuse the dominant technology of being one of the causes of the environmental crisis. One of the most authoritative spokesmen is the American ecologist Barry Commoner[4] who points out the risks related to the indiscriminate diffusion of modern production technologies. After bringing progress, this variable is rapidly brought to the dock and accused of being responsible for heralding a new era of danger, uncertainty, in which the very survival of the human race is threatened. Moreover, industrial accidents such as those of Flixborough, Seveso, Bhopal and Chernobyl reinforce the conviction that technology may be an extremely dangerous autonomous force that can develop its own independent trajectories beyond man's control.

It is not until the end of the '80s that this approach changes and a radically different vision evolves. A fundamental phase which marks the beginning of the third phase is the definition in 1987 of the concept of *Sustainable Development* by the World Commission on Environment and Development[5]. By resolving the clash between economic growth and environmental protection the Commission also redefines the role of innovation in finding strategies to protect natural resources. If, on the one hand, it is officially acknowledged that ecological degradation stems from the global diffusion of modern technological solutions, on the other, technological progress becomes a key factor in reaching the objective of sustainable development.

Since the end of the '80s the reference framework as regards environmental issues has continued to rapidly change. There have been a succession of measures and international agreements which stress the need to reduce to a minimum the use of non- renewable energy and material resources and at the same time reduce pollution. A further turning point is represented by the Rio de Janeiro Conference, organized by the United Nations in 1992 (Conference of the United Nations on Environment and Development – UNCED) which brought together participants from national and supernational institutions and the industrial world. It is on this occasion that for the first time the concept of *eco-efficiency* is introduced. This term indicates the possibility of realizing and offering goods and services at a competitive price capable of satisfying human needs and ensuring the quality of life while at the same time reducing the environmental impact and the consumption of resources during their entire life cycle to a level which is at least in keeping with the carrying capacity of the planet. Technology and innovation, therefore, make it possible to unite the two objectives of competitiveness and protection of the natural environment. More recently, the concepts of *Factor 4* (Weizsäcker et al. 1998), *Factor 10*, and *Natural Capitalism* (Hawken et al. 1999) emerged, showing the practical possibilities of increasing wealth while reducing the environmental impacts, as will be explicited in subsequent sections.

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[3] Of these, the oil shock of 1973 for the first time focuses the attention of world public opinion on the problem of the scarcity of resources.

[4] Barry Commoner, father of the American environmental movement, identifies as the cause of the modern environmental crisis the success of technology and the incompatibility between biological time, on which natural cycles are based, and the technological and economic cycles, on which industrial growth is based. (Commoner 1971)

[5] See The World Commission on Environment and Development 1987.

The new vision of technology which evolved also brings about a significant change in the way this variable is dealt with and managed. In fact, in the last few years, the direct approach to ex-post control of environmental risks correlated to widespread technological solutions, typical of the second historical phase we have mentioned, becomes outdated and inadequate. Instead, in the new reference framework, there is a shift of emphasis on ways of promoting eco-compatible technological change by attempting to direct the process ex ante towards sustainability.

Table 1 – The evolution of the relationship between environment and technology in industrialised countries.

Historical Phase	*Principal events*	*Reference framework*	*Vision of technology*
From the industrial revolution to the ‘70s	None	Environment as an unlimited resource	Positive vision, confidence in technology
From the ‘70s to 1987	General environmental crisis and significant industrial accidents	Clash between economic and ecological issues	Negative vision, technology as a threat
From 1987 to the present	Notion of Sustainable Development and notion of Eco-efficiency	Resolution of the clash between economic and ecological issues	Vision of technology evolves, technology as cause of environmental degradation and as possible solution

2. The key role played by technology in fostering sustainable development

Of the many models meant to represent the impact of the human species on the natural environment, particular attention should be given to the equation put forward by the American ecologist Paul Ehrlich[6] which first appeared in an article published in Science in 1971. The formula defines the impact on the biosphere I (ecological hazard) as the product of three fundamental variables: the dynamics of demography P, the degree of wealth or affluence A, measured, for example, as GDP per inhabitant, and technology T which indicates the amount of pollution per unit of GDP (i.e., as related to production and consumption of individual goods or services):

$$I = P \times A \times T$$

The equation which has been revised by the author himself and by other scholars, is functional, even in this simplified form, for our purposes and highlights the importance of the technology variable to contain or reduce environmental degradation. In fact, it is true that in

[6] Paul Ehrlich, Professor of Biological Sciences at Stanford University, has published many works on Sustainable Development, paying particular attention to the issue of demographic growth. His works, which contain catastrophic forecasts regarding the future of humanity, have often been harshly criticized for their excessively radical approach. The works of this scholar, however, have been decisive in fostering the debate regarding sustainable development. See. Ehrlich & Ehrlich (1972).

moving towards sustainable development, it is necessary to map out strategic measures which target all three of the variables indicated so as to reduce the planet's overall carrying capacity. However, as we will subsequently see, there are conditions and various factors which make it extremely complicated, though necessary, to influence demographic growth and well-being.

As regards the population (P), it is clear that the impact on the natural environment correlates positively with the current number of living beings. For many years the issue of the demographic increase has been at the center of international discussions and debates in an attempt to find effective policies to contain growth rates, especially in the economically less developed countries[7] where these rates are the highest. Despite the efforts made, it is difficult to predict whether there will be a significant reduction in the annual population growth rate which, according to official U.N. estimates, is expected to remain between 1.7% and 1.2%. In the face of these increases, it is forecast that in 2025 the world population will amount to about 8.4 billion people, over 84% in the poor countries, with an additional burden obviously put on the planet's resources.

As regards the second aspect of the equation, namely, the link between the level of well-being (A) and the impact on the biosphere, some points need to be clarified. Firstly, a positive correlation between the two variables is hypothesized, namely, an increase in A corresponds to a greater impact on the ecosystem since more resources are used. Based on this assumption, the overall stabilization of the level of well-being should be a condition for not worsening the overall carrying capacity of the environment. This, however, presents a number of problems related to the need of improving living conditions in the poorer countries - which inevitably means increasing incomes and consumption – and to the growth rates in the emerging economies.

A second factor we should consider refers to the nature of this variable and the positive dependence between increase in per capita income and technological efficiency. In fact, it is true that increased levels of well-being are usually accompanied by increased technical and scientific knowledge and profound changes in production and consumption patterns. Some phenomena, such as the "dematerialization" of the economy and the "decoupling" between economic growth and some forms of pollution are the effect of the economic development obtained by the industrialized countries. Moreover, in these countries the attention paid to the quality of life and greater environmental awareness - the undisputed effect of improved economic conditions - influence the choices of governments and companies in favor of protecting the natural environment. Therefore, if an increase in per capita income is accompanied by a positive effect on I, it is also true that the relation between these two dimensions is not linear[8] but balanced by technological improvements and the efficient use of resources (T) resulting from the levels of well-being reached. These considerations draw our attention to the key role played by technological progress and innovation, represented by T in Ehrlich's equation.

