INTRODUCTION
Cleaner Production

Industrial Environmental Management through Cleaner Production

Throughout the second half of the 20th century a growing worldwide movement has attempted to change the way industry interacts with the environment. Governments and industry alike have contributed to this movement. The focus has been to reduce environmental impacts from industry through changes in industrial behaviour and technology.

The background is a common recognition that human activities have contributed to the deterioration of the environment and the loss of natural resources. Many significant steps have been taken towards restoring the natural environment. Still pollution of air, water and soil remains one of the largest environmental challenges facing today's world.

Over the period Industrial Environmental Management (IEM) practices have developed gradually by the evolution of strategies for mitigating the environmental problems. Practising IEM could be understood as walking in a staircase. The concepts and strategies for pollution abatement make up the steps. Concepts higher up the staircase include the concepts below, and add additional elements of scope and complexity. The art and science of management expands as one moves up the staircase.

Below some of these steps – concepts and strategies – will be introduced. All of them are relevant. Some are however in themselves insufficient to solve the environmental problems of an industrial activity. For many of the more efficient strategies the problem is rather that they have not been fully used and implemented.

The Staircase of Industrial Environmental Management

A number of terms have been used to describe both the movement and the approaches used. The concepts on the staircase (Figure 1) are, from lowest to the highest:

- Waste Disposal
- Pollution Control
- Recycling
- Waste Minimisation
- Pollution Prevention
- Cleaner Production
- Industrial Ecology
- Sustainable Development

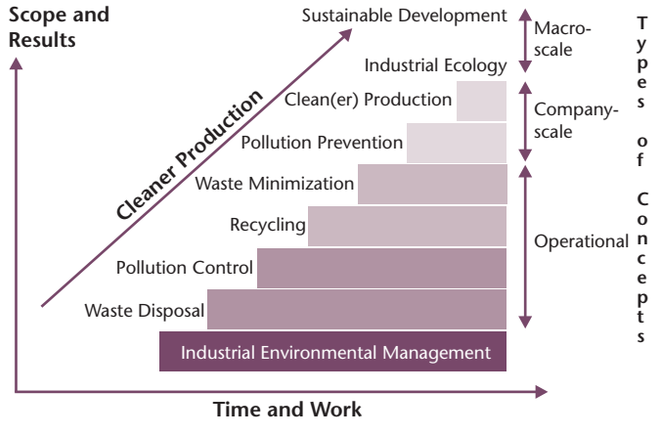

Figure 1 *Staircase of Concepts of Industrial Environmental Management [Adapted from Hamner, 1996].*

The relationship between these terms is one of subsets and supersets. The lower terms are part of the higher terms. The highest term, sustainable development, also includes other "staircases" of concepts such as social responsibility, natural resource management, and economic development, as well as the staircase of industrial environmental management.

There are three types of concepts on the staircase. The *macro-scale* concepts of sustainable development and industrial ecology extend far beyond the firm and include relationships between companies, social institutions, the public and the environment in all its facets. The *company-wide* concepts of environmental management systems and cleaner production address all aspects of the firm's operations in a life cycle approach, from the use of natural resources via suppliers, production, marketing and product use to product disposal. The *operational* concepts address specific activities, aspects, of the company, aimed to reduce its environmental impacts.

Pollution Control

In the past, *pollution control* was seen as the key to a cleaner environment. Pollution control refers to the measures taken to manage pollution after it has been generated.

One example is the extensive investment in the building of sewage or wastewater treatment plants, both in industries and in municipalities. This took place in Western Europe typically during 1960s and 70s, while in Central and Eastern Europe it was not until after the systems change around 1990 that WWTPs were built on a significant scale. Another example is the installation of flue gas cleaning equipment, for instance different types of filters for separation of dust and particles from industrial flue gases produced by incineration of oil and solvent wastes. Also here equipment for gas cleaning was being installed in Western Europe long before it was in Central and Eastern Europe.

