15th Triennial World Congress, Barcelona, Spain

MANAGEMENT OF MATERIAL AND ENERGY FLOWS AS CHALLENGE TO ENGINEERING - CURRICULAR IMPLICATIONS

***Ulrich Briefs and **Dietrich Brandt**

**Department of Mathematics and Computer Science*
University of Bremen, Bibliotheks-Str 1, D 28359 Bremen, Germany
E-mail: u_briefs_irs_paris_berlin_p_holt@com-puserve.com

***Department of Computer Science in Mechanical Engineering*
(HDZ/IMA),University of Technology (RWTH), Dennewartstr. 27
D 5206 Aachen, Germany, E-mail: brandt@hdz-ima.rwth-aachen.de

Abstract: Every human movement and action is unavoidably linked to the metabolism of human with nature. Modern technology-based civilization has enhanced this metabolism by several orders of magnitude and thus, created the bulk of pollution problems. To control this metabolism will be the future task of engineering. A withdrawal from high-technology based production is not viable. Instead solutions for the polltion problems will have to be looked for in the core of industrial design and production. The self-understanding of engineering has to be re-directed towards mastering the ubiquitous metabolism of human with nature. Implications of this change of engineering for education are subsequently illustrated. *Copyright © 2002 IFAC*

Keywords: Education, environmental engineering, information systems, production systems

1. BALANCING INDUSTRIAL GROWTH AND POLLUTION

Germany - still one of the major industrial countries in the world - is heading for withdrawing from the production of nuclear energy. This decision appears unique among the highly industrialized countries of the world, although several other countries are thinking about the same stragegy. The long-term outcome of it is uncertain. It is questionable whether Germany can sustain this decision in the long run against future pressures of industry and politics. One of these pressures is generated by the observation that the per capita emission of carbondioxide in Germany is about 160% of the corresponding value of Germany’s neighbour country France.

France, Germany's long-term enemy neighbour nation, has become Germany’s much cherished partner in manifold forms of symbiosis for half a century now. This country is presently maintaining its thrust for high-technology based solutions for economic and environmental problems. She has undergone a remarkable process of industrial modernization. It has, however, taken place largely on the basis of nuclear energy generation: 75% of the country's electricity generation capacity is incorporated in nuclear power plants.

Due to recent political and economic decisions, France is presently about to exceed Germany's overall economic performance as for example measured by per capita GDP (The Netherlands by the way succeeded in overtaking Germany economically already in 1999).

These few remarks may illustrate that the technological philosophy prevailing in a country is intimately linked to its economic and "environmental" performance. This illustrates as well that the withdrawal from parts or the total of modern industrial production is not a viable way to cope with the increasing environmental problems of the modern way of life and especially of its productive basis although nuclear energy is not the “easy way out”.

This holds especially in view of the fact that apparently there will be no way out of the existing high degree of unemployment even in the developed industrial world without an increased long-term real economic growth. The case of Germany - once a locomotive engine in the international trade context, now for a decade already a country of low real-growth and high unemployment - teaches that we will have to look for other means to combat pollution than fostering a policy of industrial withdrawal and low growth.

A basic "strategic" political task in the future thus will be, in every country, to balance economic, technology-based growth and environmental protection.

2. CONTROLLING THE HUMAN-NATURE METABOLISM: AN ENGINEERING TASK

Every human activity, human life in general, is unavoidably linked to metabolic processes with the natural environment. The great achievements of the industrial era in human history have enhanced these metabolic processes by several orders of magnitude. This will continue in the future for a rapidly growing world population.

The development into the service industries or into the information society will not change the basic challenge to control these metabolic processes where they occur - and they occur everywhere and continuously.

The basis of the service or information society is a more and more sophisticated high-tech industrial production sector in which the need for automated systems creates additional needs for automated systems. The challenge thus is to provide for a better and especially more efficient environmental protection in the core of the present and the future society which is industrial production, including its concomitants in transportation, infrastructures and services, and increasingly high-tech-based industrial production.