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[7] It is well known that in the industrialized countries demographic growth is extremely low. In the next few years, the annual increase is expected to be between 0.6% and 0.3%. In some contexts, such as Europe, expected growth rates are equal to zero. See Livi Bacci (1995). See also the Lugano Report (George 1999).

[8] This nonlinear effect is well characterized by the so-called environmental Kuznets curve, or the inverted U-shaped curve, based on observations of environmental conditions in various countries, implying that for low GDP levels, increasing income is accompanied by increasing environmental impact, up to a threshold after which the correspondence becomes opposite. The dependence, however, is valid in the case of some pollutants and not all; consequently, there is much debate about the Kuznets curve (see, e.g., Arrow et al. 1995; Munasinghe 1995).

To sum up the above discussion, and to give some idea of the scale of the problem, let us consider the following example. Presently, the growth rate of the human population is such that it doubles every 40 years. Assuming a growth rate of the per capita income (term A in the equation) of plus 5 percent per year[9], implying a multiplication by a factor of more than 5 in 40 years, the first two terms, P and A, would together increase by a factor of more than 10. If we consider as reasonable to maintain the environmental impact at its present level for the next 40 years (which in many domains is even considered as insufficient), the equation would imply a reduction in the last term, T, by at least 90 %. Taking again simplifying assumptions, let us consider the framework of Fig. 1. Considering mass-balance relationships around the system lets appear four possible strategies to reduce the global amount of waste generated by production activities, or, equivalently, the global amount of resources used as inputs (i.e., raw materials and energy). Two strategies can be classified as *prevention* strategies, namely, a reduction in the consumption of goods and the use of prevention technologies, i.e., technologies producing less waste at the outset, such as, e.g., clean technologies. While the first strategy is, strictly speaking, outside the realm of technological innovation (although it should be considered as a meaningful means of achieving rational resource use), the second strategy is clearly to be pursued in this perspective, as examplified by the many situations reviewed in the aforementioned research on Factor Four, Factor Ten and Natural Capitalism. The other two strategies, on the other hand, should be regarded as *repair* strategies, i.e., strategies that aim at enhancing the recycling ratios of either production residuals, or consumption residuals.

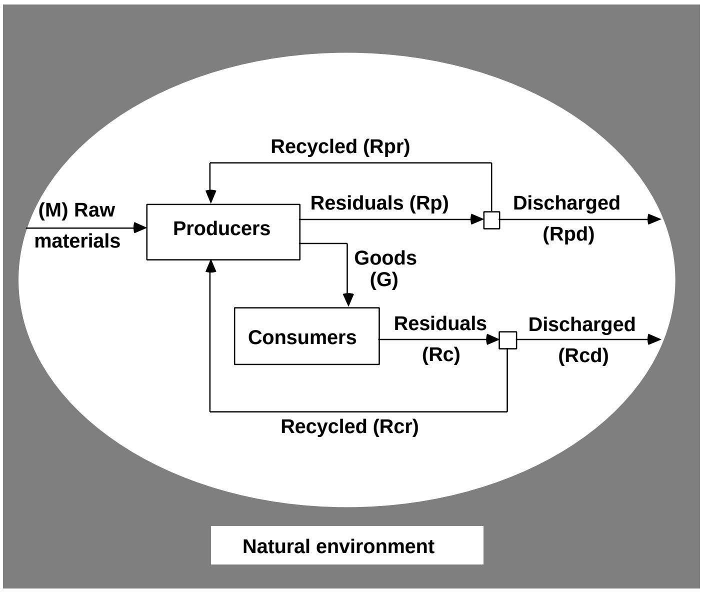

Figure 1. – A simplified situation of a system producing consumption goods and residuals, with possible recycling loops (after Field & Oleweiler 1995)

Thus far we have seen different areas for possible technological innovation, i.e., those acting on the processes themselves, and those aiming at adequate management of residuals. The result of both kinds of strategies will incur both efficient resource use and adequate reduction of pollution levels. This makes it necessary to consider both areas as potential *drivers* of innovation.

[9] This growth rate need not be accomplished in developed countries, whereas it is reasonable to assume that the GDP increase in developing countries could be more than 5 % year, yielding a global average of 5 %.

3. Dimensions of technological innovation

It is obvious that reducing the burden on the environment is only possibly by improving the dominant technology and using eco-efficient innovations capable of replacing production processes and current services on a large scale. The debate, therefore, comes to center on how technology can be directed towards sustainable development. The seriousness of many environmental problems makes it imperative to accelerate the process of technological change. In this sense, there seem to be three critical dimensions:

- the speed of generation and diffusion of technology;
- the intensity of the innovation process;
- the pervasiveness of technological change.

3.1. The speed of generation and diffusion of technology

The theory of technological change and innovation management, namely those areas of industrial and corporate management which study the phenomenon of technological and organizational innovation, distinguishes between two fundamental aspects of the process leading to the successful introduction of a new technological solution:

- the generation of innovation, namely, the period which goes from R&D activities, to finding the creative idea and realizing the prototype on an industrial scale for a potential market.;
- the diffusion of the innovation, namely, the time needed for a new technology to make a name for itself alongside other products or replace existing products/processes and become the standard reference point.

Both phases are the result of a process which is extremely uncertain, complex and non-linear[10]. There are many factors outside the company such as, for example, the demand, advances in science, governmental technological policies, etc, which influence innovation capacity. These factors interact with internal variables such as corporate culture, available skills and access to financial resources, etc, which influence the outcome of the innovation process. Obviously, not all new ideas are successful on the market.

The second phase mentioned is equally complex and difficult to forecast. Firstly, the diffusion of a technology is influenced by the social and economic system which can limit or favor adoption by part of the demand. For example, we refer to consumer preferences and habits which are directly influenced by the diffusion of technological solutions. Indeed, consumers might be unwilling to change their lifestyles in order to adopt market innovations. We also refer to government policies which establish norms or specific regulations which either support or hinder the diffusion of new products and processes. Another factor is whether the new technology is compatible with the dominant technological standards or existing infrastructures. For example, in the case of automobiles, the new models of eco-compatible motor vehicles (electric or hydrogen-powered cars) cannot be marketed without completely redesigning the fuel distribution systems.

[10] See Tidd et al. 2001; Freeman 1992.

Finally, the success of a new technological solution is influenced by factors related to product competitiveness. For example, it is well known that the success of an innovation largely depends on the ability of a company to develop an effective marketing strategy. Indeed, it is often the case that companies, especially those operating in the high tech sector, concentrate too much attention on R&D and neglect the commercial side. Such a policy has inevitable negative repercussions since the company is unable to create a demand for the innovation. Indeed, the best technologies are not always successful on the market. For example, we have the case of the Sony Betamax video reproduction system compared to the VHS technology.

The issue of the development of new technologies, which is central to achieving sustainable development, can be interpreted in the light of the two dimensions we have pointed out. Studies on innovation theory clearly demonstrate that it is difficult to predict the course of technological change and the time it takes to generate and spread new solutions in the market can be extremely rapid or very slow. Consider, for example, how rapidly the chips in PCs have improved their performance compared to that of batteries. In the first case, exponential increases have been obtained in very few years. By contrast, in the second case, despite the investments made by the companies which produce these components, it is still difficult to find a a lap-top with a battery-life of more than three hours.

