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Towards a sustainable society: United Nations University's Zero Emissions Approach

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Abstract

The Zero Emissions approach comprises a research and action-based program, launched at the Tokyo-based headquarters of United Nations University (UNU) in 1994 and actively supported, among others. by the Japanese government as part of its security policy. Through the Zero Emissions lens, material cycles from intake to emissions should be managed as a holistic system. Thus, the primary focus is the intake of natural resources within renewable limits and final emissions within acceptable limits. This implies the optimisation through an integrated system of processes and consequently the mimicry of the hierarchy of natural ecosystems in the anthropogenic sphere. A network of industries through clustering builds integrated systems in which everything has its use. The Zero Emissions concept requires industries to re-engineer their manufacturing processes in order to fully utilise the resources within the systems—the set target of Zero Emissions. Other concepts such as cleaner production emphasise the minimisation of emissions and wastes through recycling, reuse and reduction, but mainly concentrate on the ''end of pipe''.

In the anticipated ''Zero Emissions society'', consumers would preferentially purchase functions instead of material goods and thus, be actively involved in the creation of a new service economy where all materials are automatically sent back to the producers after they lose their function. Additionally, the design of goods should lead to eradication of the concept of waste.

The UNU Zero Emissions Forum—through networking with academia, industry and governmental policy-makers—promotes international multidisciplinary research and development efforts to analyse trends in society and technology and pave paths for concrete pilot projects. Thus, the Forum has gathered concrete experience through a number of case studies all over the world.

Keywords: Zero Emissions society; Zero Emissions; ZERI; The Natural Step

1. Introduction

''A production without wastes and harmful emissions; hardly any idea is more convincing and challenging''. That was the introduction to a radio story by the German Bayerische Rundfunk in late 1997 about enterprises without chimneys. First reactions called this a crazy idea, another product of eco-hysteria or simply impossible. But these critics have become more careful when it turned out that the government of Japan together with industry, sciences and local governments are strongly supporting this concept and substantially investing in the research of if and how Zero Emissions could become a new industrial standard and a model for a sustainable society [1]. What is this real Utopian concept about, which has already entered the PR campaigns of big automobile manufacturers [2–4] which serves as the title for future oriented task forces on, e.g. sustainable production and consumption, the reorganisation of cities, and which is attracting growing interest in regional planning?

2. Zero Emissions: the term

The key question of many conferences has been and still is: To what extent should we reduce wastes and harmful

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emissions and how much does it cost? Following the Zero Emissions approach, the response is simple but rather provocative: We are reducing wastes and harmful emissions to zero and make money in the process.

The careless disposal of residues from production chains, the resulting environmental problems and the enormous costs for resources are the starting points for a new concept. ''We are using everything, and when we are using everything, there will be no wastes left'', the former Vice-Secretary General of the United Nations and co-initiator of the Zero Emissions Concept, Heitor Gurgulino de Souza summarised this new concept in a few words.

Here, Zero makes sense as it refers to the material flows and harmful emissions, but not to emissions as such. Consequently, Zero Emissions certainly does not approach the thermo-dynamically impossible. Chemical reactions, for instance, do not reach exactly 100% yield and waste heat emissions are inevitable. The Zero Emissions concept does not assert that all emissions of a set of industrial processes can reach precisely zero. The meaning of Zero Emissions has two aspects. One is to force a systems perspective: even if an emission is inevitable from a given process, viewing it in the context of other industrial and natural processes that utilise this waste can possibly lead to effectively ''zero'' emissions, meaning no measurable impact on the environment. Thus, Zero Emissions is not only concentrating on materials; however, the minimisation of e.g. carbon-dioxide, methane and CFC is also a key issue.

Also, the term refers to management standards such as Zero Defects and Zero Inventory. Together with Zero Emissions, these approaches symbolise a process of continuous improvement towards an idealised goal, improving the industrial performance in a sustainable way through a growing effectiveness coming along with decreasing volumes of wastes and harmful emissions.

In the early 1980s one came to the opinion that quality or Zero Defects is an elementary prerequisite for growth and profit [5]; at the end of that decade another step was added: Zero Inventory. Through this, companies reduced the costly stock-keeping through the so-called ''just-in-time'' systems [6]. These two steps found world-wide acceptance, even though flawed production and stock-keeping will never be completely eliminated. And in the mid-1990s a new industrial triad occurred. In this, the environment as origin of the resources for production chains is regarded as an additional potential to reduce costs and maximise profit [7].

