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INDUSTRIAL POLLUTION PREVENTION STRATEGY - CLEANER PRODUCTION

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Contents

Summary

Being coined by UNEP in 1989, cleaner production is the continuous application of an integrated preventative environmental strategy applied to processes, products, and services to increase overall efficiency and reduce risks to humans and the environment. The precaution & preventative principle, the integration principle, the comprehensive principle and the continuity principle are implied under the conception of cleaner production. Compared to end-of-pipe approaches, cleaner production is a win-win strategy.

After about 20 years' effort, the implementation of cleaner production has become a global activity, and has gained many achievements and had significant impact. These achievements and impact can be assessed at various levels: the technology promoter, the managerial catalyst, the paradigm reformer and the conceptual bridge connecting industrialization and sustainability. However, cleaner production also faces some challenges, such as cultural reluctance, organizational resistance, technology innovations and sustainable consumption, etc.

To implement cleaner production, a multi-tool strategy and integrated framework should be adopted: environmental management systems and other socio-economic incentives create the framework for changes. Government policies and strategies orient this framework towards clear objectives, technological tools will ensure their realization and environmental education and training will ensure a long-term result.

In the 21st century, cleaner production should expand both the stakeholder base and the activity base. Furthermore, it should be integrated into the core decision-making at both governmental and enterprises levels. Cleaner production will thus be a part of conventional economic and social practice by paying more attention to ecological

industries and sustainable consumption.

1. Introduction

The 20th century shows a clear evolution in the general attitudes of governments and industries regarding environmental impacts. Correspondingly, the awareness of the need for an integrated approach to environmental pollution and resource depletion problems is a step-by-step process.

In the earlier decades of the 20th century, three categories of environmental attitudes can be summarized: *foul & flee, concentrate & contain and dilute & disperse*. However, all these attitudes prove to fail in the long run, and cause many environmental problems and even environmental disasters, such as the photochemical pollution in London, the mercurialism accidents in Japan in the 1960s. All these problems showed that the dilute & disperse strategy was no longer effective for important point-source pollutions, and led to the first change of general attitude about the 1960s. Industries began to install purification units at the end of the emission pipes of various production processes. This reactive waste management is the so called "end-of-pipe approach (EOP)" From a historical point of view, EOP approaches played an important role in controlling industrial pollution to a certain extent. However, the EOP approach is not "the solution" because it usually causes secondary pollution and increases both the capital costs and operation costs that are burdensome to most enterprises. Even worse, the EOP approach has deeply penetrated into the routine decision-making of both industries and governments, which brings the most stubborn barrier to implement cleaner production (see in later session). In 1970s, with the emerging of the concept of sustainable development, cleaner production was proposed and advocated based on the lessons learned from traditional industrial pollution control practices. It is a pro-active and integrated solution to pollution problems by eliminating or reducing pollutants at the source during the course of production processes. These *pollution prevention* and *waste minimization* strategies appeared to be necessary to reduce the enormous costs of clean-up actions, certainly from the moment that the polluter pays principle was brought into legislation. By bringing the environmental and the business concern together, the new approach of cleaner production has proven its benefits and will be promising in the 21st century.

With the changes of general attitudes regarding environmental pollution, environmental technology, management and legislation also evolve. The technical solutions for environmental problems show a clear evolution from end-of-pipe approaches towards precaution and prevention. Since the middle of 1980s, source-oriented and product-oriented technologies are highlighted in almost every basic discipline. For example, *Green Chemistry, Green Materials* and *Green Design* are standing on the frontiers of each of their research scopes. In respect of environmental management, in the 1970s, business focused on end-of-pipe activities, i.e. to measure, prevent, limit or correct environmental damage to air, water and soil, as well as those dealing with problems related to waste, noise and ecosystems. Since the 1980s, business began to integrate the ideas of cleaner production into all business activities from production, management, budgeting, to marketing activities, instead of purely technological solutions. A similar situation also takes place in respect of environmental legislation. Early environmental legislation was introduced to solve specific and sometimes local pollution problems.

Therefore legislation was pollutant and source-specific and concerned single environmental media. This type of legislation was of the command and control type. Under this type of environmental legislation, mostly end-of-pipe technologies were sufficient to meet legal requirements. As a consequence, environmental policy and legislation did not give clear incentives to invest in cleaner production. Later in the 70s and the 80s, market instruments like charges and taxes were introduced, environmental legislation began to evolve into a more integrated market-oriented or hybrid type. After the 1990s, with the globalization of environmental problems, environmental legislation becomes more and more guided by global problems.