However, the environmental crisis calls for rapid responses. In this sense, the pressure from institutions (incentives for research, economic subsidies, regulations etc.) and from demand can play an important role in fostering the development and spread of environment-friendly solutions which are thus generated and adopted more rapidly.

If we consider the case of CFCs, norms and consumer demand, especially strong in the developed markets of northern Europe, have strongly encouraged innovation and, in a few years, this led to the development of alternative technologies and the gradual replacement of CFCs. We should remember that the discovery of the hole in the ozone layer over the Antartic dates back to 1985 and the Montreal Protocol was signed in 1987. This was the first agreement which blocked production levels of chlorofluorocarbons. Today, CFSs have been completely replaced by other products (cooling fluids in refrigerators, foams, etc).

A completely different case which highlights the complexity of the phenomenon of innovation and the difficulty of accelerating environmentally-friendly technological change is the diffusion of renewable energy sources. Despite the R&D programs financed by public institutions or carried out by private companies, solar energy has not become widespread due to the high costs and the lower yield compared to traditional sources. Another example is the replacement of the dominant technologies in the transportation sector with cleaner technologies. Although the environmental issue is pressing for rapid changes in the currently dominant standard, namely, the endothermic gasoline engine, it will take many years for alternative technologies (hybrid engines, electric and hydrogen engines) to be marketed on a wide scale.

3.2. The intensity of the innovation process

A second concept which needs to be explained in order to better understand the relationship between technological change and sustainable development, is the intensity of the innovation process. By this expression, we mean the level of environmental efficiency that the new generations of products and services must have. However, before discussing this concept, some principles on innovation theory might be useful to better pinpoint the typologies of the existing phenomena.

An initial aspect refers to the importance of the innovation,. Redesigning the packaging of a detergent to make it more eco-compatible is different from changing its chemical composition and replacing the noxious ingredients which pollute the environment. Even more so, choosing new colors for a line of automobiles is completely different from developing a new model or innovating the product concept (a new engine or new transmission system). Technological solutions, therefore, can present different degrees of innovation which have a completely different impact on the economic and social system. For example, just think of the changes brought about by the information and communication technologies or, in the past, by the invention of steam engine. Both had a global reach affecting all sectors of the economy. additional services by a bank.

In this context, the English scholar Christopher Freeman distinguishes between three types of innovation according to the degree of innovation analyzed (Freeman 1992):

- *incremental innovation*, namely, innovations of a continuous nature which lead to a gradual improvement in product/service/process performance (for example, a new PC with a bigger memory);
- *radical innovations*, namely, innovations of a discontinuous nature which can lead to considerable cost reductions or the creation of completely new markets (for example, the introduction of the CD by Philips and Sony in the sector of sound reproduction);
- *new innovation clusters*. This expression refers to families of radical innovations which cross-fertilize and combine, thereby giving rise to new industrial sectors. One example is represented by synthetic materials or environmental technologies (for example, water depurators or technological waste treatment).

In the last few years, the environmental issue has stimulated the development of numerous incremental innovations designed to improve product/service performance and production processes with respect to the "ecological" parameter. This is the case of the measures introduced in transformation processes which have led to a reduction in noxious emissions and improved efficiency in the use of raw materials. Moreover, product innovations have made products more eco-compatible, for example, by reducing the consumption of electricity or making packaging lighter. If we consider automobiles, incremental innovations applied to engines, transmission systems, the car body, etc. have improved performance and reduced fuel consumption per kilometer. Similarly, innovations in fuel (for example gasoline which delivers greater power) and catalysts have led to a considerable reduction in noxious emissions of lead and NOx.

However, according to numerous authors, the objective of sustainability requires the development and diffusion of radical innovations, namely, solutions which can bring about real breakthroughs with respect to current performance. The most obvious example is represented by the new hybrid or hydrogen engines[11]. Moreover, new technology families, which Freeman calls innovation clusters, will have to be rapidly launched on the market. This is the case of the new materials technology and nanotechnology which, in the future, will bring considerable savings in the utilization rate of environmental resources. Although

[11] This and many other examples can be found in "Natural Capitalism" (Hawken et al. 1999).

necessary, incremental innovations are not expected to be sufficient to curb the demographic and economic growth now underway on the planet.

3.3. The pervasiveness of technological change

The last dimension identified refers to the pervasiveness of technological change. If, in fact, the environmental issue is global in nature and has an impact on all sectors of production and consumption, similarly, the processes of the diffusion of environmentally-friendly innovations must also be all-embracing and pervasive. This means that all industrial sectors must be involved and that there must not be any barriers of a geographical nature to the diffusion of innovations.

As regards the first aspect, we must point out that within the economic system the innovation process takes on different connotations in accordance with the characteristics of the production sector being considered. In fact, there are numerous studies which show the existence of great differences between sectors as regards the source and direction of technological change. On the one hand, there are sectors which play a key role in generating innovations, on the other, there are sectors which mainly acquire innovations from abroad, incorporated in the supply of goods and services[12].

In this context, since some companies, such as those operating in the scientific sector, will be in a position to generate and spread new technologies in the economic and social fabric, they will assume a key role in the process of environmentally-oriented technological change. If we consider the example of new materials, the technique of manipulating the structures and therefore the properties and behavior have made it possible to obtain materials which, when applied in different areas, will be able to provide better performance in terms of intense resource utilization and energy efficiency. This is the case of the automobile industry and the design of innovative vehicles which in the next few years will benefit from the results of this new industry to build extremely light car bodies. The same holds true for the telecommunications industry where the development of optic fiber cables, which are replacing the copper ones, is making it possible to obtain exponential increases in efficiency.

As pointed out earlier, the pervasiveness of change depends on the global diffusion of the new eco-efficient technologies. This leads us to one of the most current issues, which is central to the current debate regarding sustainable development, namely, technological transfer and technological cooperation between the advanced economies and the emerging or developing countries.

In fact, although it is true that the industrialized world is responsible for much of the current pollution, it is also true that the emerging and developing countries, which have so far played a secondary role in contributing to the earth's pollution, represent a potential environmental threat[13] because of their expected demographic and economic growth. Some of the reasons for this situation are the following :

[12] In this connection, see K. Pavitt's classification which distinguishes between five sector types according to the capacity to develop and transfer innovation: supplier dominated, scale intensive, science based, information intensive, specialised supplier (Pavitt K 1984).

[13] In this case we refer to global forms of pollution such as the greenhouse effect or the hole in the ozone layer. In fact, in the last few years an increasing number of environmental crises has involved the developing countries. In this connection, the Brundtland report underlines how underdevelopment poses serious problems of the exploitation of natural resources and pollution. For example, we can point to the industrial accident in Rumania in early 2000, which caused one of the worst ecological damage to an uncontaminated ecosystem, i.e. the river

- the significance of this process of growth which involves a large part of the world population. Numerous nations, in fact, still have not saturated their need of durable and non-durable consumer goods. For example, just think of the diffusion of products such as electrical appliances and the automobile in new markets like China and India, today considered of the utmost strategic importance.
- lower environmental awareness resulting in less stringent laws and less social control so that the ecological issue is much less important than other political and economic goals. As a result, the industrial sector is not very sensitive to the issue of sustainable development and there is a prevalence of process and product technologies which are environmentally inefficient;
- a gap in terms of scientific and technological competence in many industrial sectors which makes the development of technologies with low environmental impact even more problematical.

