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ScienceDirect
Journal of Cleaner Production 15 (2007) 1316–1320
Journal of Cleaner Production
www.elsevier.com/locate/jclepro

Environmental technologies – from misleading interpretations to an operational categorisation & definition

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Accepted 12 July 2006
Available online 28 September 2006

Abstract

Environmental technology (ET) has become a catchphrase during the past decades. Nevertheless an operational definition is not yet plain, allowing manufacturers and engineers to add to their technologies the supplement ''environmental'' whenever they feel it is appropriate – even for marketing purposes only. Key institutes for the transfer of ET in Germany and Japan for example base their attempts on misleading interpretations about ET. But an analysis of existing literature allows the separation of ET into four categories, including Zero Impacts or Zero Emissions Technologies – the paradigm for ET. This moves towards a first attempt of an operational definition of ET.

Keywords: Environmental technology; Cleaner technology; Clean technology; Zero Emissions technologies; Definitions

1. Introduction

There is a growing emphasis in the areas of development and environmental protection on modern technologies to make efficient and effective use of available resources and reducing a negative environmental impact. Simultaneously industry and applied sciences are strengthening their efforts towards a further cost minimisation through novel technologies since substantial saving potentials through the concepts of total quality management and just-in-time are no longer obvious. Furthermore environmental pollution of local, regional and global dimensions through industrial processes sometimes with disastrous direct impact on human life, demonstrated the necessity not only for improvements, but also to find new production and development paths especially taking the paradigm of sustainability into consideration.

This led to the development of novel technologies and techniques, not only concentrating on production of goods and services in a most efficient way, but also taking possible negative, as well as possible positive impacts on the environment into account. Doing so, at the beginning attention was predominately focused on direct human health aspects. With the growing knowledge of interrelations in environment it became clear that human beings are subordinated elements of a complex environmental system, underlying its laws and thus, also depending indirectly or directly on other elements, which man can only, if at all, partially influence.

These new requirements were met by technologies for which the combination of the terms environment and technology appeared appropriate, so that they finally became titled ''environmental technology'' (ET) or sometimes synonymously ''environmentally sound technologies''. ET has become a catchphrase illustrating the enormous growth potentials predicted for these markets coined by expressions such as ''Green Gold'' [1]. Recent studies estimate the world-wide market for ET is valued at EUR 478 billion and for a country such as Germany, it is EUR 40 billion [2,3].

Among ETs several have become rather popular, supported by political incentives to widely apply them. Among those, ozone-monitoring systems in the cities, end of pipe technologies such as catalysts in the automotive sector, non-fossil energy-production technologies and most recently industrial

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doi:10.1016/j.jclepro.2006.07.015

conversion processes, based on special methods used in biotechnology. For some time ''Zero Emissions'' has become a slogan in the automotive industry to promote technological developments in reducing emissions through usage to zero and thus to start a novel marketing offensive referring to an environmental issue in times where climate change and ozone depletion are increasingly leading to public awareness.

Notwithstanding that the social production system is regulated by written laws and the comprehensive usage of ET in politics and literature, an operational definition of ET is not yet plain [4]. But it is important to have a clear, correct and commonly agreed on definition to ensure that it directs the development of these technologies in the right direction that is to approach sustainable business models which diminish the stress and burden on the environment, ideally to zero. As the editors of this special issue of the Journal of Cleaner Production pointed out in their call for papers, various market and systemic failures and cultural barriers hindered a wide-spreading of appropriate ET. A lack of clarity in defining ET supports its usage as a catchphrase, but thus, also a diversity of strategies, which might even impede each other towards the realization of a Zero Emissions society.

The objective of this article is to demonstrate the need for a thorough discussion of an appropriate categorization and definition. Towards this purpose, it starts with the presentation of international attempts in defining ET, followed by few sample institutions in Japan and Germany that are engaged in transferring ET and their respective approaches to define them. From the following grouping of ET into four categories, it develops a first attempt for an operational definition for the future.

2. International attempts at definition

Rath and Herbert-Copley [5] argue that in the case of environmental technology, environmental impact depends on the way it is used. But the same applies for every kind of technology, so that this approach does not appear very useful in defining ET. Also Förster's [6] attempt to broadly define ET must be evaluated similarly. In his understanding

> *''Environmental Technology combines technology with natural resources''.*

This definition is not only too general to be useful to provide an operational definition, but is also misleading. All kinds of technologies are directly or indirectly networked with natural resources through their utilisation in production. One fundamental of technology is that it requires natural resources. Following Förster and Rath/Herbert-Copley the expression technology and environmental technology could be used equally. Consequently the purpose of the term environmental technology could be questioned if it is not only a reminiscence of an environmental movement.

