

THE WIDENING CONCEPT OF “CLEANER PRODUCTION”

Ampliación del concepto “Producción más limpia”

Recibido: Agosto 16 de 2016 – Aceptado: Septiembre 30 de 2016

DOI: 10.17981/cultedusoc.07.2.2016.1

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Para citar este artículo / To reference this article:

Van Thanh, N., Hens, L., Chamorro, C. y Dinh Lan, T. (2016). The widening concept of “Cleaner Production”. *Cultura Educación y Sociedad* 7(2), 9-25. DOI: 10.17981/cultedusoc.07.2.2016.1

Abstract

“Cleaner production” (CP) emerged in the aftermath of the 1987 Brundtland Commission (WCED, 1987) call for less and more efficient energy and materials use efficiency and the suggestion to substitute more harmful products (for the environment and health) by less dangerous ones. Cleaner production was the reply of industry to the inter-sectorial and socio-economic call for sustainable development. The technical aims widened. Originally they were targeted to improve environmentally inferior products to less inferior ones. Today the goal is producing quality products using renewable energy efficiently and producing zero waste, while emitting no pollution.

The perspective of the scope also changed from environmental sustainability to the wider “Corporate Social Responsibility” (CSR). This includes that post-modern companies have not only responsibilities on their economic performance and the environment, but should also act on issues including human rights and resources, business ethics, and community involvement. This widening of contents necessitates more and better adapted methods. During the past 45 years the number of assessment methods (preventing pollution and its effects) increased significantly from environmental aspects (EIA), over health (HIA) and policy aspects (SEA), to sustainability assessment, addressing not only environmental, but in an integrated way also social, economic, and ethical issues of the evaluation.

This paper reviews this evolution of ideas. It provides not only the concepts, but is equally based on case studies and examples illustrating different aspects of this evolution. It acts as a guide towards contemporary CSR and advocates its support towards education and research.

Keywords

Cleaner production, Corporate social responsibility, Renewable energy.

Resumen

“Producción más limpia” (CP) surgió a raíz de la Comisión Brundtland de 1987 con el objetivo de requerir menos energía y de manera más eficiente con respecto a su uso, sugiriendo sustituir los productos más nocivos (por el medio ambiente y la salud) por menos peligrosos; la producción más limpia, fue la respuesta de la industria a la llamada inter-sectorial y socioeconómica para el desarrollo sostenible. Los objetivos técnicos se abrieron ya que originalmente estaban dirigidos a mejorar los productos de calidad medioambiental inferior a los menos inferiores. Hoy en día el objetivo es producir productos de calidad utilizando energía renovable eficiente y productoras de residuos cero, mientras que emite ninguna contaminación.

Desde la perspectiva del ámbito de aplicación se incorpora la sostenibilidad ambiental a la “Responsabilidad Social Empresarial” más ancha (RSE). Esto incluye que las empresas de post-modernos no sólo tienen responsabilidades sobre su desempeño económico y el medio ambiente, sino que también deben actuar en temas como los derechos humanos y los recursos, la ética empresarial, y participación de la comunidad. Esta ampliación de contenidos requiere más y mejor adaptados métodos. Durante los últimos 45 años el número de métodos de evaluación (prevención de la contaminación y sus efectos) aumentó significativamente de los aspectos ambientales (EIA), más de la salud (EIS) y los aspectos de política (SEA), con la evaluación de la sostenibilidad, abordar no sólo el medio ambiente, pero en una también forma integrada social, económica, y las cuestiones éticas de la evaluación.

Este documento analiza esta evolución de las ideas. Ofreciendo no sólo los conceptos, sino que se basa igualmente en estudios de casos y ejemplos que ilustran diferentes aspectos de esta evolución. Actúa como una guía hacia la RSE contemporánea y aboga por su apoyo hacia la educación y la investigación.

Palabras Claves

Producción más limpia, Responsabilidad social empresarial, Energía renovable.

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INTRODUCTION

“Cleaner production” emerged as a reply of industry to its substandard management of environmental issues during the interbellum period and the first decades following the Second World War. This resulted in a series of major accidents of which the Meuse valley deaths in Belgium (Batta, 1933), the Union Carbide pesticide disaster in Bhopal, India (Lapierre & Moro, 2004) and more recently the nuclear disaster in Fukushima (Japan), became textbook examples. Although these major events caused serious damage to the environment and human health, it was the continuing series of minor events which was most impacting. The London smog – the combined result of industrial pollution, emissions of other sources as household warming, and a temperature inversion in the lower atmosphere – which caused over 4000 extra deaths, was the trigger to establish the British Clean Air Act, the first modern legislation on air pollution. This legal framework was used as a template for air pollution acts in many industrialized and developing countries.