It is, therefore, obvious that sustainable development in these countries requires considerable technological support in order to avoid making the mistakes made by the more industrialized countries and to initiate development based on the best available environmentally-friendly technologies[14].

4. Environmental protection as the driving force behind the innovation process

The relationship between technological change and the environment comprises a number of complex, continually developing relationships. Technology has an intrinsically dual nature: on the one hand, it represents an element of risk and danger since it can have negative effects on the ecosystems, on the other, by furnishing the instruments necessary to reduce the environmental impact, it probable represents the only real response to the problems of sustainable development.

Moreover, the ecology variable resulting from market mechanisms (competition between companies and the development of demand needs) and the pressure from regulations becomes a significant driving force behind innovation at different levels of individual companies, the industrial sector and the national economy. In this sense, for years governments as well as national and supernational institutions (for example, the UN and the EU) have increasingly allocated funds for scientific research on environmental issues through programs and specific projects. These funds have been used for both basic and more advanced research such as applied research and the development and industrial application of new technologies. The same holds true for the industrial sector which since the second half of the '80s has begun to allocate a part of its economic, financial and human resources for research on new solutions having low environmental impact. Some examples include the measures adopted by the chemicals sector, electric household appliances, the problems of replacing CFCs, the agro-food sector, the problem of pesticides, the paper industry with the use of pulp

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Tisza in Hungary, as well as the lower Danube basin (see http://news.bbc.co.uk/hi/english/world/europe/newsid_642000/642880.stm#text), the polluted air in megalopolies such as Mexico City, Bombay, Lagos, the clouds of dust that darken the sky of Malaysia due to the unregulated deforestation in Indonesia (in the island of Sumatra).

[14] Refering again to the environmental Kuznets curve (see § 2, footnote N. 9), it will be necessary to help those countries to pass from the positive slope part of the curve to the decreasing part, through the so-called "policy tunnel", which would allow avoiding the part of the curve where the environmental impact is maximal (Munasinghe 1995).

without chlorine and the development of technologies for processing and using scrap paper instead of virgin fibers.

Moreover, the emergence of the ecological issue has led to the creation and development of a new production sector with the exclusive aim of protecting the natural environment: the environmental industry. This industry includes air and water depuration, activities related to waste processing and disposal, cleanup operations etc. Additionally, companies now design, supply and manage plants operating in these areas. We must also mention waste collection and separation, the recovery and recycling of the materials and related logistics processes. Finally, there are increasingly significant developments linked to eco-efficient and so-called clean technologies, also leading to the development of specialized segments of industry (see, e.g., "Natural Capitalism" – Hawken et al. 1999).

Therefore, the ecological factor resulting from the stringent norms, the pressures of competition and the opportunities offered by the demand for new product/services, influences and orients the innovation processes of companies to such an extent that it becomes a real driving force behind industrial development Figure 2 below illustrates this relationship.

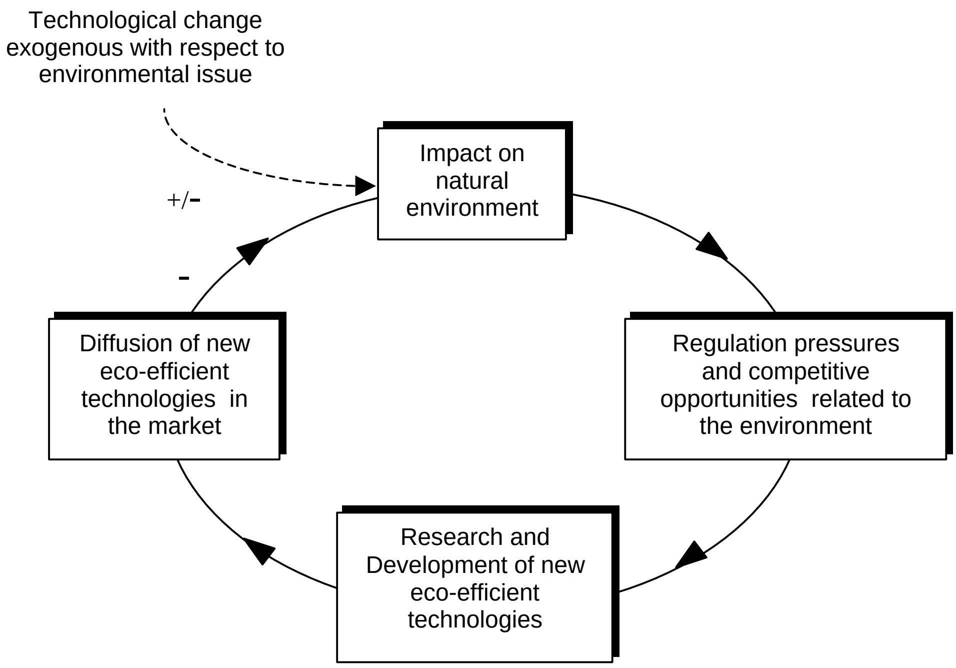

Figure 2. – Environment as the driving force behind the innovation process.

On the one hand, technologies develop independently with respect to the environmental issue, proceeding along independent development trajectories. In other words, technological change is an exogenous variable which has a positive or negative impact on the environment according to the specific kinds of innovation considered. On the other hand, the dynamics of innovation is affected by the regulations and opportunities for competition related to the environmental issue.

5. Environment as a strategic company variable

Although the models which interpret the technological change focus attention mainly on the process of interaction between the different actors belonging to the competitive and public systems, innovation usually takes place within a company. This means that the company, through activities of strategic planning, rationalizes and combines the exogenous determinants and directs the innovation process towards specific objectives based on its areas of competence, available resources and relationships with other outside subjects (customers/consumers, suppliers, competitors, research centers etc.). At the same time, the commercial and marketing activities promote the diffusion of the new technological solutions within the economic and social fabric in order to obtain the most stable and permanent competitive advantages.

These considerations attribute to companies a key role in the transition towards sustainability which becomes the protagonist of technological change. In fact, if innovation represents a process which can be planned and managed according to specific objectives, environmentally-friendly solutions must come from the headquarters, research centers, planning and engineering departments and marketing department of companies.

For years now the industrial world has been aware of its responsibilities as regards the environmental issue. Regulatory, social and competitive pressures have made the ecological factor a strategic variable which offers important competitive opportunities for those capable of correctly interpreting the current trends in a pro-active way. Obviously the capacity of a company to transform ecology into a market opportunity depends on many conditions which cannot all be directly controlled. The decisions of the public operator in terms of environmental policy and the responsiveness of the demand to ecological issues are two exogenous variables which can be extremely important in promoting or discouraging favorable/negative positions with regard to the protection of the natural environment. Moreover, a company’s capacity to compete successfully is based on its ability to interpret current trends, interact with the context in which it operates and develop adequate strategies. In this sense, a company’s areas of competence and internal resources are the key factors which allow it to turn restrictions into opportunities by developing a correct strategy, realizing technological and organizational innovations and adopting suitable management instruments. Therefore, even in the environmental sector it is the company which must first of all interpret regulatory trends, public opinion and market demands and transform them into elements which are useful for value creation.