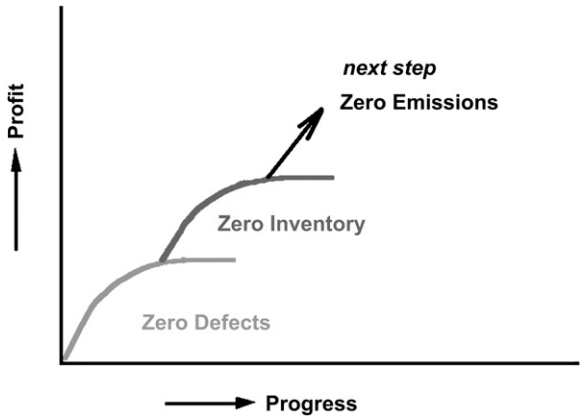

Fig. 1. Progression model based on the industrial management concept.

The term Zero Emissions attracted special attention, as it is easily understandable and does not require translations into, e.g. Japanese, German, French, etc.

3. Zero Emissions Initiative: the start

With the beginning of the 1990s, discussions about a more efficient economy arose. New catch-phrases such as eco-efficiency, factor x, dematerialisation, resource-productivity, material flow management, including the ecological rucksacks resulting from the production processes, made the rounds [8–11]. At the same time, the resource-poor Japan guided by Prime Minister Takeshita started a pioneering role in the environmental field, also to gain international recognition after the breakdown of the Soviet Union. Another reason was the prognosis of enormous growth in neighbouring countries in Eastern and South-Eastern Asia, showing the need for developing a strategy to reduce dependency from increasing prices on the world-wide resource markets. For the first time in history, conservative Japanese politicians and company representatives started a discourse about the future strategy for the environment and development [12].

In 1994, the United Nations University (UNU), with its headquarters in Tokyo, launched a new focus area, the Zero Emissions Research Initiative (ZERI), designed to investigate various approaches and technological breakthroughs requisite to the creation of a new type of industrial system, lowering the unwanted dependency and developing new jobs. In this early phase the discourses of the 1950s on economic and social costs of development played a key role. The definition of the environmental economist William Kapp, ''Environmental problems result from market failures through the ineffective utilisation of resources'', summarises in a few words the business-oriented starting-point of ZERI [13]. Thus, ZERI was in the tradition of efficiency strategies. From 1994 to 1998, UNU Zero Emissions research focused predominately on investigating technological solutions for industry, mainly for biomass-based processes. Results included the development of the idea of the ''bio-refinery'', through which input materials for plastics and other organic-based products are derived from plant matter [14].

4. Zero Emissions: the concept

At the beginning the core concept ''We are using everything, and when we are using everything, there will be no wastes left'' was not added by a profound theoretical and conceptual framework. Rather one focused on a few pilot projects in the food sector, trying to implement the core idea [15]. Since then, these experiences have been contributing to the development and sharpening of the concept.

Zero Emissions also requires a shift in society as a whole. It is widely recognised that production and consumption are tightly intertwined activities. Thus, implementation of Zero Emissions requires consideration of the larger societal system within which industrial activities take place. Achieving Zero Emissions at a societal level includes addressing such issues as urban and regional planning, consumption patterns, energy conservation, upstream industrial clustering, the reuse and recycling of products, and the interactions of these activities with the local industrial production base.

In 1997, a more holistic research meta-project was started by the Japanese universities, exploring areas where the ecological restructuring of entire communities might be achieved through changes in lifestyles, consumption and production patterns. Industrial process Zero Emissions, networking of different industries for the improved utilisation of resources, and community-based designing of complete material cycles were the three components of these research projects [1].

