Building Capacity for Sustainable Development.

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1. Summary

Sustainable development has to be regarded as a long lasting complex social process. The challenge to achieve a continuous justified level of welfare for the growing world population of future generations requires radical renewal of systems of production and consumption and of governance. This comprises integration of technological, economic, cultural, social and institutional aspects simultaneously and interacting at different levels of society from macro to micro. Essential is the driving force of a shared orientation of all involved on a sustainable future in a long lasting evolutionary process: Transition of society for sustainability.

Such process consists of numerous initiatives for renewal throughout society. The capacities to initiate, operate and manage these initiatives are developed in a "learning by doing" manner and in education systems.

In the European AIRP Project[1] learning by doing in sustainability oriented RTD-programs and its contribution to capacity building is analysed. The experiences of the Dutch program "Sustainable Technology Development" based on a "backcasting" approach fit very well in these observations.

Future capacities are also build in education systems. Based on the "backcasting" approach: "Which competences should our engineers have 10 years from now and what should the university look like", the University of Technology of Delft developed a program to embed sustainability in all its research and education programs. So far the university is well under way with three lines in education:

All graduates should be aware of the significance of sustainability for technology and its applications, sustainability should be integrated in all regular courses and there should be a possibility for students to incorporate sustainability their disciplinary graduation. In research a number of spearhead programs integrate sustainability.

A proposal has been made to integrate the line of practise and the educational line in synergistic model.

[1] AIRP stands for: Adaptive Integration of sustainable Research and Policy for development.

2. The challenge of Sustainable Development.

The Brundtland Report " Our Common Future" confirmed the name of a transition process ongoing since the "environmental warnings" (e.g. Carson, 1962; Club of Rome-Meadows, 1972) of the sixties of last century: **sustainable development** and broadened its content in time and scope: "Present and Future generations" and integrating "Environment and Development".
The Brundtland Report provided the international society with an analysis of phenomena threatening world stability, based upon hearings of stakeholders in the different regions of the world. It identifies three guiding interconnected principles briefly summarized:
Ecoefficiency, fitting of human activities within supporting systems of the earth,
Inter-and intra-generational social justice, equitable distribution of value and
Participation in decision making from local to international levels

The challenge for engineering and science lie in the "What and How".

The what

The "what" is essential to gain a view on the materialisation of the challenge for the coming decades.
In this process several modes can be recognised: cleaning up the environment and optimisation of existing consumption and production processes to begin with in the early 1970s , gradually paralleled in the early 1980s by *improvement* of existing production and consumption within the existing structures with end-of-process and process-integrated measures and later at the end of the 1980s by end-of-product measures like reuse and recycling and in the early 1990s by product-integrated measures like *redesign* for the environment (Graedel and Allenby, 1995).
"Our Common Future" induced the next phase in the transition towards a society in sustainable development marked by attempts to make more fundamental approaches to the ***restructuring of the production and consumption system*** more operational, like by UNEP, the World Council for Sustainable Development, the "factor approach" (Holden and Ehrlich 1974, Factor 10 Club 1997, Jansen 1993) and Industrial Ecology (Allenby, 1999) and in policies like the First National Environmental Policy Plan "To Choose or to Loose" in the Netherlands(1989 – 2001), opting for a sustainable Netherlands within one generation.

"Future generations" may be practically understood to define a context of three generations; a scope people usually have the experience and affinity to comprehend. Three generations cover a period of about 50 years. Moreover fundamental renewal in (technological) systems to provide for human needs takes several decades to develop from "concept to market". Therefore it is urgent that renewing innovations: system renewals, are initiated in the shortest possible time to allow sufficient time to meet this challenge.