This has been confirmed by numerous studies carried out in the last few years which show that proper environmental management based on a pro-active strategy (which proposes and anticipates) makes it possible to obtain new competitive advantages[15]. In a market in which an increasing number of sectors are finding it more and more difficult to remain competitive, the ecological variable offers the possibility to regain margins of efficiency and to identify new ways to improve product quality. In this perspective, the environment becomes an integral part of the decision-making processes of companies since, according to the sectors and companies, it can become:

- *a barrier to entry or a condition to remain on the market*. The need to compete on the global market forces many companies to adopt the rules of the more developed markets. In contexts like central and northern Europe (for example, in Germany, Holland, and the

[15] See Bennet & James P 1999; Porter & Van der Linde 1995.

Scandinavian countries), a more mature demand and regulations which often anticipate EU decisions exert strong pressure on the supply and become an entry barrier for those countries which do not guarantee adequate environmental performance. In the mid ‘90s, in the white goods sector those countries forced competitors to introduce products with high ecological performance (hydrocarbon-powered refrigerators with low energy consumption, washing machines with low water consumption etc.) or be excluded from the market. For the Italian companies, which were very competitive in many central and northern European markets, this meant accelerating innovation processes to meet consumer requirements. If the products had failed to meet environmental demands, market share would have been automatically lost.

- *a factor of rapid obsolescence of products and technologies*. The emergence of problems linked to environmental protection can lead to rapid obsolescence of products in the middle of their technical and economic life. This is the case of substances like CFCs which have been eliminated following international agreements and national norms, or fuels like the traditional gasoline which will be banned from 2001 in order to promote the spread of motor vehicles with lower environmental impact (consumption per kilometer and noxious emissions) thereby accelerating the process of replacement now underway. Another example is the use of technologies for waste disposal like landfills which are very common in countries such as Italy and Spain. Faced with the EU environmental policies, these countries will see a gradual reduction in the market of these technologies.

- *an element of supply differentiation*. The environment can become an important factor of differentiation by enhancing the product with an additional benefit. As is well known, the possibility of adopting this strategy depends on the existence of segments of the demand which have an interest in the differential value of the supply which, in this case, is represented by the ecological features of the product. Although in contexts such as the Mediterranean, environmental awareness is not easily transformed into environmentally-friendly consumer behaviour, there is ample room to position the supply as a function of the ecological factor. In this connection, in addition to examples like the Fattoria Scaldasole, the Favini Paper Company and Ecolucart in Italy, we can add AEG-Elctrolux, Patagonia and the Body Shop[16] at an international level;

- *an opportunity to create new business*. In the last few years the protection of the environment has given rise to the creation of many new markets resulting from the emergence of new collective needs and new regulatory norms. This is the case of the waste management industry which led to the development of the composting sector, the technology of waste separation, the modern incinerating technologies or the recycling industry[17]. Another example is the case of the Belgian company Ecover, which was created to produce and promote new kinds of detergent and cleaning products, much more oriented towards sustainable development (ECOVER 1992).

- *a lever to reduce costs*. A preventive approach to environmental management pays off through a reduction in production costs and waste reduction, the optimum consumption of raw materials and energy and optimization of the left-over material produced. Computerized process automation, the creation of closed or integrated processing cycles, the building of heat reconversion systems are some of the possible measures that can be adopted to make production processes more productive thus combining ecology and efficiency. Moreover, waste reduction, made possible by the introduction of technological

[16] For the Fattoria Scaldasole case study see Pogutz & Tencati 1997; for the others Italian cases see IEFE and ICEM-CEEM 1998.
[17] See SPACE 2000.

innovations in the plants, makes savings possible by reducing disposal costs and increasing the yield. Similarly, an ecological product design can prevent future problems when a product reaches the end of its life cycle. This is the case, for example, of the burdensome measures required to redesign a product in order to replace dangerous materials or to simplify operations of recovery, recycling and disposal[18].

- *an important variable in the choice of investment*. The environment becomes an important element in any kind of investment (building a plant, launching a new product, acquiring a company). This means immediately considering running costs (for example, the cost/management of production waste disposal or the cost of personnel involved in environmental activities), capital expenditure (like the investments made in emission procession plants, research and development of efficient technologies and products) related to the investment operations analyzed. The same holds true for the profits/benefits deriving from the exploitation of waste materials or the savings in raw material and energy. Moreover, particular attention must be paid to those items which are less evident or hidden and may sometimes significantly change the economic return on the investment. This is the case, for example, of the cost of demolishing and recovering sites at the end of their useful economic life or the hidden environmental passivity when Mergers & Acquisitions[19] operations are carried out.
- *an element in the proper management of contacts with stakeholders*. The increasing attention of the media, institutions, public opinion and financial intermediaries to the environmental variable requires the careful management of all production sectors. The pressure from stakeholders can, in fact, influence company operations in various ways. Communities and local interest groups can, for example, force a company to shut down a plant or force it to introduce clean technologies for the treatment of toxic emissions if it wants to continue operating[20]. Extremely high environmental hazards can, instead, weaken the confidence of capital markets, thus jeopardizing the company's capacity to obtain resources. Just think of the Exxon case and the repercussions on the value of its listed securities following the accident involving the Exxon Valdez oil tanker. Moreover, a negative environmental image can lead consumers to boycott a company's product or make the public administration impose severe controls. For example, in 1996 Greenpeace became involved in a clash with the Shell oil company when the Brent Spar oil rig. Therefore, a correct ecological policy is fundamental in creating public consensus and a positive corporate image–factors which are becoming increasingly important in guaranteeing optimal conditions for development.

The environmental variable has, therefore, become incorporated into company policy and innovation has come to be the principal instrument for reaching eco-efficiency objectives.

[18] The pilot project PRISMA (Dieleman & de Hoo 1993) demonstrated that in many practical situations (indeed, more than half of the actual possibilities investigated in ten Dutch companies), a preventive approach resulted in positive returns on investment, with a payback period as short as one or two years.
[19] Some researches have estimated that the incidence of environmental costs in some production sectors (energy and chemicals) reach values equal to 15%-20% of operational costs (See EPA 1995; EPA 1997; Shields et al. 1997; Bartolomeo 1997; De Silvio & Tencati, to be published in 2002)
[20] As regards the location of some types of plants (incinerators, disposal sites, thermoelectric or nuclear power plants, chemical plants, etc.) the term NIMBY (*not in my back yard*) has been used for the last few years. This acronym expresses the hostile response of citizens to setting up production activities in residential areas. In fact, the community refuses the negative connotations of opening a new plant (usually citing the smell, noise, atmospheric emissions, risk of accidents, reduction in land and property value, etc.) in their neighborhood. The citizens form committees (often with the support of other concerned parties such as environmental groups, politicians and the media) to obstruct the project. These initiatives are often effective and force the companies to modify their development plans with inevitable economic consequences.