The planning to move society in the direction of sustainability must be based on an understanding of the constitutional principles of the functioning of the system usually referred to as the eco-sphere (e.g. thermodynamics; the biogeochemical cycles; the ecological interdependencies of species; the societal exchange with, and dependency on, the ecosphere) [16]. Operational approaches towards, e.g. dematerialisations and substitutions need to comply with the complementary, non-overlapping, conditions for social and ecological sustainability [18,16]. Resulting actions should be fostered through a set of strategic principles defining a future ''landing place'' on the systems level first. Otherwise reaching sustainability is a rather unlikely outcome of any effort. Each investment should bring practices closer to the overall objective of complying with the system conditions [2]. This requires backcasting methodology, which means that the starting point of the planning is an envisioned successful future outcome of the planning. Based on this outcome, the strategic paths are designed. This approach involves the close cooperation with other strategic approaches towards sustainability, involves the utilisation of tools such as life cycle assessment in order to evaluate the present situation of material flows, and the implications of various technologies, industrial designs and policy options at a micro-, meso- and macro-level.

Zero Emissions represents a shift from the traditional industrial model in which wastes are considered the norm, to integrated systems in which everything has its use. It advocates an industrial transformation whereby businesses emulate the sustainable cycles found in nature and where society minimises the load it imposes on the natural resource base and learns to do more with what the Earth produces.

The Zero Emissions Concept envisions all industrial inputs being used in final products or converted into value-added inputs for other industries or processes. In this way, industries are reorganised into clusters such that each industry's wastes/by-products are fully matched with the input requirements of another industry, and the integrated whole produces no waste [27].

From an environmental perspective, the elimination of waste represents the ultimate solution to pollution problems that threaten ecosystems at global, national and local levels. In addition, full use of raw materials, accompanied by a shift towards renewable sources, means that utilisation of the Earth's resources can be brought back to sustainable levels.

For business, Zero Emissions can mean greater competitiveness and represents a continuation of its inevitable drive towards efficiency. First came productivity of labour and capital, and now comes the productivity of raw materials—producing more from less. Zero Emissions can therefore be understood as a new standard of efficiency and integration.

The experiences of the past years have led to three main conceptual paths of zero emissions work:

1. Large energy and material systems: within these, industries are clustered, so that the wastes and by-products of one company are utilised in the production chain of another, without large transportation in between. This approach is mainly based on well-known analysis approaches and means such as input–output analysis, ecobalance and/or LCA [3–7].
2. Small energy and material systems: these are material loops within agriculture and the food industry through integrative biomass systems, coming out of the traditional Chinese farming and have been tested, e.g. in Fiji, Colombia and elsewhere [17–19].
3. Regional systems: within these systems the joint development of sustainable regional planning, together with relevant stakeholders is intended, in which the experiences of other strategic approaches towards sustainability are also playing a key role in order to avoid duplication of work and successfully integrating the latest know-how [20].

Moreover it became obvious that a successful integration of the qualitative dimensions of political and social sciences into the quantitative analysis of material flows is also mandatory for the success of the Zero Emissions Concept. Protection principles, behavioural patterns, and societal norms are also important for the realisation of Zero Emissions. Moreover, a balanced communication and cooperation between all actors responsible for the material flows is necessary to come to the envisaged eco-structuring.

5. Zero Emissions and other concepts

By now, the interested reader might wonder to what extent does the Zero Emissions concept differ from other concepts of ecological modernisation such as clean or cleaner production. Cleaner production is mainly about the reduction of negative effects such as costs through wastes [28,29]. Thus, in contrast to Zero Emissions, cleaner production has a more transitional function. The overall aim shall be the creation of new industries and jobs and thus value-added. Only then is it considered to follow in the line of industrial breakthroughs in the past such as Zero Defects and Zero Inventory [35].