From a rather idealistic point of view, especially considering the paradigm of ''sustainability'', it is desirable that every kind of technology should be environmentally sound and sustainable. But this does not correspond with the present reality or the short- and mid-term expectations. Simply for the pure distinction of common technologies from those which are environmentally sound, the describer ''environment'' can be of help. The classification into the sub-group ''environmental technologies'' requires a common agreement of an operational definition. However, if every actor applies his own standard and understanding of ET, the formulation and implementation of policies along the Agenda 21 and thus, the paradigm ''sustainability'' must be questioned.

The United Nations Conference on Environment and Development (UNCED) provides a more specific definition of Environmental Technology in its Agenda 21:

> *''34.1 Environmentally sound technologies protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes.*
>
> *34.2 Environmentally sound technologies in the context of pollution are ''process and product technologies'' that generate low or no waste, for the prevention of pollution. They also cover ''end of the pipe'' technologies for treatment of pollution after it has been generated.*
>
> *34.3 Environmentally sound technologies are not just individual technologies, but total systems which include know-how, procedures, goods and services, and equipment as well as organizational and managerial procedures. This implies that when discussing transfer of technologies, the human resource development and local capacity-building aspects of technology choices, including gender-relevant aspects, should also be addressed. Environmentally sound technologies should be compatible with nationally determined socio-economic, cultural and environmental priorities''* [7].

This definition also reflects the understanding of the United Nations Environment Programme (UNEP) and its International Environmental Technology Centre (UNEP/IETC) in Japan [8]. In UNEP's eyes ET or Environmentally Sound Technologies (EST) encompass technologies that have the potential for significantly improve the environmental performance relative to other technologies.

In the eyes of the Organisation for Economic Cooperation and Development (OECD) this definition mirrors the concept of ''cleaner technologies''. Consequently technologies which are cleaner than conventional can be categorised as ET [9]. Through the introduction of these technologies the core production technology is modified so that emissions and the consumption of energy and natural resources are reduced. Thus, they lead to an optimisation of the resource efficiency with financial and economical benefits. By analogy with the Agenda 21 OECD includes goods, services, systems, technical know-how and organising as well as management capabilities into its definition. But varying from the outcomes of the United Nations Conference on Environment and Development (UNCED), OECD does not include so called end of pipe or cleansing technologies to ET because of their high production

costs without necessarily increasing the overall production. Additionally such technologies are only shifting environmental problems from one sphere to another.

Through the lack of standards of comparison the above described definitions also leave many elementary questions open. The statement that ET is less polluting and recycles more than other technologies leaves much space for interpretations. The same counts for the finding that it is typical of ET, that their utilisation of resources is more sustainable. More sustainable than what? What are the indicators?

Simply the prognosis of the growing market of ET led to the integration of ET into the portfolio of countless companies and the establishment of those around the world. Moreover, the majority of them do not define ET or provide such an insufficient description of ET that allows the categorisation of most technologies in the sub-group ET (e.g. http://www.gruenenwald-ag.ch; http://www.sternad.com; http://www.jessberger.de; http://www.ecos-consult.com; http://www.envicom.com; http://www.eco-web.com; http://www.etcentre.org).

Unfortunately the attempts of the UNCED and the OECD do not appear appropriate for a general definition of ET. Consequently it is necessary to continue the clarification through shifting the focus to two example institutions in Japan and Germany, specialised in the transfer of ET to Newly Industrialising Countries.

3. The understanding of ET transfer institutions

Within Germany's efforts to protect and preserve the environment for subsequent generations, the International Transfer Centre ITUT Association and ITUT Ltd. (ITUT) were created in Leipzig as a joint initiative of the Federal government, the German economy and the Saxonian state legislature. Experience from the redevelopment and structuring of the former German Democratic Republic, the existing know-how in engineering and planning due to the environmental protection level in Germany as well as the already developed environmental technology offer numerous foundations for possible solutions of similar problems in other regions of the world. By promoting the transfer of environmental technology and know-how, ITUT is trying to support the development towards a careful treatment of resources and the environment [10]. But surprisingly ITUT does not even distinguish clearly between techniques and technologies. The exact translation of its German name "Internationales Transferzentrum für Umwelttechnik" into English would be "Center for the International Transfer of Environmental Techniques", but the official English term is "Center for the International Transfer of Environmental Technologies". The same applies to the former "German-Japanese Co-operation Council for High-Technology and Environmental Technology (GJCC)", where "technology" is replaced by the German expression of "techniques" [11]. Consequently both institutes represent the tendency to use "technology" and "techniques" synonymously, although a clear distinction is well known. In contrast to the definition of techniques the definition of technologies implies the know-how required to develop and apply techniques and technical procedures [12]. Thus it exists embodied in machinery and equipment and unembodied in blueprints, technical instructions, manuals, etc. [13].