The accidents were of acute importance. As significant was the growing insight on the environment and health hazards caused by asbestos, benzene, mono vinyl chloride, heavy metals, PCBs and dioxins, listing just these examples (EEA Copenhagen, 2001).

The publication of the “Brundtland report” (WCED, 1987), which echoed previous calls to use materials and energy more efficiently, while at the same time limiting pollution, was a turning point. Actions should be based on using less energy from renewable resources

in a more performant way than before, saving and substituting (by alternatives with less environmental impact) materials and products, limiting waste, and being targeted to an improved environmental quality, safeguarding biodiversity, and protecting humane ante ecosystem health. All socio-economic sectors should contribute to these goals promoting a sustainable development.

Rio’s Agenda 21 specified the general guidelines of the Brundtland report. Chapter 30 addresses business and industry, advocating environmental stewardship (UN, 1992). Moreover strengthening the role of these stakeholders is addressed in many of Agenda’s 40 chapters in a cross cutting way. Since this publication, sustainable development entails a component of environmentally sound, responsible and cleaner production. The “cleaner production” concept allowed the industry contributing to sustainable development, mainly introducing a technically driven environmental management approach. A wide spread definition from this early period reads as:

“Cleaner Production (CP) strategies are fundamentally concerned with operations, environmental sustainability and maximization of waste reduction, recycling, and reuse at the enterprise level, and are thus microeconomic in scope” (Khalili, 2015).

This definition typically illustrates the technical vision on cleaner production at the local, company level scale.

During the past 25 years this vision changed: The scope of cleaner production broadened both in contents and the range of sectors applying the approach.

This widening content necessitated new methods to address the range of aspect of sustainable development which emerged. Also the targets moved: from more efficient use of inputs and less polluting output in industry, to quality of life in green and smart cities.

This paper reviews these changes in scope, methods and targets. It puts emphasis on the move of environmental management systems (EMS) towards corporate social responsibility (CSR), on the appeal for "cleaner production" in non-industrial sectors (as administration, banking and health care), on the array of nowadays assessment and monitoring methods, complementary to environmental management systems, and on targeting a more environment saving tourism and urban quality of life.

CHANGES IN SCOPE

Corporate social responsibility (CSR)

Post-modern companies realize that their role in society goes beyond making profit and running the backing financial management. Since the 1990s they address their environmental responsibilities using environmental management systems, but they also address human resources and management, union rights, relationships with the local communities, and ethical issues.

Originally environmental management systems mainly targeted legal compliance. Mainly since the 1960s-1970s companies faced increasing numbers and an increasing complexity of environmental regulations. Legal

imperatives were complemented with permits and voluntary schemes (e.g. on certification). Not all companies managed keeping up with this evolution and found themselves after some years in a situation in which they violated different legal regulations. Strengthening maintenance of environmental laws and prosecuting infractions, resulted in EMS approaches, primarily targeted to legal compliance. Today most companies developed a policy going beyond respecting the (legal) regulations. The consecutive character of the management cycles allows them emitting less acidifying substances, volatile organic products, and releasing less and less polluting liquid waste as described in their permits. As such companies adopt a more proactive attitude than before.

Although no generally accepted standard exists, and the different types of companies necessitate specific requirements, addressing the environmental aspects of a CSR company, existing systems handle the following elements:

- A vision and a commitment to environmental policy by the top management.
- A certified EMS, definitely of the most impacting sites. Certification of the EMS motivates the internal stakeholders, but also shows the outer world that the company runs an EMS according to the best available international standards. Next to ISO14001 or EMAS, which cover the full spectrum of the system, certification systems as BREEM or LEED focus on particular aspects as environmentally sound buildings or energy consumption.

- Management of environmental risks: A declining incidence of environmental accidents provides a reliable indicator or this key aspect in accident prone organizations. Related is the care a company provides to clean up and restore the impacts of previous accidents.
- Impacts on biodiversity, their remediation, and if applicable the restoration of damaged sites.
- “Green” products show a variety of aspects reflecting the DNA of the company: From IT-software to reduce CO₂-emissions, over FSC-certified timber and locally grown organic food, to degradable washing products, listing just these examples.
- Environmental performance addresses air, water, and soil pollution, next to company specific aspects on waste (see Box 1) and land use, among others. Also the environmental performance of the mobility should be assessed in terms of transport mix and pollution emission trends.