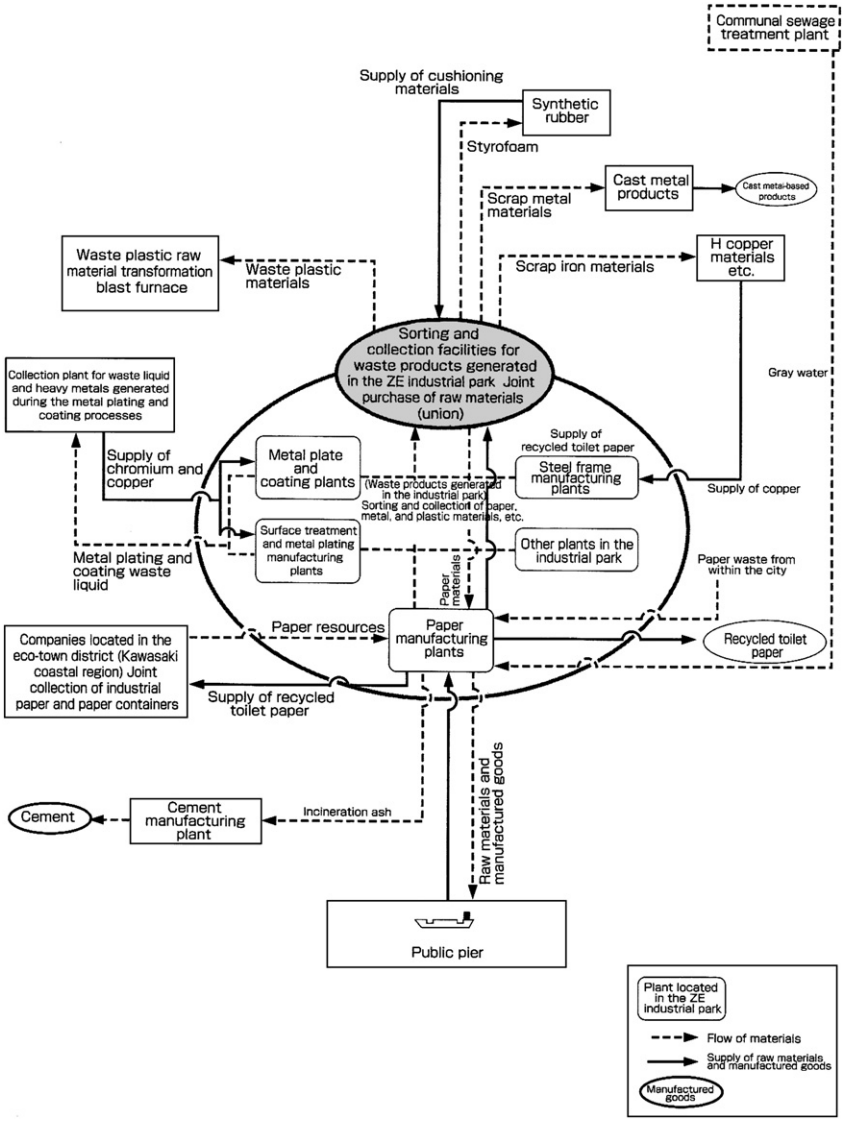

Fig. 2. Zero Emissions industrial park: the case of Kawasaki [30].

Taking a historical perspective, Zero Emissions represents the next phase in the evolution in the control and reduction of emissions from industrial pollution sources (Table 1):

1. End of pipe: use of pollution control technologies to treat process wastes.
2. Cleaner production: redesign of processes and products such that less emissions are produced in the first place.
3. Zero Emissions: conversion and use of process outputs as inputs for other processes.

When applying the cleaner production concept the necessary modifications of process units must lead to a grouping and close networking of industries, as proposed by zero emissions. Both the cleaner production and Zero Emissions Concept will require industries to re-engineer their manufacturing systems so that they can fully utilise the resources within the industries and industry networks. But one can understand cleaner production as a transit towards Zero Emissions, because the latter emphasises a clear target helping to assess the progress made, even though the ways towards this aim might be much harder and longer.

6. Zero Emissions: the present status

Now, one could easily refer to a multitude of developments in, e.g. Asian, European and Northern American industries, targeting Zero Emissions. But the majority of these were not developed from a holistic point of view, which is fundamental for the successfully application of the Zero Emissions Concept. Examples are the clean-in-place (CIP) practices in the food and pharmaceutical industry [36], the utilisation of lignin from the paper production as substitute for plastic in the automotive and cosmetic industry [37,38]. Moreover, fuel cells and their utilisation in traffic and as storage for solar energy are also showing the direction of Zero Emissions. But these are