Additionally at least two more complementary factors have to be taken into consideration to deploy technologies: (i) the qualification of the person who operates technologies; and (ii) the organisation, i.e. the integration of a given technology into social contexts and operations.[1]

The Japanese "International Centre for Environmental Technology Transfer (ICETT)", close to Yokkaichi,[2] was established through the cooperation of industry, academia, and government to serve as an organisation effecting the smooth transfer of Japan's environmental conservation systems in order to contribute to the conservation of the global environment and the sustainable development of the world economy. Thus, its basic mission is comparable to the one of ITUT in Leipzig, but in contrast to ITUT ICETT provides a comprehensive definition and description of ET:

> *"The traditional means of combating pollution has been by means of end of pipe systems, i.e. treatment of wastes and polluting streams. This end of pipe approach, while still essential for many industries and for many technologies, should only be used as a last resort and Cleaner Production opportunities should be investigated first.*
>
> *Cleaner Technology is a manufacturing process which by its nature or intrinsically:*
>
> *Reduces effluent and other waste production;*
>
> *Maximises product quality;*
>
> *Maximises raw materials and energy and any other input use.*
>
> *Thus, one technology is usually compared to some other technology or process. Cleaner Technology may be thought of a subset of Cleaner Production activities with a focus on the actual manufacturing process itself and considers the integration of better production systems to minimise environmental harm and maximise production efficiency from many or all inputs.*
>
> *Clean Technology may be an impossible or difficult goal as it can be considered as the ultimate of the search for an inherently clean technology with no unwanted by-products, total use of inputs and full efficiency. On the other hand it may be used as a comparative term, and just be better than another technology. For example, considering membrane technology as inherently clean although even this technology produces waste streams."* [14].

[1] Technology often embodies organisational factors, i.e. the involvement of organisational knowledge on the possible arrangements of the connection different manufacturing steps e.g. in the chemical industry to close loops.

[2] Yokkaichi (Mie Prefecture), about 330 km south-west from Tokyo, is one of the nation's most prominent petrochemical and industrial zones. Chemicals, like sulphur oxides, which exhausted from the chimneys, heavily polluted the air. Thus air pollution was one of the four major cases of pollution in Japan. For detailed information see e.g. ICETT 1994a.

4. Categorisation of environmental technologies

Building on the above given definitions and descriptions ET can be separated into the following four categories (Fig. 1):

4.1. Measuring technologies on the environment

Tools, instruments, machines and complex systems which measure and control or even harness the environment. One category of such technologies provides the necessary background information on deviations from the natural balance. Another one is used to prevent man from harmful effects through environmental phenomena like for example floods and shortage of water. In contrast to the following three categories, the focus of this kind of ET is not necessarily on the minimisation of anthropogenic impacts on the environment, but on the understanding of the environment and the containment of negative environmental impacts on mankind.

4.2. Cleansing technologies or end-of-pipe approaches

Processes and materials that have been developed to minimise or neutralise harmful effects due to their use, without necessarily having to alter the original process. This cleansing technology is mainly based on so called 'end of pipe,' solutions, such as the instalment of exhaust catalysts and water filters [15]. These technologies help in one direction to reduce the pollution of an environmental medium, however, they achieve the opposite in another direction through dilution, filters, and recycling. Moreover they require a higher consumption of resources and energy, which unavoidably leads to additional costs [16]. These kinds of technologies have an additive or repairing function as well as constituting degree of aftercare with a transformatory effect on emissions.

4.3. Cleaner technologies

Modifications to the process minimise or even eliminate any effects harmful to the environment, such as for instance the introduction of modern control technology and changes in types of raw materials or additional materials [17]. Such preventative measures are used for example in the area of transport to reduce fuel consumption. These so-called integrated technologies are designed to improve protection of the environment through a holistic reflection of the entire product cycle [6,18].