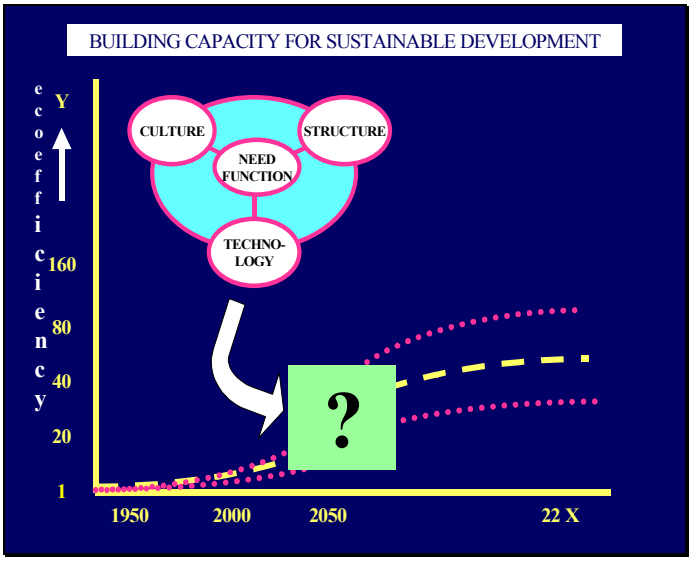


Figure 1: The Challenge of sustainable development.

Considering the almost unavoidable growth of the world population, the desired growth of welfare per capita in North and South (RIO 21) and the desired (or "necessary") reduction of environmental pressure from local up to global scales, sustainable development that fulfils peoples needs will require radical improvements in eco-efficiency (depending on assumptions and on specific need ranging from a factor five up to fifty, Weterings & Opschoor 1992).

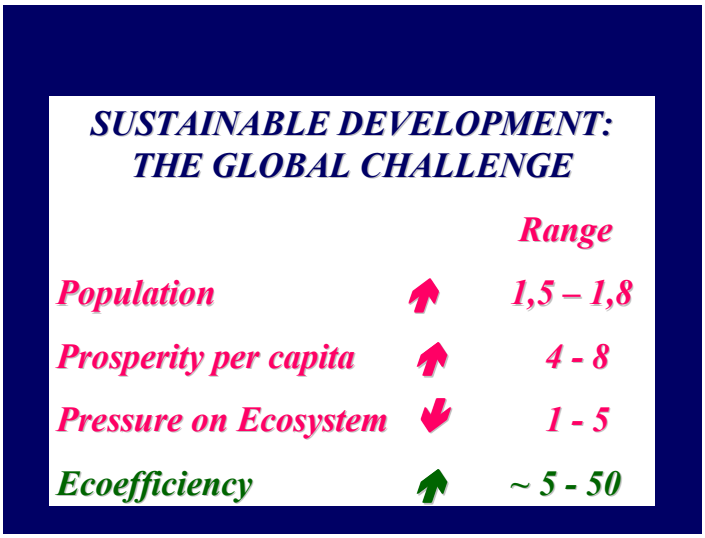


Figure 2. The material challenge of sustainable development.

This estimation of future developments in demographic, economic and ecological developments implies that the achievement of sustainable development is a question of both moralism, on ecology and on fair distribution of wealth and of strategic pragmatism from the viewpoint to ensure continuity in a stable society.
Business concerns for continuity of operations on the long term for private companies like Shell, Unilever and many others united in the World Business Council for Sustainable Development. Governments concern for long-term stable socio-economic development of nations. Consumers concern for long-term availability of goods and services of acceptable quality at acceptable prices. Morality and strategic pragmatism increasingly mix up in the entanglement of people and organizations.

Figure 3: Sustainable Development: Morality and Strategy

The how.

Systems renewal is a complex social process and encloses apart from jumping changes in technology, also changes in behaviour, organisation, institutions, power relations and many other non-technical aspects. The latter may be even more decisive for implementation than the availability of "technology". As a concept, systems renewal integrates technological, cultural and structural elements. Characteristic for systems renewal is – the long-term future orientation - for a variety of stakeholders in - fields of conflicting interests in - an environment with large uncertainties.

