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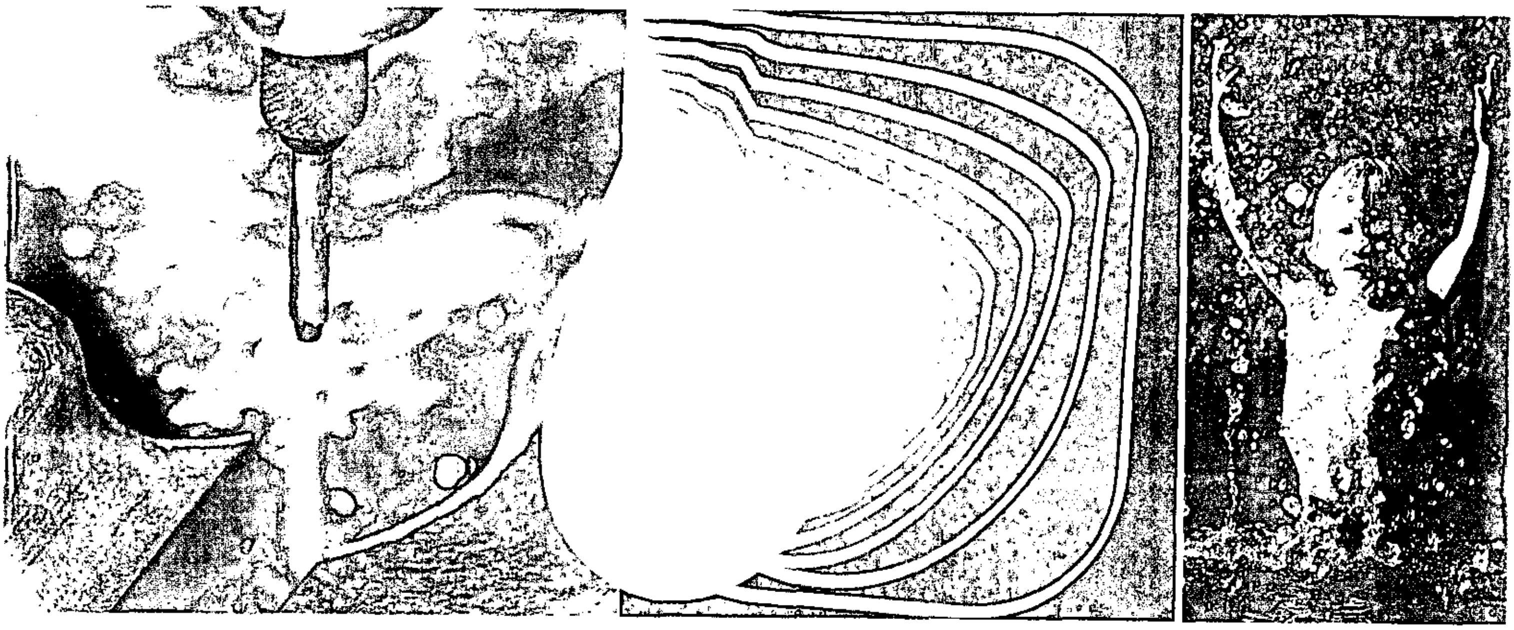

TECHNOLOGY FORESIGHT SUMMIT 2007

Budapest, Hungary
27-29 September 2007

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

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Organized by
UNIDO in cooperation with the Government of Hungary

Co-financed by
the Governments of Austria, Czech Republic and Slovenia

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2007

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This publication has not been formally edited.

Summary:

Welcome statement

Kandeh Yumkella, Director-General
United Nations Industrial Development Organization

I would like to welcome you to the Second UNIDO Technology Foresight Summit, with a special emphasis on "Water Productivity in Industry", which is supported by the Governments of Austria, Czech Republic, Hungary and Slovenia, as a regular flagship event.

The economic environment is increasingly being shaped by globalization, and the attendant need for industrial growth and enlarged international competitiveness. Increasing globalization, fierce competition and the consequent need to focus on core competencies are making both the international and the domestic business context highly dynamic. This will require every economic region to establish its strength in certain technological competencies and develop a robust innovation system. All these challenges will require a comprehensive forward-looking response driven by a relevant vision with full institutional, financial and policy support.

This is why Technology Foresight is such a powerful tool. It provides inputs for the formulation of technology policies and strategies that guide the development of technology infrastructure and innovative capabilities. It also alerts key economic actors and decision makers to the vital contributions they must make and responsibilities they must assume to achieve the desired results.