Although cleaner production has gained worldwide attention, it should be implemented and promoted further. Just as Dr. Klaus Toepfer, Executive Director of the United Nations Environment Programme, says, "to a large extent we have built the world-wide consensus on cleaner production. However, we have not reached the end of the road and we must foster greater commitment."

2. Concept and Basic Principles of CP

2.1 Definition

In the 1980s, there were a great number of competing concepts related to pollution prevention principles, such as pollution prevention, cleaner technologies, low-and non-waste technologies, waste prevention, waste minimization, etc. Against this background, UNEP first put forward cleaner production in 1989, "cleaner production is the continuous application of an integrated preventative environmental strategy applied to processes, products and services to reduce risks to humans and the environment" Since the term was proposed, cleaner production has evolved over time and there are a number of variations in the way it is defined. Table 1 provides various definitions of cleaner production.

UNEP (1989)
cleaner production is the continuous application of an integrated preventative environmental strategy applied to processes, products and services to reduce risks to humans and the environment.

UNEP (1996)
The continuous application of an integrated preventative environmental strategy applied to processes, products, and services to increase overall efficiency and reduce risks to humans and the environment.

- *Production processes: conserving raw materials and energy, eliminating toxic raw materials, and reducing the quantity and toxicity of all emissions and wastes.*
- *Products: reducing negative impacts along the life cycle of a product, from raw materials extraction to ultimate disposal.*
- *Services: incorporating environmental concerns into designing and delivering services.*

OECD *Cleaner production is an integrated preventative environmental strategy for processes and products to reduce risks to human health and the environment.*
EEA *Cleaner production is a preventative integrated continuous strategy for modifying products， processes or services to enhance effectiveness which improves environmental performance and reduces costs.*
Environment Australia *Cleaner Production is a strategy to continuously improve products, services and processes to reduce environmental impact, and to work towards ecologically and economically sustainable development.*
SETC, China *Cleaner Production is the continuous application of pollution prevention strategies to processes and products, through ongoing improvement of management practices and technologies in order to enhance efficiency of resource utilization, to eliminate pollution emissions and to reduce risks to people and the environment.*

Table 1: Cleaner Production Definitions

From all the definitions above, one common feature can be found: cleaner production is a preventative upstream approach rather than a curative downstream approach. The main target of cleaner production is to focus on the prevention or reduction of waste and inefficient use of energy and resources. To achieve this target, technological innovations or modifications should be made in process production, product design and even consumption patterns.

However, the conception of cleaner production still evolves. In parallel with the growth of CP, scientists, engineers, industrial managers, and many others have begun to recognize that true long-term sustainability of our industrial economic systems will require that societies learn to break our dependence on single use throughput of natural resources and growing production of wastes. This dependence has led to unsustainable impacts on the environment and disruption of natural systems. Instead, we must develop "cyclical" production systems that increasingly reuse and recycle all materials. Similar to biological ecosystems in which one organism's waste is the source of food for another organism, we must develop industrial systems in which there are no "wastes" but only residual materials that can be used to produce other useful products. This recognition has led to the concept of Industrial Ecology (IE) and the development of a new area of scientific study that examines industrial systems in the context of the natural, social, and economic systems that surround them.

2.2. The Guiding Principles

Four basic guiding principles are implied in the conception of cleaner production.

(a) The precaution & preventative principle

Precaution is not simply a matter of avoiding breaking the law, it is also about ensuring that workers are protected from irreversible ill-health and that the plant is protected from irreversible damage. The precautionary principle calls for the reduction of anthropogenic inputs into the environment, and this call is essentially a demand for substantial redesign of the industrial system of production and consumption which relies at the moment on extensive throughput of materials. Prevention is equally important, especially in those cases where a product or process is known to cause harm. The preventative principle is to look to upstream changes in the causal network of the system of production and consumption. The preventative nature of cleaner production calls for the new approach to reconsider product design, consumer demand, patterns of material consumption, and indeed the entire material basis of economic activity.

(b) The integration principle

Integration involves adopting a holistic view of the production cycle. One method for introducing the idea is through life-cycle analysis. One of the difficulties for the preventative approach is to integrate environmental protection measures across system boundaries. Traditional, end-of-pipe regulation generally applies to specific extent by calling for process-integrated measures to reduce the generation of pollutants. By reducing the need for emission into the environment of such substances, these measures thereby provide for an integrated protection of all environmental media.

(c) The comprehensive or democratic principle

The comprehensive or democratic principle involves people, workers and local residents, in the way where production and consumption are organized.

(d) The continuity principle

Cleaner production is a no-end process. Its implementation calls for the ever-lasting efforts of governments, industries and consumers.