Complementary to these general criteria, specific sector bound aspects should be taken into account: A fine chemicals cosmetics or pharmaceutical company shows other environmental impacts, than a company producing mechanical devices, and this latter differs from a railway company.

Companies are motivated joining these CSR dynamics, not only because of their sustainable responsibilities. CSR funds, although still limited in absolute value are among the fastest growing sectors on auction markets worldwide. Today and in the near future CSR companies,

through this vehicle of funds, will obtain easier access to capital, providing them a competitive advantage on their non-CSR competing organizations.

CSR should not be limited to industry. Other production sectors might also significantly benefit from CSR-based approaches. Contemporary agriculture and husbandry face important challenges of energy consumption and (chemical, including pharmaceutical) inputs. Striving towards sustainability, industrialized agriculture might take advantage of applying cleaner production principles to limit its energy and other (e.g. chemical) inputs, contributing to biodiversity conservation while generating less (water, air and soil) pollution, microbial resistance, and environmentally more sound outputs.

What applies to agriculture and husbandry equally applies to forestry and aquaculture, listing just these sectors.

CSR and sustainable development mirror each other. Today CSR is the prevailing way business and industry respond to sustainable development (Thiel, 2015). This offers important new opportunities. The concepts of CSR dovetail in different theories and scientific traditions. These include: economy (competitive advantage), marketing), sociology (public responsibility, stakeholder theory), ethics (abstain from negatively impacting activities, corporate behavior), management (workforce management, integrated control of processes), law (universal human rights, legal compliance, controversy responses), but definitely also in environmental performance (air, water, soil, waste, energy, biodiversity, transport) of which cleaner production is an intrinsic component.

Service sectors: Sustainable tourism as an example

Tourism is a fast growing economic sector worldwide. In 2014 international arrivals were noticed; by 2020 this figure is expected to increase to up to arrivals. Although most of the tourism activity still happens in Europe and in North-America, the growth is most pronounced in selected developing countries. In spite of its vulnerability for natural disasters, public health concerns, and political instability, these countries see tourism development as an important source of foreign money income and their support to the sector as an instrument for poverty alleviation.

Tourism development faces environmental, social, economic, and ethical problems. Environmentally the sector faces the negative effects of air pollution in skiing areas, bathing water pollution at beaches, refuse waste, high inputs of energy and materials in the increasing sea-cruises section, and suffers from the amounts of (air and car) mobility it generates. At the social side, apart from the limitations on development and the risk of increasing inequalities tourism development might introduce, the seasonal less attractive working conditions, it often attracts begging, criminality, prostitution and drugs trade. From an economy point of view over-dependence on the sector (over 70% of the economy of the Maldives depends on tourism) and money leakage are well studied problems. The ethical aspects of e.g. pro-poor tourism and neo-colonialism characteristics of tourism to developing countries are of growing concern.

On the other hand tourism offers important opportunities alleviating the above mentioned problems. A significant part of tourism activities occurs in sunny places during the peri-summer season, which provides huge opportunities using pho-

tovoltaic and passive solar energy, in national and geo-parks, both terrestrial and marine, tourism allows raising awareness on the (ecosystem) value of biodiversity, advanced combined social and technical methods exist dealing with the waste and pollution hot pots problem, and establishing pedestrian zones in intensively used tourism areas contributes to solving issues of crowding.

To handle the problem, tourism as a series of instruments ranging from preventive assessment methods, over company (hotels) and sub-sector (golf courts) specific environmental management systems, planning, policy, life cycle analysis if its products, economic instruments as taxes and levies, to education and information initiatives as eco-labels and ethical codes.

For sustainable tourism it is important embarking for these solutions while conserving and protecting its own resources. For this transition the sector should among others, make use of a cleaner production approaches bringing down its carbon footprint, and using its inputs more efficiently. As much as any other sector, tourism will benefit of making sustainability part of the sectorial culture.

Tourism is discussed here as an example of a service sector which might benefit from the experience of cleaner production methods. For many other examples, including the health care sector, taxi companies, railway companies, cultural organizations, education, or administration the same finding applies. There is no valid reason why non-production sectors in general should not take advantage of applying integrated sustainability approaches of which cleaner production is part, to bring down their negative environmental, social and economic imprints in society.

Box 1: Waste management at the Gentofte hospital (Copenhagen, Denmark)

Environmentally sound waste management is a backbone of each environmental management system, also when it is part of corporate sustainability management. Case of good waste management practices are relevant in this context.