Technology renewal is then a transdisciplinary activity involving all relevant stakeholders and disciplines. Robert et al (2002) gave an overview of applied tools in strategic sustainable development. Already the recognition of "needs" and their definition as a starting point deviates from the more traditional engineering approach to depart from technologies in existing structures. In many cases technology development as a quest will be the initiating action. In those cases the engineer has to ascertain transdisciplinarity from the very beginning e.g. the problem definition of fulfilling the needs in a sustainable manner. In his closing address to the conference Engineering Education in Sustainable Development 1 (Delft, 2002), rector Fokkema concluded that:"Also more research could be done on methods of the development and the transfer of knowledge in the field of technology, innovation and education, all focussing on sustainable development." Such research could contribute to structure the transition inside the educational system embedded in society.
Concluding on the "what and how", three dimensions of change may be identified:

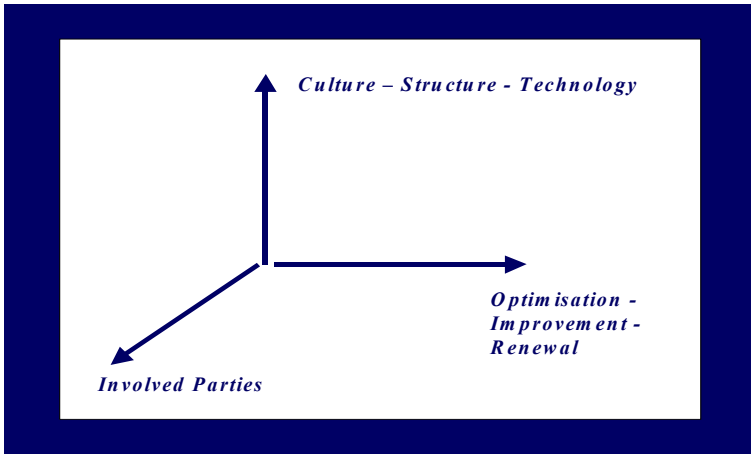


Figure 4. Three interacting dimensions of change for achieving sustainable development.

In technology development the interrelationships are stronger in the sequence from optimisation to improvement to renewal.
The challenges for innovation on the renewal track are of a different order from those on either short- or medium-term time tracks on optimisation and improvement. Innovations on the renewal track are broad, conceptual and strategic challenges, they imply new tasks and they call for different approaches to innovation and different capacities. Sustainability-oriented innovation must be concerned with ambitious performance improvement targets. Entirely new systems-solutions cannot be developed in convenient isolation but must be contextualised within a holistic vision of a sustainable future defined by its own paradigmatic cluster of technologies, institutions and social arrangements. Whereas innovators working to improve existing solutions can take the paradigmatic framework conditions for granted, those working on sustainable solutions must base their work on the belief that these will change. Moreover, they must work toward changing them if new solutions are to be implemented.

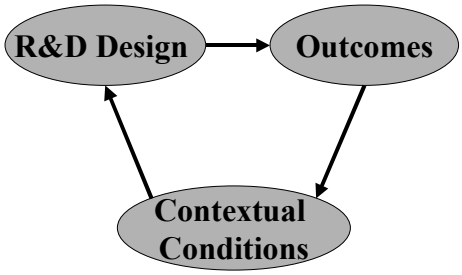
Technology development in the frame of sustainable development as a societal transition process comprises of a manifold of innovation programs and projects of different origins, different (scientific) environments, different scopes at different levels often loose from each other but inspired by a general orientation. Other examples of such general long lasting guiding orientations are the orientation on reconstruction of Western Europe in the post World War II period and the development of the city of Curitiba in Brazil on the basis of a physical and social concept (…….)
Martens and Rotmans (2002) describe transition as "the result of developments in different domains, as a set of connected changes which reinforce each other but take place in several different areas, such as technology, the economy, institutions, behaviour, culture, ecology and belief systems". They regard transition as a "spiral that reinforces itself; there is a multiple causality and co-evolution caused by independent developments".