3. Review of Status

3.1 History of Cleaner Production

Pollution prevention was practised spontaneously in many industrial sectors such as chemical industries since the end of the 1960s. However, the launch of the Pollution Prevention Pays program by 3M in 1974 is generally regarded as the first landmark on the road towards Cleaner Production. 3M thought that pollution prevention was both environmental and economic policy, it was not only the important method that leads enterprise into the clean environment, but also continuously reduced non-production cost. During these 20 years, 3P program prevented 750 thousand tons pollutants from entering the environment, saved more than 8.1 billion dollars and established the foundation of the CP concept. In Europe, the European Economic Community put forward the "low-and non-waste technologies" concept and then began to implement CP innovation, make laws, create demonstration projects of clean technology, set up information networks in 1976. The Division of Technology, Industry and Economics, United Nations Environment

Programme (UNEP/IE) formally started the CP Plan in the senior international seminar in Canterbury, UK in 1989. Owing to the catalytic role of the UNEP Cleaner Production Program, cleaner production was transferred to, and subsequently further developed in other regions such as Australasia, Asia, Latin America and Africa.

After the slow gestation period, Cleaner Production initiatives and programs go into a period of *rapid development*. A lot of industrial enterprises recognize the potential benefits of Cleaner Production and implement consciously cleaner production technologies and practices in the forms of cleaner production audit or others. Furthermore, both central and local governments begin to promote cleaner production by disseminating and training, making economic policies or formulating regulations. With such corporate efforts of industries and governments, cleaner production spreads over nations, sectors and enterprises and forms a global network.

With the progress of promotion, both governments and industries begin to recognize that whether or not 'pollution prevention pays' depends on the level of environmental legislation and its enforcement, the cost of materials and energy and the cost of management and disposal of waste and pollutants. Now, cleaner production reaches a consolidation stage. Some programs continue, some programs start with a new impetus, some programs stop, and some others experience a draw back. In one European country, about one year after CP auditing, approximately 1/3 of the factories reverted to their former state, about 1/3 retained their achieved results, few factories made forward progress.

Reviewing the present application of Cleaner Production to industrial development trends from a whole world perspective, an apparent paradox can be found: although Cleaner Production is based on a preventative mind-set, current Cleaner Production efforts are often still added in the final phases of industrial development rather than being designed in right from the start. In other words, Cleaner Production has moved industrial environmental management from the end of the *production* pipe to the end of the *innovation* pipe, but it has not yet been integrated into the innovation cycle as required for the transition towards a priori **clean** products and processes. Thus, there is still a long way for cleaner production to go.

3.2. Global Activities

The Cleaner Production concept, along with other similar meaning terms e.g. eco-efficiency, green productivity, pollution prevention etc. has earned worldwide acceptance. The implementation of cleaner production has become a global activity:

- institution of an International Declaration on Cleaner Production with over 240 senior level signatories including governments, companies, industries associations, academia, NGOs etc.
- establishment of 21 UNIDO-UNEP National Cleaner Production Canters,
- involvement of over 300 institutions, globally, engaged in CP related work
- institutionalization of CP Round Tables in major regions; Asia-Pacific, Europe, Africa, Americas along with a number of National/sub-regional Round Tables
- conducting six biennial senior level seminars on cleaner production, the latest one

being in October 2000 at Montreal
- recognition and acceptance of the concept by financial institutions like the World Bank, the Asian Development Bank etc.
- conducting innumerable demonstration projects showing the potential gains of CP,
- development and training of thousands of CP professionals

and so on…

Every two years, UNEP organizes an International High-Level Seminar on Cleaner Production to review and evaluate the progress of Cleaner Production initiatives worldwide, assess obstacles as well as opportunities for further development, and recommend future directions for UNEP's Cleaner Production Program. The 1st International High-Level Seminar on Cleaner Production was held in Canterbury, United Kingdom, in 1990. Subsequent seminars were held in Paris (France, 1992), Warsaw (Poland, 1994), Oxford (United Kingdom, 1996), Phoenix Park (Korea, 1998), and Montreal (Canada, 2000). Among them, the 5th UNEP International High-Level Seminar on Cleaner Production (CP5) marked the 10th anniversary of UNEP's Cleaner Production Program, and was the first High-Level Cleaner Production Seminar held outside Europe; The 6th International High-Level Seminar on Cleaner Production was the first of two events hosted by Canada during the week 16-20 October 2000 under the theme "Engaging the World: in advancing pollution prevention and Cleaner Production"; The 7th International High-Level Seminar on Cleaner Production (CP7) will be held in Prague, Czech Republic on April 28-30, 2002. CP7 will bring together senior-level decision-makers from around the world to address the challenges facing sustainable production and consumption.