The Copenhagen University Hospital Gentofte primarily serves the Gentofte municipality and its surroundings. By 2014 the hospital had 220 beds, equivalent to 71000 in house patient days and 1633 full time collaborators.

Waste management in the organization is based on three principles:

Waste reduction at the source.

Sorting and recycling the waste.

Incineration of the remaining fraction with flue gas treatment, energy co-generation, and landfilling of the ashes.

650.755 kg of the 784.586 kg waste produced yearly by the hospital is domestic waste, while less than 5% (29.860 kg) is potentially contaminated hospital waste. The remaining fraction is mainly paper and carton board and to a lesser extent metal and glass.

The collected and sorted waste is locally pretreated. The organic kitchen waste and the leftovers of 284.000 meals per year are cluttered and collected in large plastic containers in the kitchen department of the hospital. The content of the containers is further handled by an external composting company, which also recycles the released methane.

The system needs logistics for sorting and pre-treatment on site, next to transport facilities. This generates a cost which is a structural part of the hospital budget.

The environmental attention of the hospital management and the food selection (85% of their food is organic-ecological and from Danish origin) recycling initiatives in particular is highly appreciated by the patients. Questionnaire results these latter score the highest degree of satisfaction among the Danish hospitals. Moreover the (limited) extra cost of the organic option fits in the food budget. (<https://www.gentoftehospital.dk>)

Green, blue, healthy and smart cities

The widening area of application of cleaner development is not limited to the increasing number of sectors which might benefit of applying the concept. Also larger structures and organizations will benefit. Cities offer an example.

Cities host more than half of the world population, receive every week 1.4 billion commuters, and generate over 85% of the GDP worldwide. Most of them are localized at the borders of the continents, providing them with a significant blue water aspect.

The idea of eco-cities dovetails in the environmental problems post-modern cities face: Increasing urbanization and modernization, cleaning-up the industrial heritage of the past century and declining attraction and quality of life. Cities emit major amounts of carbon, are hot spots of water pollution, areas where land is scarce and land use critical, and intense waste producers. This affects not only the quality of the environment, but also human health. This applies in particular to “civilization diseases” as diabetes: 2 people out of three suffering from diabetes live in cities; its incidence and risk of type 2 diabetes is affected by particulate

pollution in the air; multiple and complex links exist between "urban diabetes" and climate changes (IDF, 2015). Cities increasingly emerge as key places interlinking climate changes, environmental quality and health.

Green cities are a major reply to these problems. Green cities have low air pollution levels which do not threaten human health or the urban physical environment, establish a water use and quality policy, strive towards zero waste emissions, are carbon neutral, and offer a sufficient amount of accessible green spaces for each inhabitant (Lucarelli & Roe, 2012).

Cities bordering the sea or localized along main rivers, will pay special attention to their sea-bound economy. Ports and port areas, facing specific environmental (space and pollution) problems will require advanced environmental management systems, supported by the cooperation of all involved stakeholders. They deal with the extra (heavy) traffic the port activities generate, moving towards sustainable, long term solutions.

Political realities often strive towards combining these green-blue and health aspects of nowadays cities with the idea of cities as knowledge centers (De Jong et al., 2013). Combining environmental quality, urban health, and knowledge, smart cities develop improved IT-managed traffic systems, promote low emission (new, electric) vehicles, and limit the access for old, polluting cars. They use advanced IT-techniques optimizing their public services and cultural offer.

The more complex the system is, the more holistic the cure proves to be. The management of green cities necessitates an integrated vision on the future of the

city. In the end green cities aim at creating beautiful and livable cities for the inhabitants and the visitors.

Counties as Vietnam give priority to greening their cities (Textbox 2).

Green economy

The green economy is defined as the aggregate of all activities with the primary objective of minimizing all forms of environmental impact. This presumes the articulation of other disciplines that contribute to its main objective: green administration, green accounting, and green finance, among others. (ECO CANADA, 2010).

Green economy can also be considered as a system of economic activities related to the production, distribution and consumption of goods and services that result in improved human wellbeing over the long term, while not exposing future generations to significant environmental risks and ecological scarcities (Fareed, 2012).

Green economy contributes at using the natural capital efficiently by addressing not only economic, but also social, organization, cultural and educational aspects.