Figure 2 Pollution control. *During the 1960s and 1970s wastewater treatment plants were built at all urban centres in Western Europe to save the recipients - rivers, lakes, and coasts. (Photo: iStockphoto)*

The operational concepts also include the strategies of *waste minimisation* and *recycling*. Waste minimisation includes both *waste avoidance* and *waste utilisation*. Waste avoidance refers to the actions taken by producers to avoid generating hazardous waste, while waste utilisation includes a variety of actions which make waste a useful input into the production processes.

The overall concept of recycling can also be broken down into a number of subsets, with terms as *reuse*, *recycling*, and *recovery*. Reuse, or closed loop recycling, refers to the repeated use of a "waste" material in the production process. Recycling occurs when one producer is able to utilise the waste from another production process. Recovery refers to the extraction of certain components of a "waste" material for use in a production process.

Pollution Prevention and Cleaner Production

In recent decades we have witnessed a paradigm shift from pollution control to *pollution prevention* (sometimes referred to as P^2). Pollution prevention is the use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source. It includes practices that diminish the use of hazardous materials, energy, water, or other resources, and practices that protect natural resources through conservation or more efficient use.

Most recently, the concept of *cleaner production* (CP) has entered the global environmental arena. CP fits within P^2's broader commitment towards the prevention, rather than the control, of pollution.

Cleaner production refers to the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment. For *production processes*, cleaner production includes 1) conserving raw materials and energy, 2) eliminating toxic raw materials, and 3) reducing the quantity and toxicity of all emissions and wastes before they leave a process. For *products*, the strategy focuses on reducing impacts along the entire life cycle of the product, from raw material extraction to the ultimate disposal of the product. Cleaner production is achieved by applying know-how, by improving technology, and by changing attitudes.

P^2 is an approach which can be adopted within all sectors, whether it is a small service operation or a large industrial complex. CP, on the other hand, directs activities toward production aspects. Unlike in the past, when pollution was simply controlled, P^2 and CP programmes attempt to reduce and/or

eliminate air, water, and land pollution. Therefore, the P^2 and CP approaches benefit both the environment and society.

Economically, P^2 and CP can actually reduce costs and in some cases, generate profit. Both approaches are practical and feasible, and can consequently contribute to a sustainable future.

Eco-efficiency

The concept of eco-efficiency was introduced by the World Business Council for Sustainable Development, WBCSD, in 1992 and since then has been widely adopted. Many businesses in all continents have been pursuing ways of reducing their impact on the environment while continuing to grow and develop.

According to the definition given by the WBCSD Eco-efficiency is a management philosophy that encourages business to search for environmental improvements that yield parallel economic benefits. This concept describes a vision for the production of economically valuable goods and services while reducing the ecological impacts of production. The reduction in ecological impacts translates into an increase in resource productivity, which in turn can create competitive advantage. In other words eco-efficiency means producing more with less.

However, the concepts of Eco-efficiency and Cleaner Production are almost synonymous. The slight difference between them is that Eco-efficiency starts from issues of economic efficiency which have positive environmental benefits, while Cleaner Production starts from issues of environmental efficiency which have positive economic benefits.

Sustainable Development

Cleaner production, pollution prevention, etc. are all subsets of the concept of *sustainable development*, which states the basic problem that the other concepts attempt to address: There are

Figure 3 Changing technology. *The chlor-alkali factory outside Skoghall in west Sweden once used the mercury electrode method to produce chlorine. In 1987 the new membrane-based technology was introduced, replacing all use of mercury. There has been a 100% change to this new technology in Japan, a partial change in Western Europe and USA, but no change has yet taken place in eastern and central Europe. (Photo: Courtesy of Akzo Nobel Industries)*

Box 1 The Concept of Cleaner Production

Why Cleaner Production
Cleaner Production (CP) begins with the insight that even if environmental technologies has lead to a significant reduction of emissions (at least per product) they are expensive and need further input of materials, energy and manpower. Environmental technologies therefore offer no economic incentives for industry. On the opposite they generally lead to higher production costs, and they include a regulatory approach. Industry may avoid environmental technologies by investing in countries with less strict regulations.

Cleaner Production, on the contrary, aims to reduce both the negative effects to the environment and the operating costs. Cleaner Production works with process integrated – preventive – methods instead of End-of-Pipe solutions. Cleaner Production is the conceptual and procedural approach to production that demands that all phases of the life cycle of a product or of a process should be addressed with the objective of prevention or minimisation of short and long-term risks to humans and to the environment.