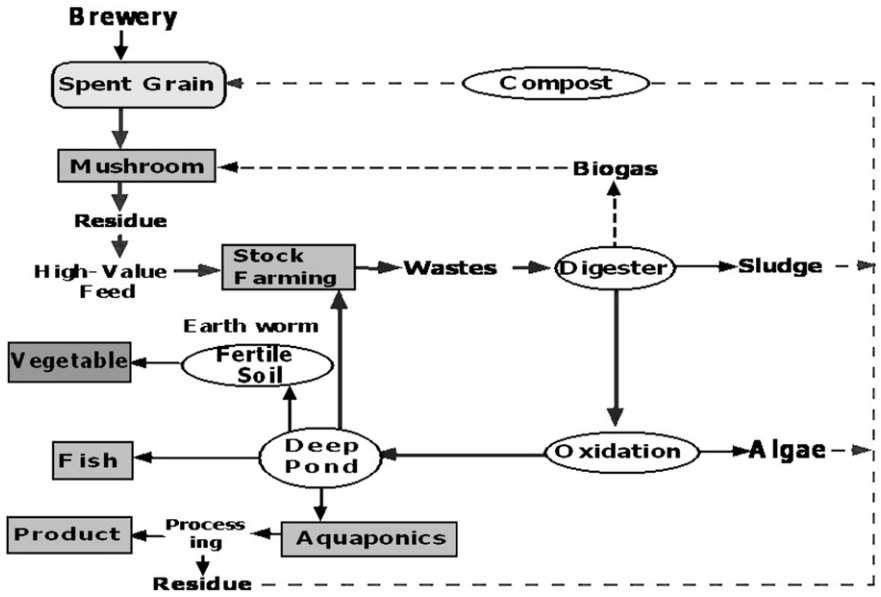

Fig. 3. Integrated biomass systems: simplified illustration of a Zero Emissions Brewery.

mainly success stories of engineering and natural sciences, in which the development of material flows due to the social, political and economic frame-work conditions, are hardly reflected. Hence, one will not succeed in identifying *the* Zero Emissions demonstration project for the industrialised and post-industrialised world—it does simply not yet exist. And the multitude of Zero Emissions projects in industrialising and developing countries illustrated the problems in its implementation, but nevertheless its mid-term and long-term feasibility.

There is still a long way to go to realise Zero Emissions. In addition one should keep in mind that Zero Emissions is not a protected term and is thus applied under rather different circumstances and for different purposes. The experiences of 11 years of Zero Emissions work illustrate that the present activities in the field of environment and sustainable development are still dominated by traditional thinking with disciplinary boundaries, world views and methods. The interdisciplinary perspective to describe and define problems is still a big challenge of Zero Emissions.

Table 1

End-of-Pipe	Cleaner Production (reduce, recycle, reuse)	Zero Emissions (total productivity)
Minimise effects on downstream	Minimise effects on downstream	New industries at upper stream
Minimise waste	Minimise waste	Value added
Cost minimum	Cost minimum	Increase revenue
Existent production processes	Modification of unit processes	Clustering of industries
Countermeasure at the outlet	Input–output analysis	Output–input connection
Individual problems: water, energy, wastes, …	Waste minimisation by modification of production process	Integral approach, job creation
Starting point	Transit	Final goal

Over the past years The United Nations University, together, with The Natural Step and the Factor 10 Institute, have been key drivers in initiating a close cooperation among models towards sustainability such as Ecological Footprinting [21], Sustainable Technological Development [22], Natural Capitalism [23] etc. It was concluded that a systems perspective is helpful for comprehensive and strategic planning, and for the selection and design of tools to monitor the transition towards sustainability. The variation in primary focus, multiple perspectives, and numerous tools of different organisational initiatives provide a potential for an increasingly synergistic approach to sustainable development. There are also no major obstacles stemming from the philosophical standpoint or strategic origins of the different initiatives studied. This creates opportunity for cooperation. Further, since the primary foci are different, perspectives and experiences should be different enough to allow synergies that could evolve as greater cooperation is established and emphasised among these concepts [24].

7. The zero emissions forum

The Zero Emissions Concept was also communicated to industry, government and civil society through events such as the yearly World Congresses on Zero Emissions from 1995 to 1998. As a result, many businesses, local and national government agencies, and local communities, particularly in Japan, adopted Zero Emissions as a basis for activities to improve environmental performance.

From 1999 onwards, UNU adopted a facilitating role in fostering Zero Emissions related activities through formation of a new organisation, the UNU/Zero Emissions Forum (ZEF). In its current form, this forum has international and Japanese components, the latter involving over 150 representatives

from Japanese business, local governments, academia, and NPOs.