3. Capacity building for sustainable development.

In the late 1990s the question of "HOW" to design and support sustainable development through research and technology programmes was put on the agenda in the EU 5th Framework (e.g. in the EU JRC STRATA programme). The core of a contribution on the how question was presented was presented earlier in a STRATA workshop in Maastricht in January 2000 and in the European Conference on Cleaner Production in Lund, (Jansen, 2001),. Since then the Factor 10 Institute has published an analysis of complementary approaches to the "HOW" question (Robèrt et al, 2002). And the EU JRC has set up an inventory and analysis of sustainability-directed research programmes (Whitelegg and Weber 2002). In the STRATA programme, the AIRP project funded by the STRATA Programme of the EC was started in January 2002 with the goal of answering the question by mid 2003 (Hinterberger 2001). This project aims to deliver recommendations for new programmes on options for sustainable development and their contexts. In a complementary contribution (Weaver& Jansen 2004, this conference) the ins and outs of the AIRP Project and its findings are described in detail.

Working Hypotheses of AIRP.

In the AIRP project working hypotheses were formulated which are utmost relevant for social and scientific capacity building.
Based on a normative-deductive approach and reflecting upon the challenges that sustainable development poses for innovation, the project set out a broad set of generic outcomes that innovation for sustainability could target including: visions and indicators of desirable socio-economic futures; new solutions to development problems consistent with such visions (e.g., new production-consumption systems or elements thereof); models and information in support of transition processes.
This identifies scientific and social competences relevant to set up sustainability oriented RTD and the implementation of its results.
From the AIRP analysis strong evidence as obtained that there exists a spiralling connection between the context in which a program is designed, the design itself and the outcomes in broad. The latter influences the context leading to improved conditions for further programs.



To determining conditions for program design belong:
- Understanding and conceptualisation of sustainability in public and policies.
- Organisation of science and research and its allowance / appreciation for inter- and transdisciplinarity
- Availability of scientific capital and capacities.
- Presence of social capital and capacities to absorb new paradigms.

Successful execution of sustainability oriented RTD Programs will increase the above-mentioned competences of the innovation system and of the individual participants in a program. This means that on top of search for "narrow" objectives e.g. new social embedded technological approaches such RTD Programs can also be considered as contributors to sustainability oriented innovation system in engagement with the *process* of designing and implementing paradigmatic change. This is a strategic management challenge that requires special ways of working and a special toolkit to deal with the issues entailed, such as creating visions of sustainable futures, handling the dynamics of co-evolutionary change on several innovation fronts, handling uncertainty that is inherent when shifting into realms not previously experienced and communicating with stakeholders and decision makers about options and their implications.
This function was explicitly part of the mission of the Dutch program "Sustainable Technology Development:

- Explore and illustrate
- Together with policy makers in industry and government
- How technology development can be shaped and organised from future orientation based on sustainability
- And develop instruments to implement this.

4. The Dutch STD Program.

The Netherlands in sustainable development.

In 1972 most copies of the report of The Club of Rome were sold in Japan and in the Netherlands. Does this mean that the Japanese and the Dutch were (and are) gentler towards the environment than other people? This is not to be expected. Rather the specific situation of these countries with respect to the environment creates a greater sense of urgency than in the rest of the world. In Japan the dependence of external resources together with the high population density may explain the concernedness. In the Netherlands the combination of a high population density and a relative high level of welfare and its delta character result in the highest burden on the environment. As a nation the Netherlands have:
The highest GNP, the highest energy use, the greatest number of cars, the greatest length of high roads, (until recently) the greatest number of pigs per square km
An economy which depends for 50 % on import / export, raw materials are imported and products are exported while the wastes in between are kept in the Netherlands. A striking example is pigs breeding; Soya fodder is imported from abroad and pigs (meat) is exported keeping the enormous quantity of manure threatening soil and groundwater inland.
The geography of The Netherlands as a delta means a very vulnerable soil, which is easily, poisoned once (dangerous) waste is deposited while additionally many wastes are "imported" via the rivers from upstream countries. This poisons the sludge of the ports. The first recognised big soil contamination affair passed on in Lekkerkerk a village near the Rijnmond area, where chemical wastes were deposited as "underground" in the construction of a new urban area.
This may explain the importance of innovation for sustainability in the Netherlands.