The International Declaration on Cleaner Production can be considered as the symbol of CP's becoming a worldwide activity. Being a voluntary but public statement of commitment to the strategy and practice of Cleaner Production, it was launched in October 1998 at Phoenix Park, South Korea, with 67 inaugural signatories. Signing ceremonies at other national and international venues are continually adding more Declaration partners to the Signatory List The number of regional and national signatories is now totals over 1700! UNEP encourages government leaders, company presidents, NGO executive directors, business association presidents and other community leaders to publicly affirm their commitment and exercise leadership in Cleaner Production by signing and implementing this Declaration.

3.3. Main Achievements

As a set of tools, as a program and even as a way of thinking, cleaner production has gained many achievements and had significant impact after decades of effort. These achievements and impact can be assessed at various levels:

- First, cleaner production has been a technology promoter. At their simplest level cleaner production programs have advanced more resource intensive and less hazardous production technologies. Aqueous cleaning, powder coatings, solvent recycling, non-cyanide plating, counter-current rinsing, lead-free soldering,

water-based paints, vegetable-based dyes and bead-blasting strippers are all physical ramifications of many cleaner production initiatives. Cleaner production initiatives have supported or spawned a collection of new tools including facility assessments, full cost accounting, technology assessments, eco-balances and life cycle assessments.

- Second, cleaner production has been a managerial catalyst. Cleaner production has liberated environmental values from the dungeon of residual management and regulatory compliance and placed them nearer the center of product and process design. Environmental performance is increasingly considered as an important management system that needs to be optimized along with management systems for quality and financial return.
- Third, cleaner production has been a paradigm reformer The conventional economic view of environmental protection located pollution control investments as a business cost. By promoting full cost accounting and green marketing, cleaner production has restructured environmental economics, converting environmental protection investments into productivity benefits. Environmental values have proven to add to, not subtract from, economic performance.
- Finally, cleaner production has been a conceptual bridge connecting industrialization and sustainability. Since the Brundtland Commission and the United Nations Conference on Environment and Development the concept of sustainability has been enshrined as the global vision for a healthy future. Cleaner production has allowed industrial production to find a place in this vision by recasting negative images of polluting industrial processes into positive images of materials conserving, energy efficient, non-polluting and low-waste technologies generating ecologically friendly products that are responsibly managed throughout their life cycle.

Not satisfied with cleaning up production processes alone, cleaner production programs have also addressed the products of production and the problems of consumption. This effort has produced new approaches to product management that include eco-design, integrated product chains, life cycle assessments, and extended producer responsibility initiatives. Adding environmental values to product design, marketing and management, like adding environmental values to process management, has opened up new opportunities to improve business performance and competitive advantage.

3.4. Current Challenges

The achievements of cleaner production are quite impressive. However, a few trends are disturbing.

- CP is not yet internalized in the day-to-day decision making processes of companies;
- the work by CP institutions has mainly been confined to demonstration projects, awareness creation, training and information dissemination;
- there are only a handful of financial schemes supporting implementation of CP;
- CP is still not integrated as a cross cutting theme in the educational system;
- Cleaner Technologies is still not a targeted program area of many R & D institutions

- there is still a lack of supportive governmental policy frameworks,

All these show that the current cleaner production programs have run up against several significant challenges. These challenges can be categorized in four areas: culture, mechanism, technology, and social consumption.

From the cultural point of view, the entrenched habits and reluctance to change make the adoption of implementing cleaner production difficult. It is not always a problem to find the right or new technology. But it does always require changes in attitude at all levels of a firm, from top management to shop floor. Cleaner production is a corporate cultural shift; from the "pollution control culture" to the "waste reduction ethic."

From the organizational and mechanical point of view, at the enterprise level, costs of end-of-pipe treatment strategies have been accepted as a cost of doing business since in many cases-especially in good economic times-these costs are not very high in relationship to other costs of production. Furthermore, in many middle and small enterprises the proprietor determines everything, and CP can't be implemented because of the narrow awareness of the proprietors; at the government level, current policy and regulatory systems overwhelmingly focus on end-of-pipe solutions. There is no strong economic policy to support CP and the difficulty of raising funds impedes enterprises from carrying out or continuing CP. So, economic obstruction is a key problem in implementing CP.