"Green economy" became a buzzword in the aftermath of the Rio+20 Conference (UN, 2012). The green economy in the context of sustainable development and poverty eradication was an attempt to balance the economic value of "green policy", and the concern that sustainable development should not disappear from the political agenda. The discussion highlighted once more that an increasing GNP was not the best economic measure for sustainability, and warned against the pitfalls of green washing and suspi-

Box 2: Green cities

Over 50% of the world's population lives in cities; urban metabolism consumes about 65% of the resources, they mainly attract from outside their territory; this causes some 70% of the total anthropogenic emissions (Schnitzer, 2015). On the other hand, cities around the world work hard on their attractiveness and livability. City centers become pedestrianized, motorized traffic is deviated to ring roads surrounding the city, public transport is on its rise, bicycles reappear, traffic bound air quality improves, and the number of accidents declines. This results in an improved environmental quality, contributing to a better quality of life for residents, workers, and tourists.

The targets and challenges of the sustainable city of tomorrow are however wider:

On their environment cities should go for more green, carbon neutrality, zero waste (in which all waste is used as a resource), clean surface and high quality of drinking water, and optimal use of the scarce soil.

Socially, cities should offer a healthy environment, respond to changing demography trends (as aging and migration), and provide a safe and equitable (income, opportunities) place. They should be places of inter-individual tolerance and fulfill the (changing) housing needs of their residents.

Cities have to deal with a changing (growing, sector needs) economy.

Cities hosting main ports have a particular role in this respect:

Ports have specific environmental problems on pollution and spills, on treats to biodiversity, on attracting mobility, and as a rule, they have major opportunities operating on a space saving and efficient manner.

Cities with main ports have an outspoken cosmopolitan character, where a variety of nationalities and cultures provide added value. However, they also have to fulfill the specific housing needs of their population.

Ports have a key role in the economic transition for the next generation. They are crucial in implementing both the green (UN, 2012) and the blue, marine based economy.

These different aspects on what cities are expect to realize during the decades to come, are combined in visions on the city of tomorrow, aiming at establishing a better, safer, and more equitable place to live for the citizens. Although no single, generally accepted definitions exist in this domain, major components of this multidisciplinary and integrated vision entail environment, health, green and blue (water bound) economy, and innovation ("smart cities").

The North Vietnamese city of Hai Phong is one of the multiple examples of "green cities" worldwide. Situated on the North-Eastern coast of the Gulf of Tonkin, at 102 km from Hanoi capital and at 200 km from the Chinese border, Hai Phong is not only a seaport, but also the main gate to the sea of Vietnam's Northern provinces. Trade with the South-Western, landlocked provinces of China increases fast. Hai Phong is a key transportation hub of the North of the Vietnamese nation and the starting point of an important economic corridor between China and Vietnam. Hai Phong is not only Vietnam's second main port; with its over one million inhabitants it is equally a main city, hosting in Cat Ba a UNESCO reserve, a geological park, and a gateway to the unique seascape of Ha Long Bay.

Hai Phong profiled itself as a green city focusing on environmental quality (including traffic), social aspects, and a blue-green economy. The green city policy is strongly supported both by the Vietnamese government and the local decision makers.

Green cities are closely linked with "cleaner production" through the concept of industrial ecology. Industrial ecology is about optimizing materials and energy flows through life cycle analysis and green supply chain management, among others (Korhonen, 2001; Zhu and Cote, 2004). Moreover cleaner production is important to ensure that prevention is taken into account in sustainable tourism. It contributes both to strategies and specific cases, for which tools, concepts and policies have been developed (Lee, 2001).

cious, insufficiently documented "green labeling". It put emphasis on the beneficial economic aspects of investing in improved environmental management (including technical aspects as water and air treatment, and waste management) but also in their link with assessment, management and monitoring. Green economy aims at joining economic security and environmental protection (Dodds and Strauss, 2012).

"Green economy" is a complex, multi-dimensional concept. Box 3 describes "Environmental accountancy" as an essential element of this scientific space.

Green economy is closely linked with cleaner production through factors as advanced green technology, green consumerism, green innovations, appropriate sustainability models, green and lean supply chain management, listing just these elements (Tseng et al., 2013).

During the past few years "circular economy" emerges as an eco-strategy rather than a purely environmental strategy. The major objective is promoting the sustainable development of economy and society, while also contributing to environmental protection and careful use of resources.

Box 3: Green Accounting

Green accounting is an essential element in a green economy.

Initially green accounting was a model that mirrors - through the recognition, measurement, and disclosure within the regular accounting system - the environmental impact generated by companies during all (production and corporate) its activities. Green accounting offers and obtains rational knowledge of the company's environmental information. In this way it identifies the environmental patrimony of the organization and fosters the implementation of environmental strategies and policies that protect and care for the environment (Chamorro, 2015).