The core of the program

The Dutch Sustainable Technology Development (STD) programme was developed against the backdrop of a policy commitment by the Netherlands to sustainable development and a set of background studies made in the late 1980s and early 1990s. One such study estimated the scale of the resource productivity improvement that the Netherlands should target by the mid 21st Century in order to meet its policy goal, placing this at an order of magnitude or more (Weterings and Opschoor 1992). Around the same time, an inquiry by a special Dutch Commission for Environmental Policy concluded that incremental innovation would be incapable of meeting such a target. The mismatch led

to a review of the status of Dutch research activities and the decision to re-direct some of the innovation effort toward long-term sustainability objectives and related capacity building.

Inspired by the Brundlandt report and in the framework of the first Dutch national environmental policy Plan the STD Programme was established as a programme for long-term technological innovation in support of sustainable development (Jansen et al 2001). It was designed to have critical mass and wide-ranging scope, to take a long-term time horizon and to target jumps in eco-efficency. It was designed to be process-oriented. This means that the STD Programme was focused on influencing the micro- and macro- innovation contexts and on developing new innovation methods and processes rather than on promoting specific technologies.

These defining aspects were reflected in the STD Programme aims and objectives. The programme (1992-97) was established with a mandate for 'learning by doing'. Its aims were: i) to use a set of case studies to develop and illustrate a methodology for exploring long-term, systems-level solutions to meeting the needs of future generations; ii) to initiate several new innovation trajectories (illustration processes) aimed at long-term renewal of production-consumption systems; iii) to create new transdisciplinary networks of scientists, technologists, business managers, investors, policymakers and societal stakeholders engaged in searching together for new solutions; iv) to induce policy measures and social innovations to facilitate the process of innovation for sustainable technologies; v) to embed programme outcomes in the national innovation infrastructures and institutions so that these would continue to be used and developed after the programme itself had ended; and, vi) to leverage the impact of the programme by disseminating a proven innovation methodology along with any transferable lessons learned.

Programme funding of €12 million came from a combination of sources - 85% from government and the remainder from public and private sources. The government proportion was funded by five Ministries: Agriculture and Nature Conservation; Education, Culture and Science; Economic Affairs; Housing, Spatial Planning and the Environment; and, Transportation, Traffic and Water Management. Hence the programme is widely referred to as the "Inter-Ministerial" STD Programme.

The essence of the STD method lies in the mutually supportive use of 'need-driven' approaches to problem redefinition, 'backcasting' and the development of new innovation networks to explore the challenges to innovation and technology development posed by sustainability.

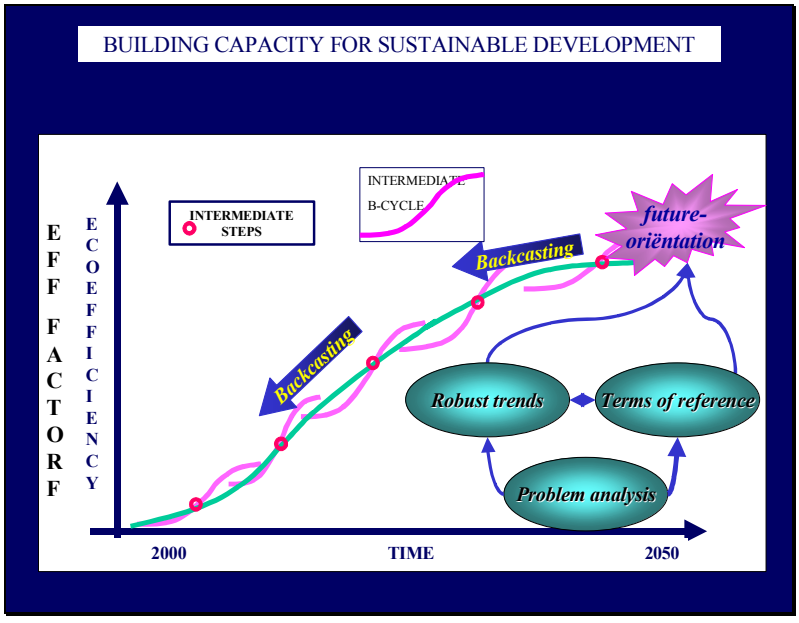


Figure 4: Backcasting from future images.