Indeed, Technology Foresight has increasingly been recognized throughout the world as a powerful instrument for establishing common views among policy-making bodies on future development strategies. Its novelty stems from the wide participation of major actors, such as Government, academia, industry and NGO towards formulating systematic projections of long-term trends in the development of science, technology, the economy, and social needs. The aim, of course, is to identify emerging technologies with the highest potential to provide economic and social benefits.

The Second Technology Foresight Summit focuses on consolidating new visions for sustainable water management in industry.

Industry – as one of the main users of water – faces the challenge of finding sustainable solutions to handle this precious resource. "Water productivity in Industry" is therefore the focus of this year's Technology Foresight Summit. The Goal of the Summit is to present, and discuss at a high political and scientific level, future technologies to enhance the sustainable use of water by industry.

It is very timely to approach the water scarcity and pollution problems at a high decision making level and examine the role that industry can play in offering solutions.

Water scarcity will lead to conflicts

Many experts believe that water will be a more important cause for future world conflicts than oil. Of the total amount of water in the world, only 2.5 per cent exists as freshwater, while 97.5 per cent is seawater. Of the relatively small proportion of freshwater, about 90 per cent is inaccessible for human use. Two-thirds is locked up in glaciers and ice caps, while most groundwater cannot be sustainably extracted.

The importance of industry

Between 1950 and 2000, world industrial water withdrawals increased from 200 km3 per year to almost 800 km3 per year. This now represents around 20 per cent of global water withdrawals.

While the quantity of freshwater available represents one side of the coin of the water crisis, the quality issue represents the other. Water that is too polluted to be used for a particular purpose, whether for drinking, for industry, for irrigation, or for sustaining ecosystems, is in effect water that is not available for use. Hence, if we are looking to preserve and maximize the quantity of this resource, it is essential to ensure at the same time that its quality is fit for the use for which it is intended. In short: water pollution and water shortages threaten future water security both for communities and eco-systems, as well as for industry itself.

Industry is a major contributor to water pollution, but at the same time needs water supplies of a high quality. It is, therefore, in industry's own interest to ensure that it uses water efficiently and does not pollute existing water supplies.

Technology Foresight is a key to success

Technology foresight is a key tool in the identification of innovations that will help industry to reach a turning point in its use of water. The Technology Foresight Summit 2007 in Budapest will constitute a decisive step towards putting in place the policies and strategies which will lead to improved water security and sustainability.

Increased awareness of the current situation and the proper application of industrial technologies in the future should make it possible to:

- Reduce freshwater intake by industry from rivers, lakes and aquifers;
- Increase industrial water productivity in terms of the value added by industrial production, relative to the volume of water used;
- Avoid water pollution by industry;
- Encourage the achievement of zero water discharge at both enterprise level and local district level;
- Provide effective mechanisms for such encouragement, such as information exchange, economic incentives and regulation.

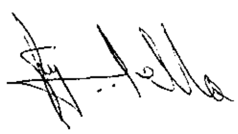
During the UN "Water for Life" Decade (2005-2015) UNIDO is dedicating its endeavours – together with industry, experts and decision makers – to developing approaches for protecting the availability of water supplies, without reducing industrial growth.

I have had many opportunities to express my vision for "green" industrial development. This is one where economic and environmental objective reinforce one another. I believe that water, like energy, must be used in a sustainable way that promotes economic development, but does not harm the environment. In this connection, the UNIDO Technology Foresight Summit represents an expression of our commitment, and will provide us with important guidance for the future.

I am very thankful to the Government of Hungary for having generously agreed to host the Second Technology Foresight Summit. This vital support is a clear indication of Hungary's commitment to UNIDO's efforts to raise awareness and to set new standards in sustainable industrial development. We recognize and congratulate Hungary for the leading role it is playing in the innovation network for environmental technologies in Central and Eastern Europe and the Newly Independent States (CEE/NIS). The fact that Hungary is hosting the UNIDO Technology Foresight Summit for the second time underlines its strong commitment toward the establishment of a robust platform for strengthening innovative capabilities in the CEE/NIS region. More importantly, to it also highlights Hungary's commitment to finding viable new approaches for to meeting the important challenges and opportunities towards a better life in the future

I would like to express my appreciation to the Governments of Austria, Czech Republic and Slovenia for their financial support to this Summit.