Other hand, green accounting contributes to providing data for the indicators which measure sustainable development. Traditional economic measurements as GDP or HDI have limitations measuring the welfare and sustainability of the present and the future generations. Conventional national income accounts ignore to a large extent (externalize) the value of environmental goods and services.

Green accounting offers an important link between economy and environment because most of the natural resources are poorly reflected by or absent in market prices. Moreover for traditional economy environment issues have a negative co-notation. The fundamental problem is that nature and ecosystem services are overlooked in the macroeconomic model. This calls for an urgent accounting of the value of nature and documented estimations of the cost of environmental damages.

A series of models of environmental accounting have been published (Paul, 2013). E.g. the national income of the yearly economic production should take into account the depreciation of manufactured, or fixed, capital, such as buildings and machinery. As the yearly economic activity provides society with the new goods and services, the value of previously produced assets declines, and this loss should be accounted. Standard national accounting methods provide estimates of the net domestic product (NDP), which starts from the GDP and reduces it with the annual depreciation of the existing fixed capital.

This allows concluding that green accounting aims is to realize improved long-term natural resource management using four strategies: Providing new and more appropriate data for monitoring natural resource use on the long-term; providing data which are compatible with traditional economic accounts to facilitate the integration of natural resource and economic figures; avoiding double efforts in data collection and analysis; and developing a standard procedure presenting and analyzing natural resources, ecosystem services, and environment.

MORE ADAPTED METHODS

Although during recent years major progress has been realized in integrating cleaner production in the widening landscape of areas where the concept is applied, intellectual investments in fundamental, applied and practical tools remain required. Moreover the broader application field generates new needs. A few examples will illustrate this.

Indicators

One of the early instruments measuring sustainable development, the effectiveness of its (policy) instruments, and the trends in its evolution, are indicators. Among their originally defined characteristics is that indicators should use existing data (Bell & Morse, 1999). Experience with indicators convincingly showed that the relevant data are limited and dispersed. Moreover, gap analysis showed data gaps and also the quality of the available data raised concern. These remarks require a reply which basically comes to generating more indicator relevant data.

Next to this, the issue of specificity has been raised. Measuring eco-efficiency aims at obtaining an idea of the social, economic and environmental efficiency of an organization or a sector. It is about attaining a higher value with fewer inputs of materials and energy, and more output while avoiding pollution and waste. There is currently no widely accepted, single indicator, nor index integrating these three aspects of sustainability, enabling the monitoring of an organization or a larger unit. There is a need of establishing these specific measures targeted to assign the effecti-

veness and efficiency of cleaner production (Henriques & Catarino, 2015).

Finally, although developing sustainability indicators traditionally is the subject of complex manuals and guidelines, an imminent need remains standardizing the procedures more, in such a way that international, intra- and inter-sectoral comparisons provide more reliable results.

Assessment methods

Environmental Impact Assessment (EIA) originated during the 1970s as a systematic process analyzing and assessing the impacts of new projects on the environment. The aim was preventing, avoiding and/or mitigating the negative effects on the environment (Devuyst, 1995).

This was followed by realizing that plans, policies, and programs might be as impacting on the environment as

These impacts were addressed by strategic environmental assessment (SEA) (Dalal-Clayton & Sadler, 2005). The widening of its impact assessment scope necessitated an extension of the methodological arsenal: the science and technology driven approaches prevailing in EIA, were complemented by methods dovetailing in planning and socio-economic sciences.

Further widening of the assessment methods targeted specific areas of impact prediction and evaluation. Health impact assessment is an example. Its characteristic hazards-exposure—dose dependent effects logic, which only partially coincides with forecasting environmental impacts, necessitated a

specific framework, which is commonly referred to as health impact assessment (HIA). Also for policy targeted impact assessments and focusing on social impacts, proper schemes have been developed.

This range of assessment methods appealed for synthesis. This was partially realized with the introduction of sustainability impact assessment (SIA). Although no generally accepted definition exists, SIA can be defined as "a formal process of identifying, predicting and evaluating the potential impacts of a wide range of relevant initiatives and their alternatives on the sustainable development of society. SIA has similar targets as EIA and SEA: improving decision making and bringing environment/sustainable development on board in decision making, but the method differs in scope from its predecessors. While EIA is targeted to environmental impacts of projects, SIA deals with sustainable development at all levels of decision making (Hugé & Hens, 2010).