There are some basic methods/techniques to implement CP in companies, but every single company has a different problem. You do not have the same solution twice! Every solution is unique, due to the specific features of every company.

Five Basic Principles of Cleaner Production
Cleaner Production requires that resources be managed efficiently. This consists both of careful use of resources, the closing of material streams, and resource substitution. It is possible to outline five general principles of Cleaner Production:

1. *Input-Substitution*
   - Use of less hazardous raw-, auxiliary- or operating materials.
   - Use of operating materials with a longer lifetime.
2. *Good Housekeeping*
   - Increase the Material and Energy efficiency of actions in the process. Try to fetch the "low hanging fruits" first, e.g. reduce losses due to leakage. It is important to train employees.

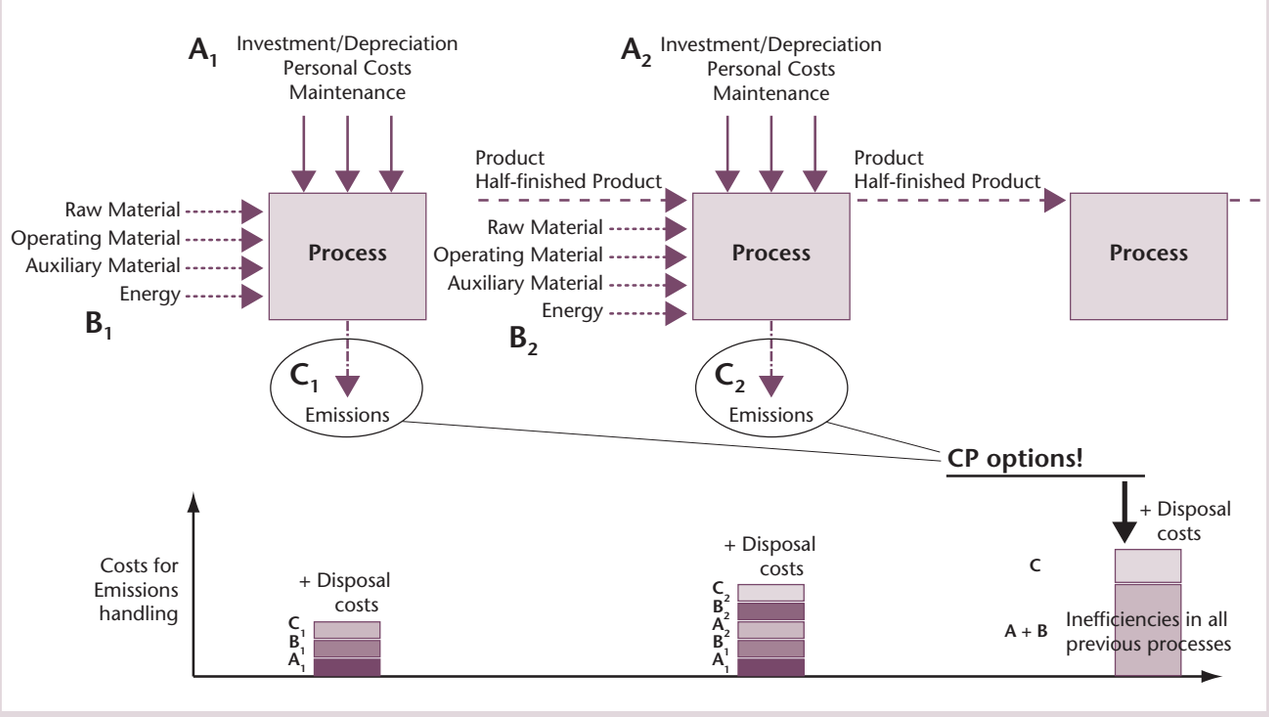

Figure 4 Cleaner Production opportunities. *An industrial production can be seen as consisting of a series of processes, each with its investments (A) inputs of raw material, energy etc (B) and outputs of product/half-finished product and process emissions (C). Costs for emission handling of each partial process originate in inefficiencies in raw material use etc (A), investments (B), or process emissions (C). To that should be added the cost for disposal of the product after use. Cleaner Production may be directed to all these inefficiencies [Based on a diagram from Planasch, 2006].*