6. The company and the forms of environment-friendly innovations

For the last few years scholars and businessmen have dealt with the issue of environment-friendly innovations and have proposed several models in an attempt to rationalize the different possible ways companies can intervene. The approach adopted here is very simple and refers to some typical concepts of innovation management. On the basis of the dimension and the object of the innovation, we can therefore distinguish between (see Table 2):

- *process innovation*, namely, new technological solutions which modify the characteristics of production systems and are aimed at plant operations (new installations, new production methods, etc);
- *product innovation*, namely, changes in products/services made by the company which range from product improvement, to product redesign up to radical changes in the product concept (e.g. function innovation);
- *system innovation*, which identify new organizational solutions at the supply chain level, in the contacts with competing companies and subjects outside the competitive system such as consumers, institutions, environmental groups etc.

Table 2. – Forms of environment-friendly innovations

<table>
<tr><th>Type of innovation</th><th>Process innovation</th><th>Product innovation</th><th>System innovation</th></tr>
<tr><td>Competitive advantage obtained by the company</td><td>Cost leadership</td><td>Differentiation</td><td>Both</td></tr>
<tr><td>Intensity of the environmental benefit following the innovation</td><td>+</td><td>+/++</td><td>+++</td></tr>
<tr><td rowspan="2">Theories and managerial approach to the issue of sustainable development</td><td>End of pipe technologies</td><td>Design for Environment</td><td rowspan="2">Zero waste management
Industrial ecology and Industrial Ecosystem</td></tr>
<tr><td colspan="2">Cleaner technologies</td></tr>
</table>

It is obvious that this distinction is mainly systematic. In fact, innovation phenomena often develop at the same time. This means that, for example, product innovations almost always imply reviewing how a product is made and this means modifying existing production plants. Similarly, new supply chains can lead to product redesign (just think of the need to standardize packaging to make transportation more efficient). Moreover, new process solutions can lead to new products as in the case of chemical substances or pharmaceuticals.
This classification allows us to examine the different ways companies can increase their environmental performance, considering the competitive dimension (the opportunity to obtain competitive advantage), the ecological one (intensity of the environmental benefit). Table 2 also shows some of the managerial approaches to the environmental innovation issue. The

following paragraphs analyze the different types of environment-friendly innovations shown in Table 2.

6.1. Process innovation

This includes all new technological and organizational solutions designed to promote, directly or indirectly, improvements in environmental performance stemming from operations related to resource transformation. More precisely, the measures can involve:

- reducing the consumption of natural resources (for example, water and raw materials and energy per product unit;
- reducing polluting output (air, water, soil, waste emissions and noise) per product unit;
- minimizing the risk of accidents.

The object of innovation can include:

- *the overall production process*. For example, adopting new processes which are intrinsically less polluting, that can be the result of acquiring patents or in-company development of new technologies. Another option could be to rationalize the production phases (for example, by reducing them) thus reducing the amount of waste produced and lowering the risk of accidents;
- *the plants*. This is the case of control systems (new measurement switchboards), energy sources (the adoption of renewable sources of energy in place of the existing ones), machines for individual operations (for example, replacing materials which are dangerous to operate with those less harmful to the environment);
- *the recovery and recycling.* This means shutting off production cycles in the factory (for example, the recycling of processing water), heat reconversion, or using production waste/leftover material in other company plants.
- *the process management*, namely the introduction of innovations at the organizational and procedural level thereby making it possible to utilize plants and existing resources more efficiently[21].

Starting from these considerations, some additional points should be made, regarding the economic advantages connected to the introduction of these innovations. First of all, it is opportune to recall the concept of the productivity of the resources. In fact, the protection of the environment, when it favors the development of more efficient production processes as regards the use of energy and raw materials and waste reduction, is absolutely in line with the search for economy. It is therefore a matter of close interdependence between competitiveness and ecology. Moreover, as M. Porter (Porter & Van der Linde 1995), points out, the managerial approach commonly adopted in the 80s such as *Total Quality Management*, *Lean Production* and *Just in Time* aimed to optimize production cycles but also favored better environmental yields. Environmental innovation, therefore, makes it possible to obtain a competitive advantage by pursuing a strategy of *cost leadership.*

[21] The rules of good housekeeping can considerably promote improvements in environmental management. Possible areas on intervention include: optimizing the use of the production capacity installed, minimizing interruptions, programming maintenance, training personnel, reducing set-up times etc.

In this connection, it is useful to introduce an additional classification of environmental technologies which distinguishes between end of pipe technologies and cleaner technologies. The first concept refers to the treatment of pollution following the production processes. These are *ex*-post measures which do not imply modifying production plants and merely transform substances which damage the environment into other which are less noxious. Typical are depuration plants for toxic emissions (in the air, water, soil) and solutions to the reuse or disposal of waste. However, a different approach characterizes the second type of solution. By cleaner technologies we mean preventive measures (ex-ante) which imply making radical changes in processes and which reduce the environmental impact. These innovations therefore intervene at the source of pollution produced by the plant thus avoiding costly investments in ex-post technology. The technological transformation is definitely high since the solutions which directly transform the plant are quite complex whereas the end of pipe technologies are added to existing processes with partial or marginal adaptations. An additional difference refers to the economic aspect. The cleaner technologies, in fact, represent true investments since by modifying the characteristics of the process they can lead to a number of benefits such as, for example, saving in the use of materials, increases in yield, waste reduction at the source with obvious economic benefits in terms of treatment/disposal costs, reutilization of leftover material and by-products. Instead, the end of pipe technologies mainly generate operating costs which can hardly bring the company economic benefits. As the example given in Table 3 shows, end-of-pipe solutions can never be profitable, while prevention technologies (including clean technologies), in addition to obvious environmental advantages, can be profitable, even in some cases with very short payback periods as we have mentioned above for the PRISMA project. This is mainly because end-of-pipe technologies imply only add-on operating costs, while in most situations prevention solutions allow for a significant reduction in operating costs, which can even be accompanied by an increase in annual returns due to better product quality and improved brand image. The result, even if investment costs can be considerable, is a positive payback period, while this turns out to be negative for end-of-pipe solutions.

In conclusion, the development of an innovation strategy along the lines described above makes it possible to improve environmental performance and can, at the same time, favor a reduction in production costs per product unit.

Table 3. **-** Comparative economic advantages of end-of-pipe and prevention technologies.

	Current situation	New situation	End-of-pipe technology	Prevention technology
Investments	I1	I2	I2 > I1	I2 > I1 (>>?)
Annual operating costs	O1	O2	O2 > 01	O2 < 01
Annual returns	R1	R2	R2 = R1	R2 = R1
Payback period			T < 0 !	T > 0

Note: Payback period defined as

$$T = \frac{I2 - I1}{(R2 - O2) - (R1 - O1)} = \frac{I2 - I1}{(R2 - R1) + (O1 - O2)}$$

6.2. Product innovation

The integration of environmental aspects into product design and development is one of the most interesting challenges companies have to face in the very near future. As seen in the previous pages, the road to sustainability forces the diffusion of a new generation of products and services with a higher eco-efficiency (see Table 2). According to this principle, environmental attention in the last decade has rapidly shifted from production processes to products and services across their whole life cycle (from cradle to grave)[22].