The mastering - minimization and if possible optimization - of the material and energy flows linked to the universe of technological systems, will have to be a new element of the engineering paradigm of the future.

The design and production of technological systems - what we call engineering - therefore will be in a crucial position with regard to mastering the material and energy flows linked to our future civilization. Two realms of increased endeavours emerge in this context for engineering: establishing a sound information basis for environmental assessment of technological systems, and encorporating and integrating the relevant knowledge into engineering education.

3. SECURING THE INFORMATION BASIS FOR THE HUMAN-NATURE METABOLISM

Hence, what we need, firstly, is environmental pollution control in every of the "pores" of industrial processes (and likewise in all service processes). What we need is the control of the multifold acts of metabolism in the consumers' spheres of our modern societ-ies, which are increasingly determined by high-tech end-use technological systems.

In order to control pollution at the sources - and not only in the final phases of these processes by "end-of-pipe-solutions" - we have to collect all the information already available on the metabolic processes in industry, transportation, services, administration, consumption in households etc.. And where the information available is not sufficient we have to analyze and evaluate the metabolic processes, construct models and conceive theories, design and develop remedies on the basis of these models and theories.

In short: we have to extend the processes of scientific discovery and of technological innovation to the sphere of metabolism of man with nature in view of controlling it to a much higher degree than is traditionally done. This implies a collective, societal process to push forward the borders of control which combines ele-ments of "muddling-through" with optimization approaches, regulatory impositions with results achieved in economic competition, scientific knowledge as well as the tacit knowledge of e.g., human operators in in-dustrial or agricultural production (the latter is especially important in the so-called Third World).

The adequate concept for the information handling of this complex processes of extending scientific research and technical innovative capacity to the metabolic sphere are - in modern firms - the EISIFs - environmentally-oriented information systems in firms (Haasis et al,, 1995). These systems will be collecting, storing, processing, communicating data and information on all sorts of material and energy flows *into* firms, *out of* firms and *inside* firms. They will establish input-output reviews of industrial processes, facilities, production sites and products. They will evaluate these flows according to environmentally relevant criteria like toxicity, garbage intensity or CO_2 emissions. And they will finally establish a relationship to the traditional economic and financial objectives of firms.

They thus give the management the clues with regard to trade-offs between more environmental protection and any other business objective. Environmental protection thus will be made operative, an everyday concern in any decision-making process. And business firms are and will be the decisive actors in an increasingly globalized market economy.

The management of material and energy flows in firms needs to be based on modern information and communication technologies with all their off-springs like Internet and Intranets. The mastering of such management tasks will be one of the great achievements of applied sciences and sophisticated technologies, in the just beginning century. Furthermore it will to a certain degree, generate new and rewarding jobs and induce new directions for research, consultancy and training. The production engineers of the future will have to acquire a sound knowledge of this management of material and energy flows. And so will have, e.g., the investment analyst and the civil servant in urban planning.

It is imaginable that twenty years hence no more or less complex piece of machinery including equipment for direct consumer use will be delivered without a built-in control system of all its metabolic processes comprising software components which allow for a dynamic automatic internal adaptation of the relevant parameters.

This new orientation in engineering and manufacturing may even give new and dynamic outlets to the traditional manufacturing industries in developed countries thereby remedying to some degree, the problems of excess capacities in the bulk of these industries.

4. NEW CHALLENGES FOR THE ENGINEERING COMMUNITY

The "optimization" of technical systems and other complex systems like firms with regard to environmental pollution criteria comes into the reach of humankind. This re-direction of efforts appears to be a much more realistic answer to the challenge of pollution than the projects of abandonning certain lines or the whole of industrial production (as was dreamt - and still is being dreamt- in some parts of the "Green" movement).