3. *Internal Recycling*
   - Close Material and Energy Loops for water, solvents, etc.
   - Cascading of Material and Energy streams.
4. *Technological Optimisation/Change*
   - Implementation of new technologies.
   - Improved process control.
   - Redesign of processes.
   - Change in or substitution of hazardous processes.
5. *Optimisation of the Product*
   - Increasing the lifetime.
   - Easier repair.
   - Easier de-manufacturing, recycling or deposition.
   - Use of non-hazardous materials.

Recycling
Setting up well functioning cyclic material flows is crucial for good resource management. Internal recycling refers to actions within a process (closed loop), while external recycling refers to actions after production (open loop) where the material may be fed into different and multiple processes. Internal recycling reduces the amount of materials purchased. External recycling has no influence on the amounts of materials purchased. Finally the use of wastes/emissions in another process, even if at the same industrial site, is not considered as recycling.

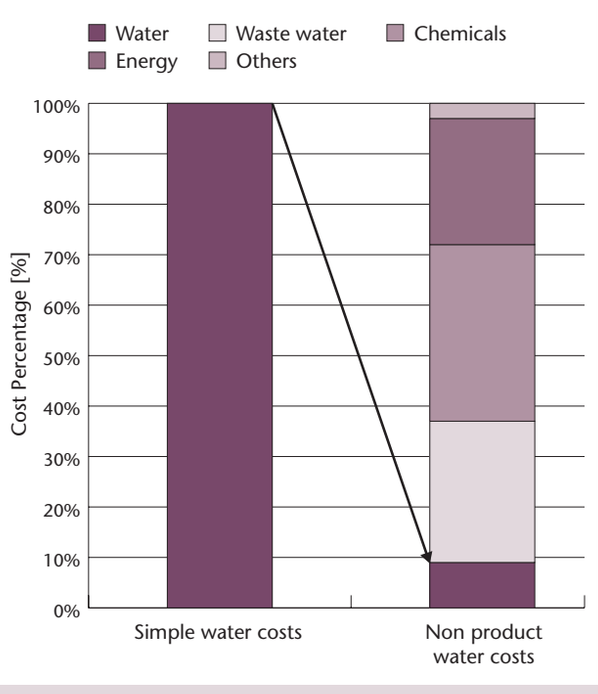

Figure 5 Total industrial water costs. *The costs for handling resources and emissions in a company are often underestimated. In this case, from a textile company in Austria in 2005, the costs of water (left) is only about 20 % of the total costs for handling the water (right). This consists of the water costs, the costs for wastewater treatment, for chemicals used, energy needed and some other costs. Taking components such as depreciation, maintenance and personnel costs into account thus adds a factor 4-5!! [Based on a diagram from Planasch, 2006].*

Internal recycling includes:
- Re-utilisation of materials, such as solvents, for the same purpose.
- Reuse of materials for different purpose (paper, solvents for inferior use i.e. pre-cleaning etc.
- Closing of loops (water).
- Multi-way systems (packaging materials).
- Reclaiming of materials with high value.

How to implement CP actions in companies
Start by getting to know the process. Important tasks are:
- Define the processes units, e.g. in electro-plating; degreasing, etching, bondering, rinsing.
- Understand the process with its chemical and physical connections.
- Draw a flow sheet with all (!) Input and Output-streams and all interrelationships (quantitative).
- Take a closer look at the most important material streams (qualitatively and economically, m³/a, EUR/a).
- Look at existing cross-media effects.

Identify the weak points of the process: it is easier to convince companies to take actions if the economic benefits are clear at the start, so identify the low-hanging fruits, and define process optimisations.

In the longer term Cleaner Production will shift from being a process of continuous improvements to a process of redesign of production. The goal is to reach zero emission, that is a process in which all input material is turned into products, either to be sold or used in another process.