From the technological point of view, obstacles in technology development and transfer processes hamper CP achievement performance. Now, in methodology, CP auditing can suit the various requirements of different industrial sectors and enterprises. In assessment methodology, the current CP assessment is usually from technology, economic and environment. However, there is not enough internal infrastructure needed for research. There are few original records and reports relating to CP, the blocking of the channels to use technology information prevents the wide spreading of much effective technology of reducing waste and makes technology obstructive. In all, CP has laid emphasis on practice but has not formed its own theoretical system.

From the sustainable point of view, the big challenge for cleaner production is to be integrated into social consumption. The coming 7th International High-Level Seminar on Cleaner Production (CP7) addresses this challenge as follows:

- To internalize the sustainable production and consumption agenda into the mainstream decision-making processes so as to provide an opportunity for more productive investments and thus contribute to a sound future - both economically and environmentally.
- To make market forces work better so that the environmental and social costs of production processes and of product use and disposal are reflected in the product price, and not covered by direct or indirect subsidies.
- To use policy instruments, technologies and management practices more effectively as drivers for promoting life-cycle approaches in sustainable production and consumption, thereby bringing triple dividends - economic, social and environmental.

4. Ways of Implementing CP

To implement cleaner production, a multi-tool strategy and integrated framework for cleaner production implementation should be adopted: environmental management systems and other socio-economic incentives create the framework for changes. Government initiated instruments orient this framework towards clear objectives, technological tools will ensure their realization and environmental education and training will ensure a long-term result.

4.1. Management and business instruments

Cleaner production corresponds with the integration of environmental and economic decision-making on an industrial site basis. It is as much about increasing efficiency, reducing costs, improving flexibility and gaining a competitive advantage as it is about enhancing the ability to protect the environment. That is to say, cleaner production is the most effective and efficient approach to environmental management. However, cleaner production will not be realized without the active and full support of the employees. Thus, gaining the support of the workforce is one of the key elements in changing the environmental performance of a company. The challenge for companies is to fully integrate cleaner production into their environmental management systems and strategic business plans to take full advantage of potential opportunities.

Good environmental performance is always a multi-instrumental and continuous effort. Possible management instruments are environmental standards, risk analysis, state of environment reporting, environmental impact assessment, life cycle assessment, environmental auditing and other economic instruments. These instruments can be a government initiative, but since the 1990s evolution emphasizes more and more the important role of private initiative, because only the responsibility and the conviction of the company managers can fundamentally make cleaner production move forward. Without being exhaustive, some important management tools for companies are explained below.

Environmental Management Systems
An environmental management system is a complex of policies, standards, practices and tools to increase an organization's effectiveness in dealing with environmental matters. An effective environmental management system is consistent with sustainable development principles and integrates all relevant functions within a company. One of the main Environmental Management Systems is the ISO's ISO 14000. The ISO defines an Environmental Management System (EMS) as "a systematic approach to dealing with the environmental aspects of an organization. It is a 'tool' that enables an organization of any size or type to control the impact of its activities, products or services."

Environmental Management Standards
Nowadays, two important models for environmental management standards have been developed: the international ISO 14000 standards and the European directive 1836/93 (EMAS), adopted on 29/6/93 by the European Council. ISO 14000 is a standard for all types of organizations, EMAS for industrial companies. ISO 14000 certifies organization structures, EMAS certifies single sites.

Company environmental co-ordinator The environmental co-ordinator is responsible for environmental care within a company, and is imposed by law in various countries. The task is advising and co-ordinating, and the job evolves from control (pollution prevention) to environmental care. **Public Environmental Reporting** Public Environmental Reporting is a process whereby organizations, including governments, can examine their environmental performance over a specified reporting period and disseminate that information to a wide audience. **Corporate Environmental Reporting** A corporate environmental report informs the shareholders about the environmental performance of the company. To have an added value, the content of this report should be sufficiently detailed and show a certain uniformity. In many companies, environmental reporting is a task exclusively delegated to the environmental department of the company. As a consequence, there is no trace of the environment in the budgeting and the other parts of the company are poorly involved. Environmental reporting should be supported by a full commitment of the senior executives of the company. This will motivate the environmental managers and all other stakeholders. **Company performance ranking** In addition to other types of ranking based on stock exchange results or other criteria, environmental performance ranking as an integral part of the international business news can be very stimulating for real integration of environmental purposes in business. Indicators to calculate a green performance ranking are being developed.

Table 2: Some environmental management tools

4.2. Government Policies and Strategies

The implementation of policies, strategies and instruments will be decisive for the success of cleaner production. Some policy instruments available are illustrated in Figure 1. The figure also contains a number of environmental tools, such as life cycle assessment (LCA) and environmental management systems (EMS) that can form part of a policy intervention.