The engineering community will have to play one of the key roles in this process. Engineers will have to reconceive their professional roles as "masters of the metabolism of humankind with nature". The paradigm which underlies the self-understanding of engineers *today* may be characteized as "increasing the domination of natural forces incorporated in a technological system". In the *future,* it may need to change to "balancing the different elements of these systems in view of a minimal use of natural ressources". An addional component of this paradigm to be developed will be the consciousness about the scale effects of industrial mass production of technological systems.

This new challenge essentially implies for *engineering education*:

Changing the view of technological systems in teaching

This means to enhance the view of technological systems as they are linked (in terms of usage rates and similiar measures) to the natural environment. A more holistic and complex view of these systems is needed.

Teaching how to build a new knowledge base

This means to accumulate the knowledge relevant to the different interfaces of technological systems and the natural environment, and make it transferable into engineering curricula. Such knowledge should be integrated into existing teaching modules or transferred via additional modules. Teaching the use of appropriate data bases and the links to them will be further curricular elements.

Encorporating material and energy flows into teaching technological systems design

This means to conceive design patterns and processes which allow the concomitant evaluation of all these material and energy flows linked to the technological system which is being designed. The structures and processes of material and energy flow and their use have to be taught in this context.

Teaching the use of tools for environmental evaluation

This means to teach the use of information systems including e.g., simulation and optimization models, expert systems etc. and the use of internet and intranet functions. They provide the tools to project usage rates, their environmental and economic evaluation as well as alternative ways of providing, using and substituting resources and energy sources.

Teaching the interrelationships between environmental, financial and economic effects

This means to teach engineers about the interrelationships between variances in technological design and environmental impacts as well as in economic and financial effects on the firm level. It may be based on concepts like teaching the philosophy of "environmental protection integrated into production" and the design and use of EISIFs. Such teaching may incorporate the principle of creating “chains of added value“ in manufacturing which are prophylactic with regard to the environment.

Teaching how to enhance transfunctional and trans-departmental information exchange

This means e.g., to establish links to CSWD and CSCW approaches pertinent to engineering professions. Computer Supported Work Design and Computer Supported Cooperative Work provide organizational techniques which combine the distributed knowledge of environmental effects in firms and other organizations.

Teaching to become sensitive for non-mainstream solutions

This means to enhance the engineers' sensitivity towards non-technological and non-orthodox solutions of handling engineering tasks. It comprises e.g., approaches developed in the context of low-cost automation design, or approaches based on the tacit knowledge of human operators in manufacturing. This may be of particular importance in developing countries.

Teaching accountability about global implications

This means to develop and teach the consciousness about the global implications of engineering and engineering products (Beedle, 1995). It is basically aiming at understanding the interrelationships between the design and manufacturing of technogical products, and the scale effects of mass production and the global extension of technologies and technological products.

5. CONCLUSIONS

At the turn of the century, the enormous contribution of the engineering community to the development of our modern civilization is challenged in a very fundamental way: we need to control the voluminous, sophisticated and increasing arsenal of technological devices of this civilization according to the imperatives of environmental accountability. This task means to develop and teach the technological philosophy which takes into account the unavoidable environmental impacts of modern technology on our individual and collective lifes.

We may tackle this task by starting with the engineering curricula. It means approaching the sources instead of doing another end-of-pipe job.

REFERENCES

Beedle, M.A.S. (1995). *An Integrated Solution to the Demands for Environmental Accountability*. Internal report of ICI Eutech Engineering Solutions

Briefs, U. (2000). Implications of "Environmental Protection Integrated into Production" for CSCW Approaches. *Proceedings of the ICSC Symposium on Intelligent Systems and Application (ISA 2000),* Wollongong, Australia, Dec. 2000, 1574-316

Haasis, H.-D., Hilty, L.M., Kuerzl, H., Rautenstrauch, C. (eds.) (1995). *Betriebliche Umweltinformations-systeme (Inter-company environmental data processing systems)*. Metropolis-Verlag, Marburg