Based on a presentation by Planasch, 2006.
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limits to what the environment can tolerate, and society needs to ensure that development today does not cause environmental degradation that prevents development tomorrow. There are many issues here but the role of industry and industrial pollution is obvious. Industrial systems and individual companies will need to make changes in order to prevent future generations from being unable to meet their own needs. Sustainable development is thus the long-term goal of individual companies rather than a business practice.

As expressed by the Brundtland Commission in 1987:

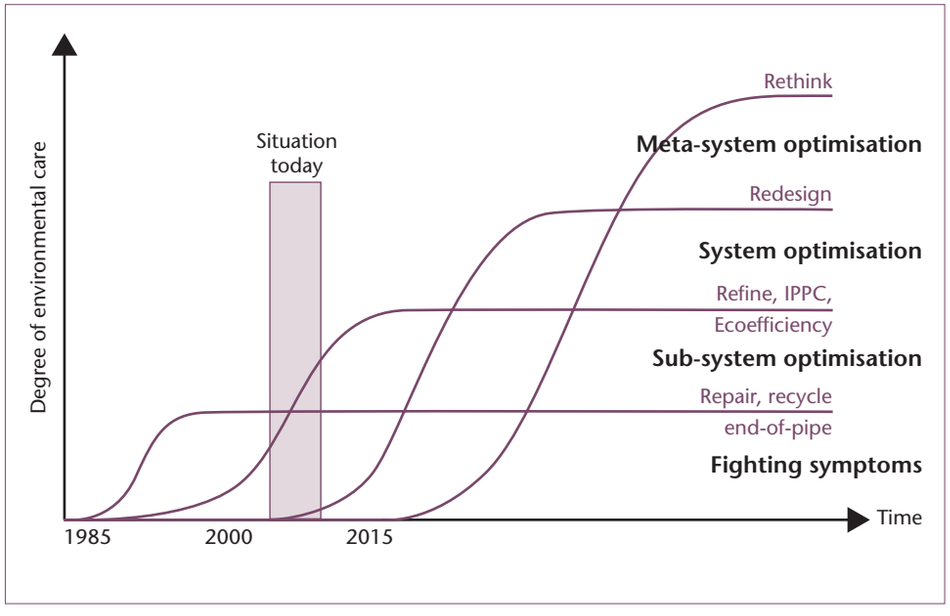
"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

It contains within it two key concepts:

1. The concept of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given.
2. The idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs.

Thus the goals of economic and social development must be defined in terms of sustainability in all countries, developed or developing, market-oriented or centrally planned. Interpretations will vary, but must share certain general features and must flow from a consensus on the basic concept of sustainable development and on a broad strategic framework for achieving it.

Whatever interpretation is chosen it remains clear that sustainable development is a goal, not a thing. The real problem with the Brundtland Commission definition is that it does not include or imply real actions in any particular dimension, so no one knows what to really do about it.