Particular aspects are provided by risk assessment. In a sustainable development context financial exposure and its inherently associated risk will most likely be assessed on acceptability. Environmental and human health risks might be quantified and assessed too. The results are based on the level of hazard the pollutants pose. The information can be used in two ways. First it allows setting an environmentally "safe" level. Second, it may be used in conjunction with an exposure assessment to prepare a probabilistic risk assessment (Johnston et al., 1999). In contrast to EIA and its related assessments, environmental risks have limited prevention capacity: They are merely used stating

that the pollution of water or another environmental medium has exceeded what is considered acceptable. Social (e.g. reputational) risks assessment is possible, but rare. Nevertheless the social risks are considered essential in the process of sustainable development transitions (Almeida et al. 2015). This heterogeneity of risk approaches results in almost absent combinations, providing a basis for sustainability risk assessment. While a holistic risk management (e.g. on eco-pharmaceutical risks, combining risks of products with life cycle analysis, evaluation and re-assessment of the environmental, social and financial aspects) is most necessary in a context of the widening application area of cleaner production, its functional application, looks remote today.

The impact assessment family of methods, summarized above, is most relevant for cleaner production. They allow identifying the contribution of cleaner production to preventing or mitigating foreseeable impacts and point to gaps in current knowledge. This latter also demonstrates the need for new, specific, additional assessment methods in a range of domains targeted to realizing aims where cleaner production is able removing or alleviating current bottlenecks.

Management

During recent years major progress was realized both in developing fundamental and applied aspects of (environmental, sustainability targeted) management systems (Heesterman & Heesterman, 2013; Halkias & Thurman, 2012). Early and simple approaches targeting general aspects on water, air, soil, energy, waste, and mobility evolved to systems ad-

addressing both the direct and the indirect impacts of the equation. EMSs for hospitals e.g. not only deal with general considerations on energy use, CO₂-emissions, water use, waste reduction, and pollution by likely hazardous chemicals. Over the years they became targeted towards specific issues as the occurrence of *Legionella pneumophila* and/or *Pseudomonas aeruginosa* in tap water and other water distribution facilities, eliminating mercury, reducing anesthetics contributing to GHG-emissions, environmentally sound antibiotics, PVC-free “safe” blood bags, other plastics and polymers used in health care, and medicines and other chemicals) with endocrine disrupting properties (Schroeder et al., 2013; WHO-Europe, 2016). Moreover significant progress was realized in the collection and treatment of specific data, green procurement for hospitals, and linking subsections as waste management and food.

On the other hand, significant unmet needs exist. Examples entail:

- The mechanisms underlying the effectiveness of green procurement.
- Product sustainability of supply chains. And detailed systems replying to the increasing complexities.
- New organizational capacities
- The integration of the currently insufficient environmental and socio-economic data.
- Stakeholders involvement in developing new management supporting technologies with a toxicity reducing character.
- The wider contribution of these approaches to well-being and quality of life.

Monitoring, modelling and reporting

Under the heading “measuring provides knowledge” both impact assessment studies and environmental management systems rely on measured data. Therefore, collecting data, including on the monitoring of foreseen (and overlooked) impacts are essential to enhance the reliability of these methods.

Models are an important instrument in this respect. They enhance the predictive capacity of the assessment approaches. Their validation is driven by data of high technical quality (Moffat et al., 2001). This technical quality depends to a large extent on the quality, the availability, and the accessibility of data bases and reporting.

The experience with life cycle analysis (which also is strongly driven by the use of process specific data) illustrates the fragmentary and partial character of the available data, which are often difficult to control on their scientific validity. Data relevant for sustainable development suffer even more from fragmentation, partiality, and lack of quality assurance. More and easier accessible reliable data, reported according to strict quality guidelines are mandatory at this moment and for the years to come.