7.1. Objectives/activities

The United Nations University Zero Emissions Forum (UNU/ZEF) [25] brings together representatives from business, local government, academia and NGOs in pursuit of three main objectives.

(a) Research: realisation of Zero Emissions requires new methods for analysing and planning integrated industrial systems as well as technologies either yield reusable outputs or act as interfaces between processes. ZEF academia and industry networks are active in developing and implementing new methods and technologies. In addition, two new approaches are being pursued since 1999:
   - Zero Emission Economy deals with the question of what economic transformations are required to realise a zero emission society. The ultimate goal of this work is to suggest system changes that will steer society towards a sustainable ''landing point''. The initial phases of this research focus on clarifying the contribution of energy and materials efficiency to macro-economic growth, in addition to attitudinal, philosophical, sociological, psychological, political and ethical dimensions, even though Zero Emissions is a rather applied than scientific approached.
   - synergies between approaches to sustainability examine the array of strategies/tools that have been emerged in addition to Zero Emissions, such as Cleaner Production, Factor X, Life Cycle Assessment, The Natural Step, and pollution prevention. The goal is to understand how these tools relate to each other and how they can be collectively combined to plan for sustainability [26]. For this purpose the ''Alliance of Global Eco-Structuring (AGES)'' under UNEP's Cleaner Production Network was founded [39,40].

(b) Inter-sector collaboration: ZEF is intended to promote collaborative projects between industry, government, and academia to implement Zero Emissions. The Kawasaki Eco-industrial Park, the Honjo International Research Park, Fujisawa Eco-Industrial Park, Nairiko Industrial Park, Kokubo Industrial Park and the Eco-town of Kitakyushu represent good examples of such collaborative initiatives [30–34]. ZEF encourages additional projects by creating a forum for different sectors of society to work together [30]. Results are published in UNU's Zero Emissions Booklet Series [41].

(c) Information exchange and outreach: ZEF provides a platform for exchange of information between acting and potential practitioners regarding best practice as well as to promote the idea to new audiences. These objectives are performed by holding events such as conferences, symposia, lecture series and study groups as well as through print and electronic dissemination, which are available on the UNU/ZEF website [42].

8. Conclusions

The experiences of the first 11 years of Zero Emissions work have proved the feasibility and attractiveness of the concept. But future incentives will be necessary to further sharpen the concept, to diffuse the findings and to initiate a discourse with all relevant actors, for which the United Nations University's Zero Emissions Forum attempts to be the platform and mediator.