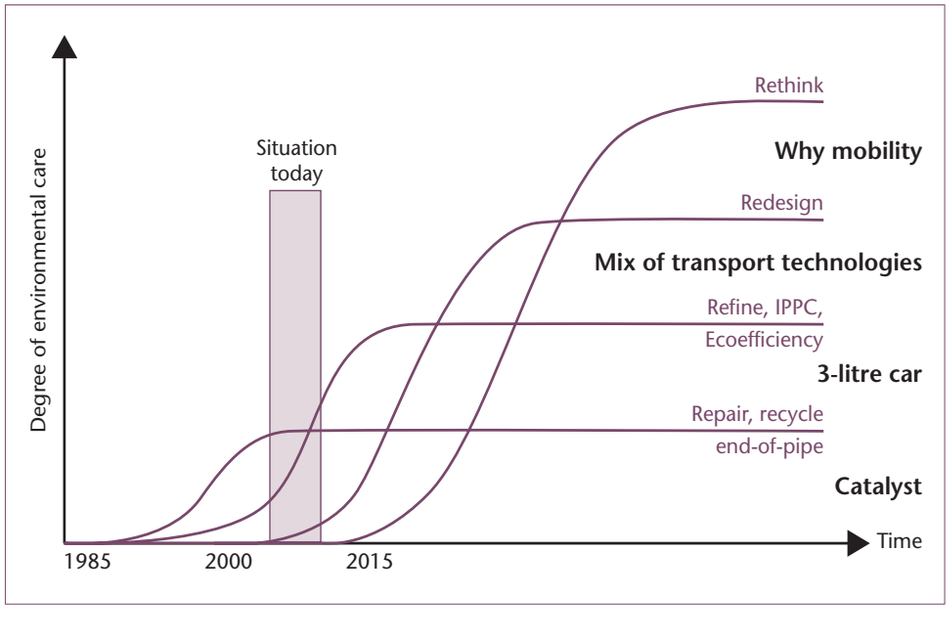


Figure 6. A. The paradigm shift in environmental protection. *The paradigm shift is here seen as four stages (Compare Figure 1). Fighting symptoms of environmental impact led to the first stage of "repair, recycle, end-of-pipe" in the 1990s. Today we are concerned with refine, IPPC and eco-efficiency. To fully implement Cleaner Production we need to address systems optimisation by redesign, or even the higher level, meta-system optimisation.* **B. The paradigm shift illustrated by the case of car driving.** *First stage, fighting pollution, led to the catalytic converter, while later stages refer to the eco-efficient car, other ways of transport or reconsidering mobility itself. [Planasch, 2006].*

Industrial Ecology

Industrial ecology can be considered the "production" component of sustainable development. The most important aspect of industrial ecology is the idea of industry as a system in which there is no waste at any step because all "waste" is a resource for another part of the industry network. Individual firms participate in industrial ecology by considering how their activities fit into the larger industrial system. For example, they have to consider what other industries can use the company's wastes as inputs, and how they can work with them. This concept is thus one of relationships and dynamics between companies. To make industrial ecology work, of course, requires conscious application of the lower level concepts on the staircase as well as a motivation to support sustainable development.

Using the same definition approach as that of the Brundtland Commission industrial ecology may be defined as follows:

"Industrial ecology is the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a system view in which one seeks to optimise the total materials cycle from virgin material, to finished material, to product, to waste product, and to ultimate disposal. Factors to be optimised include resources, energy and capital." [Graedel and Allenby, 1995].

In this definition, the emphasis on *deliberate* and *rational* differentiates the industrial-ecology path from unplanned, precipitous, and perhaps quite costly and disruptive alternatives. By the same token, *desirable* indicates the goal that industrial ecology practices will support a sustainable world with a high quality of life for all, as opposed to, for example, an alternative where population levels are controlled by famine. Industrial ecology is therefore a more realizable macro-scale goal for industrial enterprises. Eco-efficiency and industrial ecology approaches can be used as examples of wise management of raw materials-products-waste streams.

The concepts below industrial ecology on the IEM staircase are all fundamental to making industrial ecology successful.

Cleaner Production as Long-term Vision

Throughout this book the practices of the several concepts and strategies introduced here will be detailed and exemplified, on both a managerial and a technological level. The managerial level is concerned with motivating, planning, following up and evaluating a technology. The technological level is concerned with the practice and functioning of the techniques used. In all cases it will hopefully be clear that the techniques, with a focus on cleaner production, are realistic, highly profitable, and sometimes required, to follow legal requirements and permits.

It seems incredible that so far and over its entire history industrialism mostly has relied on methods and techniques that are wasteful, imprecise and polluting. We have to learn from nature where the living cell is typically resourceful, precise and non-polluting. In some cases, such as in sustainable chemistry, this is approached, but much is left to be developed in the future. We have to create a society that uses renewable resources, is efficient and non-polluting, and recycles all material. Developing and using cleaner production methods is the first step towards creating such a society.

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Lennart Nilson is researching, teaching and applying cleaner production at the university and in industries, e.g. pulp and paper production and metal processing, and is also coordinating the Environmental Management and Cleaner Production masters programme in Baltech, Baltic Technical Universities Consortium.

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Internet Resources

United Nations Environmental Programme (UNEP)
Cleaner Production activities
http://www.uneptie.org/pc/cp/

United Nations Industrial Development Organisation (UNIDO)
Cleaner Production (CP) programme
http://www.unido.org/doc/4460

Zero Emissions Research & Initiatives (ZERI)
(exploring the concept of Cleaner Production on a meta level)
http://www.zeri.org/