Because the pathways must be described through a logical sequence of coherent interim states, the traced pathways help to identify the main technological, structural and social challenges that will be faced and by when these should be overcome. Since each pathway is drawn back to the present, the first actions will be ones that can be taken today. By implication, each pathway describes an evolutionary way forward toward trend-breaking technological and paradigmatic change. Backcasting is therefore the hallmark of the method. Reeve & Gandar (2000) applied a similar technique in a New Zealand foresight project. Roots of the concept of backcasting can be traced to the OECD Bellagio conference in 1968 (E.Jantsch 1969)!
As conceived in the STD Programme, the innovation process involves a set of tasks to be undertaken in sequence, each associated with one or more targeted outcomes. The programme formalised these into a step-by-step working schedule, which sets out the tasks and anticipated outcomes, and proposes tools that can be used to accomplish each task (Weaver *et al* 2000).

Conclusion

The Dutch were early to recognise the entanglement of process and objectives in innovation for sustainability and to establish a special programme of research and technology development with a mandate not only to explore radical new ways of meeting needs in the long-term future, but also to strengthen the national innovation system in its capacity to support sustainable development, especially by developing and testing research methods and innovation management processes appropriate for supporting sustainable development.

The full impacts of STD will only emerge in the very long term (20+ years) and the Programme's influence on these will inevitably be difficult to separate from other influences. Any commentary on the effectiveness of the STD programme at this time must therefore be based largely upon interim results and early indicators of the influence of the programme that can be directly inferred. This reservation notwithstanding, there is sufficient evidence to show that the STD Programme was successful in making an identifiable, positive contribution to sustainable development. The STD-programme successfully opened new approaches for operationalising long-term, sustainability-oriented innovation activities. A methodology was developed through "learning by doing" processes to meet future needs for nutrition, shelter, mobility, water and materials. In addition, nine of fifteen innovation trajectories begun by the programme are still continuing today. In regard to improving the context for the diffusion of sustainable technologies, large numbers of actors and stakeholders were exposed to the programme and (with varying intensities of engagement) became aware of the potential role of innovation in sustainable development and the factors upon which a significant role for technology is likely to be contingent.

5. The Delft University of Technology in Sustainable development.

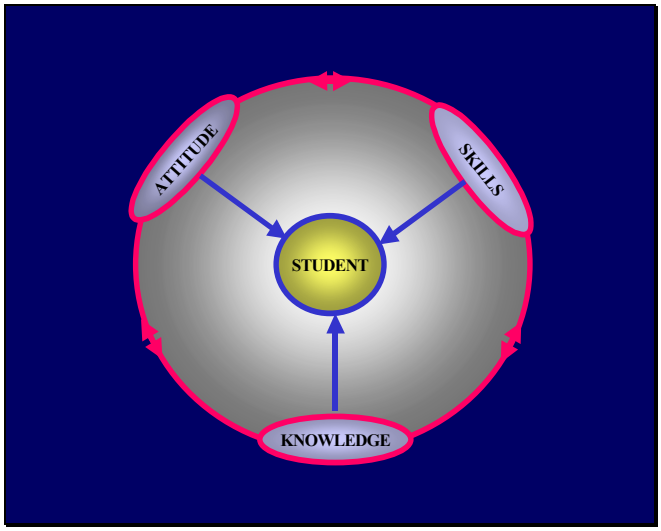
Technological universities and institutes could take the responsibility to integrate technology in sustainable development and regard the environment as an objective. They could develop and collect further knowledge on the capacities of a sustaining ecosystem and contribute to operationalise sustainability criteria as indicators and guidelines for technology development. Current trajectories of technology development could be checked on their ability to fit in sustainability.
Methods for long term programming of research and development directed to sustainable technology, and of programming of infrastructure in a context of sustainable development could be developed.
Challenges of sustainability for technology, could be detected, indicated and articulated to clients to contribute to consciousness and changing attitudes of clients with respect to sustainable technology. To this aim ways to check and to work out orders for development and application of technology in the context of sustainable development could be explored and market conditions for introduction and application of new technology could be elaborated.
They could create (financial and personnel) facilities for development of sustainable technology as a basic condition for continuity of the institute and develop a sense of cooperation for approaches which exceed the own reach of institute, discipline etc and develop structures for cooperative funding.