Generally speaking, government policy instruments can be categorized in the following three groups:

- *Regulatory (administrative or directive-based) instruments* specify what various actors are allowed to do, or not allowed to do, and how certain activities should be conducted;
- *Economic (incentive-based) instruments* create positive or negative incentives for certain activities by adjusting the financial conditions surrounding those activities;
- *Informative (information-based) instruments* are based on the assumption that actors are not rational because of a lack of knowledge or awareness, and are aimed

at compensating this deficiency by providing better information.

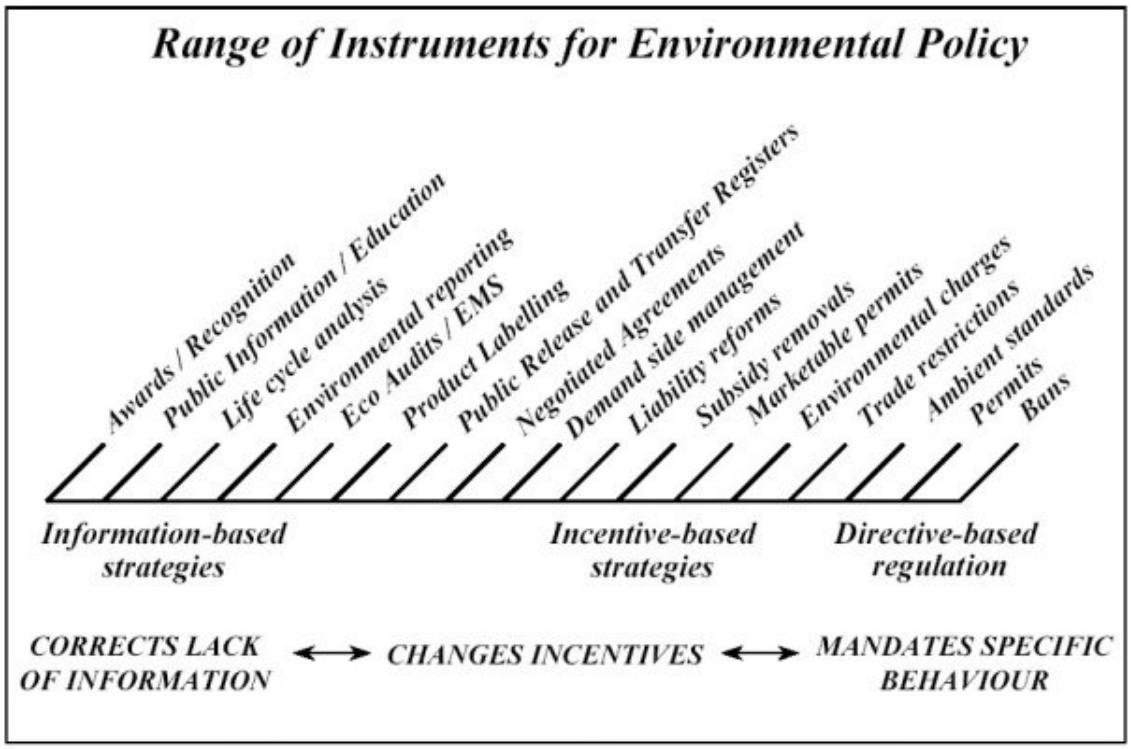

Figure 1: Some government policies and strategies

One thing should be pointed out here: the various policy instruments are not used in isolation one from another. For example, regulatory instruments are often connected with economic fines in case of non-compliance, economic instruments need a legal framework, and information is a necessary element in connection with the implementation of all types of policy instruments.

Different studies have revealed the paramount conditions to support a policy towards pollution prevention and cleaner production. The three most frequently cited conditions on which environmental policy and environmental regulation should be based are:

- long-term environmental quality standards or targets should be related to sustainability;
- flexibility and innovation-friendly;
- integrated and full life cycle approach.

Regulation and legislation systems can only be effective in promoting and implementing cleaner production if long term environmental objectives are clearly stated. In order to invest in cleaner technology, industry needs targets which are specific, monitorable and verifiable. Further legislation should give responsibility and flexibility to the target groups to choose specific technologies to meet these environmental targets. Regulatory systems should not impose solutions, but they should encourage innovation.