I believe that this Summit in Budapest will be a landmark for the region, and that it will offer powerful insights for other economies in transition and developing countries as well.



INTRODUCTION

Foresight is a systematic, participatory process, collecting future intelligence and building medium- to long-term visions, aimed at influencing present-day decisions and mobilizing joint actions. It helps in making choices in complex situations by discussing alternative options, bringing together different communities with their complementary knowledge and experience.

The Technology Foresight Summit is a flagship regular event of the Regional Initiative on Technology Foresight for Central and Eastern Europe and the Newly Independent States of the United Nations Industrial Development Organization (UNIDO).

It is intended to respond to the need for a vision of the mid- and long-term development of the region as well as for a more technology-oriented focus in the relevant national and regional knowledge-based institutions.

Each regular summit is devoted to a challenging highlight area.

For the 2007 Summit, water productivity in industry has been selected as the highlight area. The main aim is to contribute to the discussions related to the protection of water resources through more rational and sustainable use of water by industry. The Summit also addresses key technologies, which can respond effectively to major challenges for industrial competitiveness in the region.

Fresh water is a precious resource on our planet and water security is one of the main challenges for the future. Industry worldwide is a major user and polluter of water. Global partnership is needed to enhance the efficiency of water use by industry.

The 2007 Summit is organized in cooperation with the Government of Hungary and co-financed by the Governments of Austria, Czech Republic and Slovenia. It is based on the institutional framework established for the UNIDO Technology Foresight Regional Virtual Center for CEE/NIS.

The main objectives of the regular summit are:

- To build a forum for the discussion of concepts and good practices on supporting technology and innovation for industrial development using foresight as a key instrument for consensus building and strategic decision-making.
- To bring together the highest policy level representatives to discuss future-related trends, strengths, weaknesses, threats and opportunities for their countries, companies and regions, which can be addressed through the early mobilization of technology and knowledge with strong involvement of the business sector in the discussions and deliberations.
- To develop recommendations and agreements with the different stakeholders regarding support for key technological development, with special attention to water productivity and quality.

- To sustain and strengthen awareness of the critical importance of technology foresight among decision makers in the region in order to foster competitiveness and innovation.
- To initiate and implement foresight exercises jointly at the multi-national, regional, national and sub-national levels.

Significant outcomes expected from the Summit are:

- Enhanced awareness among decision makers of the importance of technology foresight in fostering competitiveness and innovation in the region.
- Important recommendations for high-level decision-makers to encourage, initiate and implement national foresight exercises in selected strategic areas.
- Identification of relevant problems in the region that can be addressed through technological and knowledge-based approaches.

The Summit will make a substantive contribution within the framework of the UN International Decade on Water for Life (2005-2015), the UN World Water Assessment Programme and the UN Millennium Development Goals, particularly through an agreement towards zero discharge.

In this context, the Summit will result in agreements and recommendations to the different stakeholders regarding support for key technological development with special attention on water productivity and quality.

The Summit will consist of four components:

The SYMPOSIUM ON WATER PRODUCTIVITY IN THE INDUSTRY OF THE FUTURE is devoted to cross-cutting issues in water availability and quality, stressing main tendencies, barriers and visions for reaching sustainable industrial development. The four sessions will give an overview of future developments in:

(1) Strategies for saving water and increasing industrial water productivity

(2) Matching water quality to use requirements

(3) Water recycling and on-site reuse

(4) Using reclaimed water (direct and indirect water reuse)

The Foresight exercise on avoiding water discharge by industry in the future–towards a zero discharge–will be presented and discussed in this plenary session.

The WATER TECHNOLOGY FAIR OF THE FUTURE consists of exhibitions and discussions presenting industry-led future trends and perspectives, prototypes, products, processes and markets regarding sustainable use of water by industry. In this context, the industry is invited to present their solutions for reducing and avoiding the pollution of water resources in the long run.

The MINISTERIAL ROUND TABLE will focus on the future of sustainable water availability and quality in the region. The ministerial consultations will address the promotion of a zero-discharge agreement and incentives at the international level. At a working lunch, key-note addresses will open discussions on the impact of industrial development on water demand and virtual water trade.

The TECHNOLOGY FORESIGHT THEMATIC PANELS focus on selected experiences and proposals using foresight as a tool for decision-making and consensus building for creating a knowledge-based society and enhancing innovation in countries in transition. The panels will also present and discuss critical technologies, which could address the challenges envisaged in the next 20 years in CEE/NIS.