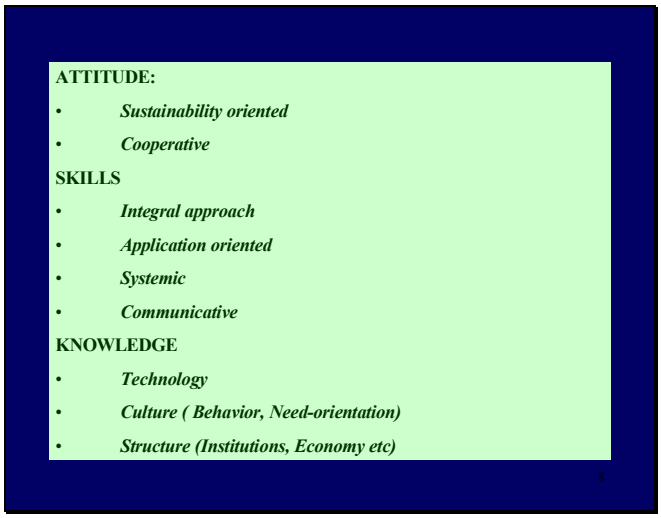
The future engineer: Attitude, Competences and Skills

In his closing address in the 2002 EESD conference rector Fokkema stated:
"I believe that each engineer has a responsibility to society. Each engineer should have an awareness of possible ethical, social, environmental, aesthetic and economic implications of their work and to act accordingly. An engineer should know the basic principles and implications of sustainable development and should be able to incorporate this in their work. It is a new element of the qualification profile of our graduates."
This is particularly at stake in finding solutions in a sustainable development.
Sustainable Technology Development is a transdisciplinary playing field where the engineer plays together with other disciplines (even within the engineering profession) and non-scientific stakeholders. In this field social parties may identify a future sustainability problem but usually then the solution is expected from the engineer.
The engineer has to meet a threefold challenge:

- Providing new concepts on the one hand in creative approaches and setting up and executing R&D programs with high performance.
- To cooperate with other disciplines and non-scientific parties on the one hand and guarding disciplinary adjustment on the other.
- Bridging between moralism and strategic pragmatism.

This reflects in the attitude, the skills and the knowledge, which we expect from our future engineers





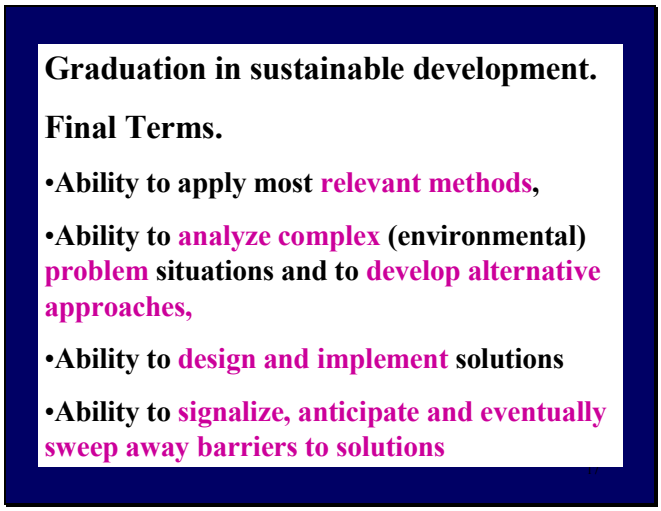


Figure 6, 7 & 8: Terms for engineers in sustainable development

To this end the TU Delft set up a program in 1997 to embed sustainable development in education and research of the university with the following mission:

GRADUATES,
• SHOULD BE PREPARED FOR FUTURE SOCIETAL CONDITIONS,
• LOOK UPON SUSTAINABLE DEVELOPMENT AS A MANAGERIAL RESPONSIBILITY,
• BE ABLE TO OPERATIONALYSE SUSTAINABLE DEVELOPMENT IN THEIR PROFESSIONAL LIFE,
THE UNIVERSITY,
CONTRIBUTES TO SUSTAINABLE DEVELOPMENT IN ITS RESEARCH AND EDUCATION

The program comprises:
An introduction in sustainable development for **all** students in the bachelor phase,
Development and a try out of a method to integrate sustainable development in regular courses as far as meaningful and reasonable,
Possibility of specialisation on sustainable development in the master phase
Review and evaluation of research programs on sustainable development.

Now in 2004 the central program is completed and the faculties accept the results and take over the responsibility.

In 2002 an international conference was organised in Delft: Engineering Education in Sustainable Development (EESD 2002). In 2004 this initiative is continued in Barcelona by the Universitat Politecnica de Catalunya (EESD 2004)

The Delft TU is associated with the Netherlands Foundation for Sustainable Higher Education.

6. Education and Practise in Sustainable Development

Almost no interconnection exists between the two manners of capacity building for system renewal: in learning by doing and by education. In both cases experiences are gained in sustainable development oriented research. The exchange of experience and results between the practical R&D projects on the one hand and the educational system on the other could deliver interesting synergy. However realisation of such synergy demands the effort to structure the process of implementation of systems renewal in both domains. Backcasting from the achievement of the full implementation of systems renewal in the practise shows a possible structuring path of interaction between practise and education. In Annex 3 this has been worked out schematically.

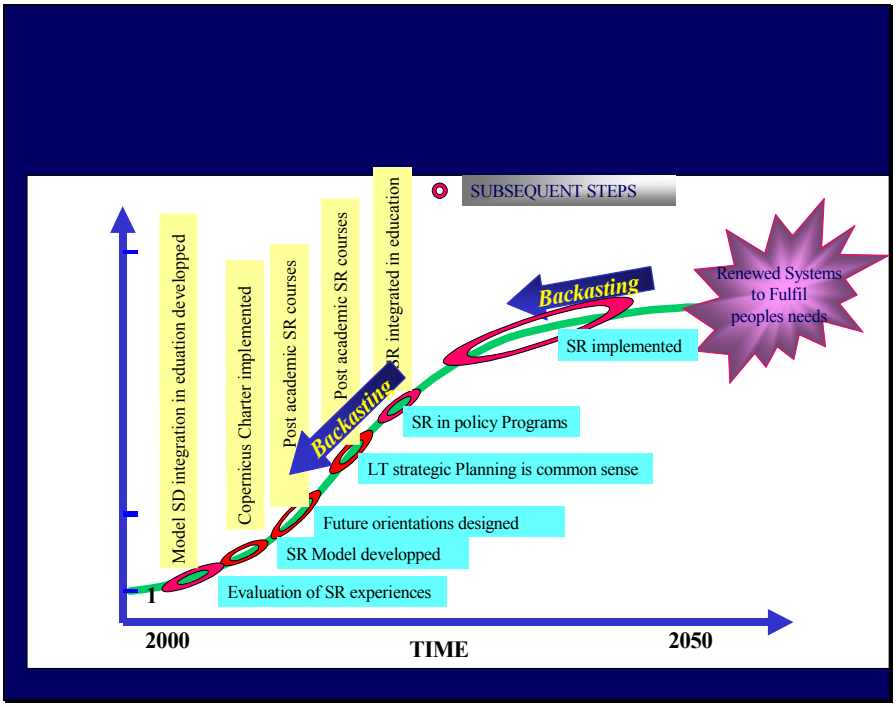


Figure 9: Programming full implementation of systems renewal

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ANNEX III: Strategy for System Renewal