4.3. Technology Innovation and Improvements

Technology innovation can be a very powerful tool to achieve CP if it is informed by effective technology assessment and supported by effective policies at the company level. A wide range of technologies and related research disciplines can contribute to CP. The development of a cleaner technology for a specific (production) process is a complex task with a large number of options. Solutions can be sought in various phases of the process and each phase may have various solutions. Furthermore, there are also relations with other parties involved in the production chain, e.g. customers buying the product or suppliers offering raw materials and auxiliary substances. Expertise of completely different fields of work must be brought together in order to be able to deal with this complexity and to reach a good assessment of the many possibilities. To cope with such a situation, some promising methodologies and tools have been developed (see Table 3)

Life Cycle Assessment (LCA)
A tool to determine if a change in a product, process, package or activity results in an environmentally beneficial move. LCA does not provide a simple yes or no answer, but it produces quantitative and qualitative information. It helps to identify opportunities for improvement.

Environmental Indicators
Environmental Indicators allow the measurement of environmental impact caused over a defined time period. They are essential to determine how well firms and other organizations are improving their "eco-efficiency". Indicators may range from the very simple to the very complex.

Industrial Ecology
Industrial Ecology is the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital. Industrial Ecology involves the incorporation of cleaner production principles into the planning of industrial developments and other projects to optimize environmental protection and cost effectiveness.

Environmental Audits
Environmental audits are carried out to identify all of the environmental impacts made by a firm. They are normally carried out before the implementation of cleaner production so that changes to practices and processes can be identified and assessed.

Cleaner production audits
A pollution preventative assessment to current and future industrial production of enterprises, that is to find the part where waste is produced, analyze the reason and put forward options to reduce or remove the waste.

Design for Environment Design for environment involves the redesign of products to minimize their environmental impact. Design for the Environment encourages manufacturers to consider the environmental and health impacts of products during the entire life cycle, from the mining of raw materials to the disposal of the products in a landfill. The EPA's approach for "Design for the Environment" is defined in various ways. Sometimes it is defined as the promotion of the incorporation of environmental considerations, and especially risk reduction, in the design and re-design of products and services. Another time it is defined so as to encompass efforts to design products and processes in ways that eliminate or minimize the creation of associated pollution. **Eco-Efficiency** Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity. Eco-Efficiency involves increasing production while reducing the environmental pressure per unit produced.

Table 3: Some technological terms related to CP

These terms involve a combination of technology (processes and tools) and techniques (ways that technology is used). Technology and techniques are mutually supporting in delivering CP as can be seen in case studies. Performance assessment is the guide to determining the optimum combination of the two.

Here, product design should be highlighted because it can be an effective tool to achieve more sustainable consumption patterns in that it addresses all stages of the product development, as well as takes consumer needs into account. Design can really play an important role in reducing energy and material throughput in the economy when based on environmental data provided by tools such as Life Cycle Assessments. Design involves most factors of the performance and composition of a product or process, as for example efficiency, multi-functionality, reusability, recyclability, and material and energy use.

4.4. Education and Training

On the third European Roundtable on Cleaner Production (Kalundborg 1996) there was a workshop on education and training. The overall objective was to discuss and assess education and training activities to realize and support cleaner production. Three main fields of cleaner production in education and training were discussed particularly: the purpose of cleaner production education and training, the institutional framework and the content of the learning process.

It is easy to imagine that the success of environmental management in the future greatly depends on successful communication of environmental concepts to the schoolchildren of today. In different countries, educational programs about environmental care for primary and secondary schools and universities have been worked out. A good overview was given on the "International seminar on environmental care and environmental management systems for schools and universities", VUB Brussels, 16 April 1997. There

exists a European network of Eco-schools, initiated by the Foundation for European Environmental Education (FEEE). The aim of the network is to meet the educational requirement by promoting a range of activities which are focused around a new European master degree in environmental management.

In order to increase worldwide awareness of the preventative environmental protection strategy embodied in cleaner production, UNEP carries out activities under the following closely related elements:

- Training and Technical Assistance
- Publications
- Working Groups, and
- International Cleaner Production Information Clearinghouse (ICPIC)

As stated in its ICPIC document, Cleaner Production: An Opportunity for Industry, the challenge for the 21st century is: "to link the different stakeholders relevant to the dissemination and application of this concept [CP] in order to promote concerted action."

5. Cleaner Production in the 21st Century

Undoubtedly, the promotion and implementation of Cleaner Production will continue in the 21st century. Increasing the spread and depth of implementation necessitates actions on the following issues:

Expanding the stakeholder base: The implementation process has to involve a larger number of stakeholders. Representatives from academia, financial institutions, non-governmental organizations, and industry associations have to join hands to further the Cleaner Production movement. Engineers, economists and financiers have to work more closely together so as to develop the economic instruments and incentives that are necessary. In companies, there is a need to bring the designers, the production managers, the marketing managers, and the financiers to work together. The environment is not an issue to be dealt with only by environment managers! Furthermore, cleaner production needs to be more effectively promoted within the investment and trade communities. Cleaner production needs to be advocated as an investment strategy and as a factor of competition. This will require a reorientation of banking and investment philosophies and the rewriting of international trade agreements.