References

[1] Nihon Keizai Shimbun. Zero emissions is becoming policy. January 17th, 1999.
[2] http://www.toyota.de/innovation/environment/cleaner_greener_engines/fossil_fuel_alternatives.asp.
[3] http://www.daimlerchrysler.com/Projects/c2c/channel/documents/595926_HTR2_04dualdrive_sprinter.pdf.
[4] Palm T. Zero emission transport possible. Bellona 2000.
[5] Tsuchiya S. Quality maintenance: zero defects through equipment management. Cambridge: Productivity Press; 1992.
[6] Hall R. The implementation of zero inventory/just-in-time. Falls Church: American Production and Inventory Control Society; 1985.
[7] Pauli G. Upsizing: the road to zero emissions, More jobs, more income and no pollution. Sheffield: Greenleaf; 1998.
[8] Von Weizsäcker EU, Lovins AB, Lovins LH. Factor four doubling wealth – halving resource use. London: Earthscan; 1997.
[9] Schmidt-Bleek F. Revolution in resource productivity for a sustainable economy – a new research agenda. Fresenius Environmental Bulletin 1994;2:245–490.
[10] Schmidt-Bleek F. MIPS and factor 10 for a sustainable and profitable economy. Wuppertal: Wuppertal Institute; 1997.
[11] Holmberg J, Robèrt K-H. Backcasting from non-overlapping sustainability principles — a framework for strategic planning. International Journal of Sustainable. Development and World Ecology 2000;7:1–18.
[12] Kühr R. Japan's approach to becoming a global environmental flagship – more lip service than reality. International Quarterly for Asian Studies 2000;31:109–25.
[13] Kapp KW. Volkswirtschaftliche Kosten der Privatwirtschaft. Tübingen 1958.
[14] Gravitis J. The concept of the zero emissions bio-refinery. Tokyo: UNU/IAS; 1998.
[15] Pauli G, Mshigeni K. First five years of action: the Zero Emissions Research and Initiatives (ZERI), 1994–1999. Windhoek: University of Namibia; 1998.
[16] Robèrt K-H. Tools and concepts for sustainable development, how do they relate to a framework for sustainable development, and to each other? Journal of Cleaner Production 2000;8:243–54.
[17] University of Namibia. A new hope for sustainable development in Africa, Zero emissions and total productivity of raw materials. Windhoek/Tokyo: United Nations University; 1998.
[18] http://envchem.iis.u-tokyo.ac.jp/ZeroEm/ze/html_e/e_zero2.html.
[19] Klee R. Zero waste system in paradise. BioCycle Magazine Feb:66, 1999.
[20] Kuehr R, Varga M, Schotanus-Sakiman J. National & international experiences with strategic sustainability approaches. Pre-study – part A., Zero emissions – an opportunity for Riau. Hamburg/Tokyo/Jakarta: UNU/ZEF; 2004. Research Report.
[21] Wackernagel M, Rees W. Our ecological footprint: reducing human impact on the earth. Philadelphia, PA: New Society Publishers; 1996.
[22] Weaver P, Jansen L, van Grootveld G, van Spiegel E, Vergragt P. Sustainable technology development. Sheffield: Greenleaf Publishing; 2000.
[23] Hawken P, Lovins A, Lovins LH. Natural capitalism – creating the next industrial revolution. Rocky Mountain Institute; 1999.
[24] Robèrt K-H, Schmidt-Bleek B, Aloisi de Larderel J, Basile G, Jansen L, Kuehr R, et al. Strategic sustainable development: selection,

design and synergies of applied tools. Journal of Cleaner Production 2002;10:197–214.
[25] http://www.unu.edu/zef.
[26] Kühr R, Suzuki M, editors. Integrative approaches towards sustainability. Berlin/Tokyo: UNU/ZEF Focal Point for Europe; 2000.
[27] Suzuki M, editor. Constructing material circulation process toward a zero emissions society. Report of the Scientific-Grant-in-Aid of the Ministry of Education, No. 292. Tokyo: Research Institute of Industrial Engineering, University of Tokyo; 2000 (in Japanese).
[28] UNEP Industry and Environment Review 1996;19(3) July–September; 1998;21(4) October–December.
[29] http://www.uneptie.org/PC/cp/understanding_cp/home.htm.
[30] Zero Emissions Manual Drafting Committee. Zero emissions manual. Realizing a zero emissions-based regional community, United Nations University Zero Emissions Forum Booklet. Tokyo: UNU/ZEF; 2004.
[31] http://www.city.kitakyushu.jp/~english.
[32] Sueyoshi K. Kitakyushu eco-town. Efforts toward zero emissions: environmental conversation and promotion of industrial development. Tokyo: Kaizosha; 2002.
[33] Takasugi S. Recyling-based industrial urban model: the example of Kitakyushu eco-town. Tokyo: Diamond; 2002.
[34] http://www.kawasaki-net.ne.jp/eco/Ecoen.htm.
[35] Suzuki M., Visualisation of a sustainable industrialised society - zero emissions approach. In: Filho WL, Ubelis A, editors. Integrative approaches towards sustainability in the Baltic Sea region. Frankfurt; 2004. p. 29–39.
[36] http://www.thomasnet.com/products/cleaninplace-cip-systems-14594451-1.html.
[37] Eyerer P, Wolf M. Zero emissions – Was geht und was geht nicht. In: Altner G, et al., editors. München: Jahrbuch Ökologie; 2001. p. 136–48.
[38] http://www.ict.fraunhofer.de/deutsch/scope/es/proj/nawaro/index.html.
[39] http://www.factor10-institute.org/pdf/CarnoulesAppeal.pdf, http://www.rio-economy.de/.
[40] Kuehr R., Strategic sustainable development: a comparison of current approaches (executive summary of a UNU/ZEF workshop in Carnoules/France June 2000). Tokyo/Berlin; 2001.
[41] http://www.unu.edu/zef/publications.html.
[42] http://www.unu.edu/zef.