4.4. Clean technologies or zero impact technologies

In contrast to Cleaner Technologies Clean Technologies do simply not have any negative impact on the environment. But these kind of technologies are not yet existing, at least from a holistic view-point.

Certain methods of production in the chemical industry and in separating membranes, not to mention the latest industrial conversion processes, based on special methods used in biotechnology are categorised as clean technologies [19]. Emissions register, however, on only a few important parameters as zero, with the others demonstrating acceptable emission values. Although the development and operation of clean or zero impact technologies seems Utopian from a thermodynamic perspective, they mark a ''landing point''. The maximal approximisation to this point is the operational target. Nevertheless some analysts believe that cleaner technology seems to be a more suitable term [20,21], since the fourth category of ET practically does not exist.

5. Concluding attempt of a tentative definition

The financial burdens are to be classified long-term as smaller during the effort of clean and cleaner technology than in the case of cleansing technology [6,16] Considerably higher capital expenditures for the prevention technologies compared to the curative, additive technologies on account of the investigation and evolution costs, which possibly even replace whole production cycles, do appear more profitable on a long-term basis through savings of resources [4,22]. But financial savings through the instalment of environmental technologies may not necessarily lead to the reduction of harmful environmental effects. In some cases, a total balance analysis will show that such saved financial resources will be reinvested [23]. These reinvestments can be for technologies, products or even a more intensive usage of the ET, which can directly neutralise the positive effects. Fuel savings of more efficient engines of automobiles can also result in a thoughtless and thus, even increased usage of the automobiles. Consequently, a total environmental balance analysis is one possible way to take the necessary holistic view for the categorisation of ET.

The ET of the first and second category have, on the whole, been more rapidly developed and adapted than those of the other categories. Especially the measuring technologies are essential for the understanding of processes in the ecosphere and the

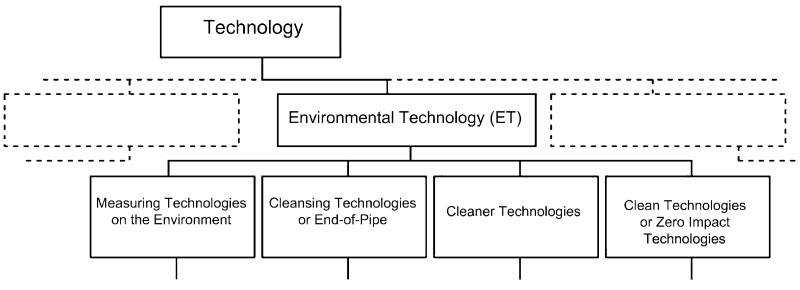

Fig. 1. Categorisation of environmental technology.

interdependencies between the ecosphere and anthropogenic activities and thus also to take a holistic view. Consequently they can be considered as fundament or elementary ETs.

Nevertheless, the term "Environmental Technology" is usually used in conjunction with approaches to minimise the production of environmentally harmful substances. This target is met by the technologies of the second and third category. But there is common agreement that preventative measures are more economical than curative, meaning cleansing technologies [24]. On top of that, the technologies of categories two and three are more widely employed than those of the fourth category. This is easily explained by the need in most cases for radical transformation. The introduction of zero impact technologies of the fourth category is greatly hindered by a rather linear thinking, not allowing a taking of the necessary holistic view and a lack of investment in environmental protection through prevention, even in the industrial nations.

Consequently the installation of cleaner and clean technology would meet the definition of sustainability by economic and ecological parameters. But higher investments for these technologies require more efforts to develop highly efficient and cheaper technologies – which will sometimes lead to models that mimic nature through integrated systems instead of installing high-tech [25]. But these medium- and long-term goals need the support of cleansing technologies to cope with urgent harmful emissions, e.g. through highly polluted sewage in drinking water or highly contaminated exhaust fumes of incineration plants. Thus, a transnational environmental policy through the transfer of environmental technology has to take all four categories into account; following the paradigm of "sustainability," preference should be placed upon clean and cleaner technologies.

As a result a first attempt for an operational tentative definition of ET could be:

> *"Environmental Technologies (ET) contain four different categories: measuring, cleansing, cleaner, and clean technologies differing in their ecological effectiveness. ET reduce pollution at least in one environmental medium, only accepting the transformation of emissions into another form or into another medium as a short term measure in order to cope with harmful pollutants. Thus, ET implements the continuous improvement of processes, products and services by the conservation of raw materials and energy and by the reduction of toxic substances, waste and emissions within the production cycle."*

But it requires further discussions to come to joint agreement on a well accepted definition among the various interest groups. The fact that this was not yet developed results also from the interest of not narrowing down the usage of the term ET, as it has become a catchphrase in both sciences and politics, so to continue extensively using it, even though not all ET are really supporting sustainable development. Consequently, a better distinction between the various ET categories would also help to see their value-added and to assess progress towards the given aims and undertake necessary corrections.