Expanding the activity base: Cleaner production needs to more aggressively address products. A healthy focus on sustainable product design and integrated product management systems should be paralleled by a vigorous movement towards product life extension, product take back, and product recycling and reuse. The promotion of cleaner and safer forms of production needs to be coordinated with a parallel and proportional promotion of sustainable consumption that is directed at cutting the material and energy consumption particularly in the more economically developed countries. In all, there is a need for more awareness raising, more information exchange, more training, more education, more workshops, conferences, seminars at all levels and in all parts of the world, more good case studies, more networking**.**

Mainstreaming: The death knell of any new concept like Cleaner Production starts ringing if it begins playing the role of 'solo performer'. For the sustainability of the concept it is essential that it gets mainstreamed into the day-to-day decision making process in all spheres of the economy. Thus, Cleaner Production has to get into the board rooms of the companies, into the agenda of politicians and policy formulators and even into the decision making processes of each consumer. That is to say, cleaner production needs to be more strategically integrated into management and marketing practices and more centrally promoted in business and technical training programs and university engineering and management curricula. In short, cleaner production needs to be integrated into "ecological industry" and "circular economy".

These are ambitious tasks, but there is plenty of foundation work already in place. This next decade could well be a time of rapid change as firms and governments re-draft their missions and re-direct their functions. The agenda ahead is to move from broad awareness and successful pilots to making CP a part of conventional economic and social practice.

Glossary

Circular Economy: Also called life cycle economy, provides an integrated approach to sustainable production and consumption policies – as chains or networks of actors. It focuses on understanding the driving forces behind consumption – using them to inspire cost-effective improvements and raising the quality of life in all parts of the world.

Cleaner Production: The continuous application of an integrated preventative environmental strategy applied to processes, products, and services to increase overall efficiency and reduce risks to humans and the environment. Production processes: conserving raw materials and energy, eliminating toxic raw materials, and reducing the quantity and toxicity of all emissions and wastes; Products: reducing negative impacts along the life cycle of a product, from raw materials extraction to ultimate disposal; Services: incorporating environmental concerns into designing and delivering services.

Cleaner Production Auditing: A pollution preventative assessment to current and future industrial production of enterprises, that is to find the part where waste is produced, analyze the reason and put forward options to reduce or remove the waste.

Design for Environment: Design for environment involves the redesign of products to minimize their environmental impact. Design for the Environment encourages manufacturers to consider the environmental and health impacts of products during the entire life cycle, from the mining of raw materials to the disposal of the products in a landfill. The EPA's approach for "Design for the Environment" is defined in various ways. Sometimes it is defined as the promotion of the incorporation of environmental considerations, and especially risk reduction, in the design and re-design of products and services. Another time it is defined so

	as to encompass efforts to design products and processes in ways that eliminate or minimize the creation of associated pollution.
Eco-efficiency:	Is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity.
Environmental Audits:	Environmental audits are carried out to identify all of the environmental impacts made by a firm. They are normally carried out before the implementation of cleaner production so that changes to practices and processes can be identified and assessed.
Environmental Indicators:	Environmental Indicators allow the measurement of environmental impact caused over a defined time period. They are essential to determine how well firms and other organizations are improving their "eco-efficiency". Indicators may range from the very simple to the very complex.
Environmental Management Systems:	An environmental management system is a complex of policies, standards, practices and tools to increase an organization's effectiveness in dealing with environmental matters.
Industrial Ecology:	The means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital.
Life Cycle Analysis (LCA)**:**	A tool to determine if a change in a product, process, package or activity results in an environmentally beneficial move. LCA does not provide a simple yes or no answer, but it produces quantitative and qualitative information. It helps to identify opportunities for improvement.
Public Environmental Reporting:	Is a process whereby organizations, including governments, can examine their environmental performance over a specified reporting period and disseminate that information to a wide audience.

Acronyms

3P:	Pollution Prevention Pays
CP:	Cleaner Production
CPA:	Cleaner Production Auditing
EEA:	European Economic Association
EMS:	Environment Management System
ISO:	International Organization for Standardization
LCA:	Life Cycle Assessment

NGO:	Non-Governmental Organization
OECD:	Organization for Economic Co-operation and Development
SD:	Sustainable Development
SETC:	State Economy & Trade Commission
UNEP/TIE:	Division of Technology, Industry and Economics, United Nations Environment Programme
UNIDO:	United Nations Industry Development Organization

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