The starting point is to define what is an environmentally friendly product. Most of what has been said about process innovation can be said about product innovation. In particular, the concept of *clean product* or *green product* is linked to the concept of clean technology. However, especially in this case, the concept has a closer relationship with the consumer and the market structure. Environmental aspects have to match with other product functions and benefits required by the demand (quality, costs, fashion, safety, etc).

According to the intensity of the innovation, we can identify three levels of product innovation:

- *product improvement.* This stage involves partial improvements in environmental impacts, mainly due to incremental innovations. For example, the substitution of hazardous substances, the increase in energy efficiency and material savings (e.g. a new washing machine that needs less electricity and water per wash), the reduction of the packaging weight.
- *product re-design.* The product concept is still unchanged, but incorporate greater environmental improvement along the whole life cycle. More radical innovations alters the system architecture of the product, the core components (new engine, internal recycling, new lighter materials) and the production technologies (cleaner technologies in paper production);
- *function innovation.* This level is related to the design of a new product concept based on the current function of the product. This means a radical transformation in the firm business model moving from product-focus to service-focus. The precondition for these changes is that the value for the customer is linked to the function of the product rather then to the product per se (Reskin et al. 2000). From an environmental perspective function innovations seem to guarantee strong benefits: through decoupling volume from profitability, firms and customers are interested in the maximization of resources efficiency. The most significant example of function innovation is probably occurring in the household appliances industry, where companies are moving from appliance manufacturers to cleaning service firms, selling pay per use service to consumers (e.g. Electrolux, Ariston, etc.)[23].

[22] International trends shows that new concepts such as Extended Producer Responsibility (EPR) and Integrated Product Policy (IPP) are rapidly becoming key tools within the policy makers and the business actors. See Ernst & Young, SPRU. 1998; European Commission 2000.

[23] Many companies in different industrial sectors are following this pattern of innovations: Xerox is moving from selling photocopy machines to providing document reproduction services; Castrol is providing customers with a series of services offering opportunities in reducing lubricant consumption (developing profit from consumers cost savings) instead of selling lubricants per se; even in the automotive some companies as Ford are following this new approach. (Reskin et al. 2000; Dobres & Wolf 1999).

On the other hand, a product can be qualified as *clean* or *green* for one or several of the following reasons: (1) because its production did not require the uptake and use of rare, nonrenewable natural resources (taking into account, among other, the possibilities of waste product re-use or recycling), (2) because it has been produced through cleaner technologies, (3) because its distribution and consumption does not give rise to excessive amounts of wastes or effluents that are harmful to human health and/or the environment. Environmental impacts occur at all stages of product life cycle. For some goods the problems are mainly due to consumption of raw materials and production processes (e.g. paper and furniture). In case of complicated products (households, cars, electronics) the use stage embodies most of the environmental load. Finally, in cases of hazardous substances (batteries) the environmental impacts might be related to waste disposal.

At a practical level, companies have to introduce environmental assessments at the design stage of the products. Most of the impacts are locked into the product since the very beginning of the concept design and development strategy (Lewis & Gertsakis 2001). The methodology that helps managers in integrating ecological issues in the product development process is called Design for Environment (DfE)[24]. DfE encompasses the entire life cycle of the product (from raw material extraction to waste disposal and recycling in other products) and provides a very powerful tool to increase the product sustainability[25]. The DfE is strictly based on the information emerging from the application of another environmental tool: the Life Cycle Assessment (LCA)[26]. LCA provides specific data on environmental impacts of different technical options and informs the product development team about critical stages of life cycle. Moreover, by mapping critical product features, LCA identifies the environmental performance targets of the new product. In Table 4 some guidelines for environmentally friendly design strategies are presented.

Table 4. – Some guidelines for DfE (Behrendt et al. 1997).

a) Minimize the use of non renewable or scarce resources
b) Use of renewable resources and available resources
c) Increase product durability (product life)
d) Design for product reuse and material recycling
e) Design for disassembling
f) Minimize hazardous substances
g) Minimize the environmental load of the production process
h) Minimize the environmental impact of product use (e.g. energy and material efficiency)
i) Use environmentally friendly packaging
j) Provide for environmentally friendly disposal of non recyclable substances
l) Increase the logistics and reverse logistics eco-efficiency

[24] Other terms that define the development of environmentally friendly products are: Life-Cycle Design, Ecological Design, Sustainable Product Design, Green Design.

[25] The number of companies that are implementing the DfE methodology is rapidly increasing: Electrolux, Philips Electronics, Hewlett-Packard, Xerox, Sony, BMW, Ford, Daimler-Chrysler, to name but a few.

[26] Life Cycle Assessment is the most important method for assessing the environmental impacts of products through the whole life cycle. According to the SETAC's guidelines, an LCA has four major stages: goal definition and scoping, inventory analysis (Life Cycle Inventory), impact assessment and improvement assessment. See SETAC (1993);

To be effective, DfE must be integrated in culture of the company as the product development is a highly inter-functional and interdependent process. Environmental designers have to work together with the design team (marketing, designer, R&D and innovation, engineering), internal functions (operations, logistics, general management, finance) and external stakeholders (suppliers, consumers, government, NGOs and other environmental pressure groups). This multidisciplinary approach is essential to develop a successful product strategy, matching different points of view inside the firm and coordinating environmental responsiveness with commercial viability.

There exist various examples of so-called "clean" or "green" products in different industrial sectors (electronics, household appliances, packaging, chemicals and detergents, etc.). An interesting and original case study is provided by an Italian company called Cartiera Favini (now Favini Group)[27]. The firm, which is dedicated to the production, commercialization and conversion of Specialties, has started in the early ’90 a process of ecological conversion. Favini has developed a strategy focusing on creating value through continuous innovation in niche markets of high quality and ecologically friendly products (Bertolini 1995). The attention for the respect of nature has deeply influenced the product development strategy. Since the ’90 the company has pursued two main ecological objectives:

- the utilization of low environmental-impact cellulose;
- the systematic reduction of wood cellulose substituting with non-scarce raw materials (corn, algae, sugar beet, etc.).

In 1992 a new family of products called EcoFavini was created (see Table 5). The innovation strategy and the investments in environmentally friendly processes and products led the Favini Group to obtain several (national and international) awards and international patents. In 1997 Favini was the first Italian paper mill to obtain the ISO 14001 certification. Furthermore, the attention to the environment initiated a virtuous circle that has allowed the company to increase the profitability through:

- reaching ecological consumer, who are willing to pay a premium price for the environment;
- reducing production costs;
- building an international ecological image with consequent advantages when participating in competitions and public projects.