EVOLVING TARGETS

The widening of the scope of problems and issues covered by cleaner production also results in broadening the aims to be realized. The focus is on three aspects:

- While originally the approach was mainly applied contributing to sustainable development in the production sector, involving the service and administrative sectors, next to the decision makers points to its relevance for a broader societal realization of sustainable development. Monitoring and assessment instruments should be adapted to this new and evolving context.
- This widening towards sustainable development has far going consequences. The main one is the dilution of the environmental targets. More and more environmental quality and responsible use of resources is not anymore a target by itself. As an element of sustainable development it becomes embedded in a wider strategy addressing also economics and social aspects. At the policy level quality of life (QoL) targets, of which environment is part, move on the forefront.
- The widening of the targets also manifests itself at a strategy level. Originally, business and industry had to cope with the effects of major calamities. They reply was first negating the issue by moving the attention towards other aspect as jobs. Following acceptance of their undercooled attention for environmental issues, they installed environmental (including energy and resources) management. This illustrates the defensive the strategy during the first post Second World War decades. Embracing environmental management fundamentally changed this strategy: It allowed industry acting in a pro-active way on environmental challenges. The ap-

proach allowed going beyond legal compliance, and performing better on energy consumption and pollution than prescribed by the permits. This provided the sector a much more reliable perception in the environmental and sustainability debate.

This fundamental move might provide a guideline for other sectors. Agriculture, forestry and fisheries e.g. should leave their environmental impacting perception behind and opt for sustainable food production methods.

DISCUSSION

This overview of 25 years of evolving ideas on cleaner production not only illustrates the logical steps taken during the widening of the concept. More fundamentally it illustrates that the environmental challenges we face cannot be solved by technology (even not in combination with socio-economic data) alone. A wider approach, combining technological advances wit human ecology, policies, psychology, and ethical aspects is mandatory to ensure further steps forwards to sustainable development.

Dealing with the historical trends in the evolution of the "cleaner production" concept allows also identifying major trends for the future:

- Cleaner production will increasingly become an important part of the vision, strategy, policy, and management not only in production sectors (industry, agriculture, forestry, aquaculture), but also in service sectors as tourism, health care, and administration.

- The growing interest of the services sector will increase the attention for cleaner consumption. In hospitals the consumption of products is responsible for over 40% of the CO₂-emissions. Green procurement, combined with in depth environmental management allows bringing down the absolute emission figures.
- To cope efficiently with this widening perspective proper monitoring and identification is essential. This should go beyond the currently existing laboratory and administrative quality control procedures. It should include among others proper environmental accountancy allowing to establish more accurate and more targeted (environmental, social, economic, combined) footprints, to mention only this most needed methodological progress.
- Cleaner production will be applied realizing targets of sustainable development coinciding e.g. with the aims of public health and clean environments as they are interpreted in a green and smart city context (neutral carbon balance, zero waste, accessible green and blue spaces), and development in general. To this end major changes and innovation will be necessary.
- Complementary to the strategic aspects, issues that will attract more attention during the years to come include:
- Integrated CO₂-reduction approaches to halt the further progression of climate changes and the associated effects. This presumes combining avoidance, reuse, stocks, minimization, adaptation and mitigation of the effects. This will necessitate improved and optimized production processes, life cycle approaches (combining the origin of the materials with production aspects, maintenance and waste, taking into account the transport aspects) better product design, monitoring of the outputs and impacts, management, sustainability targeted quality control, stakeholder involvement, awareness raising and training (Huisingsh et al., 2014).
- Water use and quality: freshwater of good quality is an increasingly rare and valuable resource. More efforts are needed to use less water (savings improving the efficiency of water use), preventing both chemical and biological water pollution, and increasing the effectiveness of waste water treatment.
- Locally produced, environmentally sound (organic, ecological, with a limited energy and chemicals input) food will become increasingly important and take advantage of cleaner production methods and strategies. Realizing the ambitious targets on this food issue will necessitate an integrated approach including green procurement, quality control (labels), good practices, and behavioral and cultural changes and transitions. More research is needed unraveling the links between environmentally sound food and health.
- Realizing these widened cleaner production targets will necessitate more and better focused research (e.g. on footprints and accountancy methods, environmental and related impact assessments, and new developments on renewable energy and energy efficiency), education, knowledge, skills and consultancy.

The widening scope of cleaner technology is promising but also has its limitations. Additional initiatives e.g. to advance CSR are often situated in the realm of the social targets and instruments. The concept of "shared value" might be provided. In the long term the financial performance of an organization depends on the quality of the environment in which it operates (Porter and Kramer, 2006). According to this vision, acting in a sustainable way goes beyond responsibility; it offers opportunities serving the core objectives of the organization, promoting innovation and establishing competitive advantage.

In the past, "cleaner production" significantly contributed implementing sustainable development in business and industry. It proved to be likely one of the most effective concepts and instruments responsabilizing this sector during the changes in a society moving towards a cleaner environment. Therefore the widening scope, targets and methods will, no doubt, contribute to a society moving towards long term, respectful and responsible transitions. It is granted this is one of the major strengths of the widening of "cleaner production".

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