References

[1] Moore C, Miller A. Green gold, Japan, Germany, the United States, and the race for environmental technology. Boston: Beacon Press; 1994.
[2] Wirtschaftsförderung und Technologietransfer Schleswig Holstein GmbH. Deutschland führend Umwelttechnologiemarkt in Europa. Kiel (Germany); 2005.
[3] Helmut Kaiser Consultancy (HKU), editor. The environmental technology markets in Asia. India, Indonesia and Thailand, Berlin (Germany); 1997.
[4] Halstrick-Schwenk M, et al. Die umwelttechnische Industrie in der Bundesrepublik Deutschland, Untersuchungen des Rheinisch-Westfälischen Instituts für Wirtschaftsforschung, Nr. 12, Essen (Germany); 1994.
[5] Rath A, Herbert-Copley B. Green technologies for development: transfer, trade, and co-operation. Ottawa (Canada): International Development Research Centre; 1993.
[6] Förstner U. Umweltschutztechnik. Berlin: Springer; 1995.
[7] United Nations Conference on Environment and Development (UNCED). Agenda 21 Geneva (Switzerland); 1992.
[8] UNEP/DTIE – http://www.unep.or.jp/ietc.
[9] Organisation of Economic Co-operation and Development. Promoting cleaner production in developing countries. Paris (France): The Role of Development Co-operation; 1995.
[10] Internationales Transferzentrum für Umwelttechnik – http://www.itut.de.
[11] Deutsch-Japanischer Kooperationsrat für Hochtechnologie und Umwelttechnik (DJR). Arbeitsbericht 1998, Bonn (Germany); 1999.
[12] Hammann P, Mittag H. The marketing of industrial technology through licensing. In: Backhaus K, Wilson DT, editors. Industrial marketing. Berlin: Springer; 1986. p. 224–42.
[13] Hilllebrand W, et al. Strengthening technological capability in developing countries – lessons from German Technical Cooperation, Berlin (Germany); 1994.
[14] International Centre of Environmental Technology Transfer (ICETT) – http://www.icett.or.jp.
[15] Almeida C., Development and transfer of environmentally sound technologies in manufacturing: a survey, UNCTAD Discussion Papers, No. 58, Geneva (Switzerland); 1995.
[16] Shen T. Industrial pollution prevention. Berlin: Springer; 1995.
[17] Cramer J, Zegveld WCL. The future role of technology in environmental management. In: Futures June 1991. p. 451–68.
[18] Brickwedde F., Umweltentlastung durch innovation, in: Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Ed.). Umwelt, 7-8/1995, p. 261f.
[19] Bizri OF. Environmentally sound technologies: their status and prospects, in: United Nations, editor. Environmentally sound technology for sustainable development, ATAS Bulletin, Issue 7, New York (USA); 1992, p. 32–7.
[20] Barnett A. International technology transfer and environmentally sustainable development, paper prepared for the UNCTAD Workshop on the transfer and development of environmentally sound technologies, Oslo (Norway); 1993.
[21] Barnett A. Do environmental imperatives present novel problems and opportunities for the international transfer of technology? Paper prepared for the UNCTAD Workshop on the transfer and development of environmentally sound technologies, Oslo (Norway); 1993.
[22] Meffert H, Kirchgeorg M. Marktorientiertes Umweltmanagement. Stuttgart: Schaeffer-Poechel; 1992.
[23] Eyerer P, Wolf M-A. Zero Emissions – was geht und was nicht geht. In: Altner G, et al., editors. Jahrbuch Ökologie 2001. München (Germany); 2001. p. 136–48.
[24] Jänicke M. Ökologische Modernisierung. Optionen und Restriktionen präventiver Umweltpolitik. In: Simonis UE, editor. Präventive Umweltpolitik. Frankfurt/Main: Campus; 1988. p. 13–26.
[25] Kühr R, Széll G, editors. "Zero Emission" – eine chance in Europa? Dokumentation des 1. Europäischen Zero Emission Kongresses, 23./24. Oktober 1997. Osnabrück (Germany); 1997.