[27] The Favini Paper-Mill was established in 1757 when the Republic of Venice authorized the transformation of a windmill in a paper producing factory. In 1906 the paper-mill came under the ownership of the Favini Family. In 1998 the company started a process of strong growth and development through takeovers and acquisitions in Italy. In May 2000 the Favini Group purchased in England Astralux, from the multi-national Sappi Fine-Paper. In September the Dutch Gelderse Papiergroep was taken over by the Italian Group. Turnover in 2001 is estimated to reach 250.000.000 Euro (31.000.000 Euro in 1998), and production will amount to 130.000 tons. (25.000 in 1988). The Favini Group controls the 14% of market share in Europe in the sector of specialty products (Graphic Specialties). For more detailed information see www.favini.it.

Table 5. – Favini Group eco-innovarion strategy (ECOFAVINI family)

EcoIris	Paper based on Chlorine free cellulose (Elemental Chlorine free or Total Chlorine Free)
Algae paper	The Algae Carta contains excessive algae removed from the Venetian Lagoon. The algae is dried, transformed in algae flour, and used in paper production without creating by-products or pollutants in the transformation process. For each kg of paper the final product contains half a kg of fresh algae (3%-24% of algae flour). The paper produced is of high quality and of light green color because of the chlorophyll. Also the technical characteristics (e.g. chemical and physical resistance) of the product are superior to other quality papers.
Tree free paper	These paper and card products are free of wood fibers and based on vegetable residues. Seaweed, the residues from processing corn, wheat, lemons, orange and sugar-beets are converted into flours for paper without using chemical products and without the formation of residuals. For example, with surpluses of sugar beet Favini created the **Sugar Paper.** Furthermore, with the residues of the squashing citrus fruits Favini has created the **Orange Paper** and **Integral Mais Paper** with corn-cob and bran flour.
Smog Paper	This paper is produced with a completely new technology. A new industrial pilot plant for the treatment of combustion gases coming from energy power stations converts them into Smog Flour that can be used in paper manufacturing. The boiler fumes are converted into the Turbofixer, the acid gases (e.g carbon dioxide) contained in the fumes are fixed in an alkaline matrix (e.g calcium residues), producing calcium carbonates and other insoluble neutral salts that are called Smog Flour. This product is ready to be used in the production of Smog Paper instead of mineral fillers used in the paper transformation. At the same time there is a positive environmental effect through the reduction of acid emission released in the atmosphere.

See www.favini.it/eng/images/crusinallo/filepdf/percorso.pdf

6.3. System innovation

A quite different perspective appears when we speak of system innovation, although the same basic concepts prevail, regarding adequate management of natural resources and pollution prevention. As the word indicates, innovation is no longer considered at the scale of individual plants or companies, but rather at the scale of whole systems of such plants or companies. It is often the case that waste products that are of no value to the company who produced them, can be exploited as useful inputs within other industrial activities. The innovation that then takes place requires a completely renewed mindset, because companies are normally not prone to collaborate with each other, in environmental matters not more than in other matters. In fact, there is no true innovation because what we do when we promote such interconnections is simply a mimicry of what nature tells us to do. In nature, nothing is lost; all wastes produced by some kinds of organisms become useful feedlot for other kinds of organisms. Such an analogy explains the terms that are generally used when we speak of such industrial associations; we speak of *industrial ecology* or *industrial metabolism*. More generally, we can speak of industrial ecology when the complete design and implementation of industrial processes are thought from the outset with the perspective of rational and sustainable management of natural resources and wasteful by-products.

Although the potential of industrial ecology is rather high, there are still only few examples of implementation. One example is provided by the cement industry, whose activities can be conceived within a system of several other industries of different types (e.g., CBR 2001). Another famous example is that of the "Kalundborg Industrial Symbiosis"[28]. In this community, the circulation of outputs and wastes is not only among industrial facilities, but also among agricultural activities and the municipality. Kalundborg was not a planned industrial park; instead, the relationships between the existing entities were at first forged for economic reasons. Now it is taken as an example for many other new industrial parks across the world.

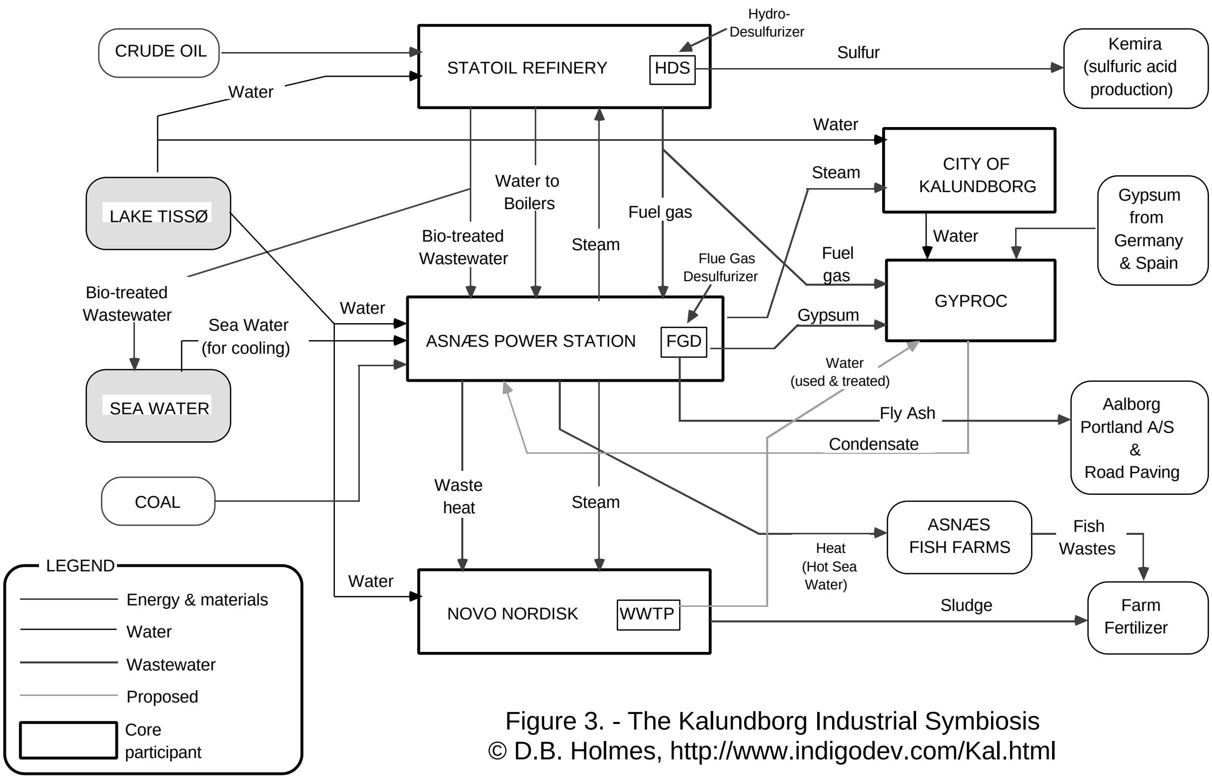

Figure 3. - The Kalundborg Industrial Symbiosis
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[28] Example taken from DeSimone & Popoff with the World Business Council for Sustainable Development, "Eco-Efficiency - The Business Link to Sustainable Development" 1997.

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