Side events:

Retreat on Technology Foresight for High-level Decision Makers, one of 5 modules of UNIDO Technology Foresight Training Programme for CEE/NIS 2007 (www.unido.org/foresight/2007), is organized in cooperation with the Institute for Prospective Technological Studies (IPTS), DG Research (European commission), in Budapest on 27-29 September in parallel to the programme of the Summit.

This exercise is dedicated to provide an introduction to Foresight as an instrument for decision making. The target participants will be High-level Decision Makers from New Member States, Acceding and Candidate Countries, and Newly Independent States. Its agenda includes both the sessions exclusively provided for participants of the Retreat and the related sessions of the TF Summit 2007.

E-posters event is an opportunity for the research community to contribute with proposals for papers on the two subjects of the Summit 2007: application of technology foresight for policy making - methodologies, cases and new issues; and future of water productivity in the industry - towards zero discharge and higher quality and availability of water. Selected e-posters will be published on the web page of the Summit. A peer review conducted by members of the Editorial Boards of the journals "International Journal of Foresight and Innovation Policy" and "Foresight" (a Russian magazine of the High School of Economics) after identifying those outstanding contents may propose selected e-posters for publication in a full-paper format.

Further information:

http://www.unido.org/foresight/summit/2007

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Technology Foresight Summit 2007

AGENDA

Day 1: 27 September 2007	
14.00-15.00	**Press conference**
PLENARY SESSION	
15:00 – 15:30	**Opening ceremony of the Summit** Keynote speakers: Mr. János Kóka, Minister of Economy and Transport, Hungary Mr. Kandeh K. Yumkella, Director-General, UNIDO
16:00 – 18:00	**Plenary session: Summit's Scope** Chairperson: Mr. Dmitri Piskounov, Managing Director, UNIDO
	Future of using water in industry Key speaker: Ania Grobicki, Research Policy and Cooperation, World Health Organization (WHO), Geneva, Switzerland
	Future of Foresighting for economic development Key speaker: Mr. Luke Georghiou, PREST, University of Manchester, UK Rapporteur: Mr. Michael Keenan, PREST, University of Manchester, UK
FAIR OF THE FUTURE	
13:00 – 14:00	**Opening ceremony of the Fair**
14:00 – 18:00	**Exhibitions and presentations by companies and R&D institutes**
19:00	**Welcome reception**
Day 2: 28 September 2007	
SYMPOSIUM ON WATER PRODUCTIVITY IN THE INDUSTRY OF THE FUTURE	
9:00 – 10:30	**W1: Saving water and increasing industrial water productivity**
	Chairperson: Thomas Jakl, Ministry for the Environment, Austria Key speaker: Jerzy A. Kopytowski, Industrial Chemistry Research Institute, Poland Commentator: Professor Mark Macklin, Institute of Geography & Earth Sciences, University of Wales, UK Rapporteur: Dmytro Rushchak, Director, Ukrainian Water Management Centre and Rabmer Ukraine Ltd., Ukraine
10:30 – 12:00	**W2: Matching water quality to use requirements**
	Chairperson: Peter Kovacs, Ministry of Environment and Water, Hungary Key speaker: John Payne, SNC Lavalin, Assessment – Risk – Remediation General Engineering & Environment, Canada Commentator: Professor Mark Macklin, Institute of Geography & Earth Sciences, University of Wales, UK

	Rapporteur: Dmytro Rushchak, Director, Ukrainian Water Management Centre and Rabmer Ukraine Ltd., Ukraine
12:00 – 13:30	**Lunch**
13:30 – 15:00	**W3: Water recycling and on-site reuse**
	Chairperson: Dimitrij Grcar, Ministry of Economic Affairs, Slovenia Key speaker: Giuseppe Genon, Politecnico Di Torino, Italy Commentator: Dr. Stephen Mudge, Biogeochemistry & Environmental Forensics School of Ocean Sciences, University of Wales, UK Rapporteur: Viera Fecková, Slovak Cleaner Production Centre, Slovakia
15:00 – 16:30	**W4: Using reclaimed water**
	Chairperson: Mr. Pavel Puncochar, Director General, Ministry of Agriculture, Czech Republic Key speaker: Marek J. Gromiec, Polish National Council on Water Management, Poland Commentator: Dr. Stephen Mudge, Biogeochemistry & Environmental Forensics School of Ocean Sciences, University of Wales, UK Rapporteur: Viera Fecková, Slovak Cleaner Production Centre, Slovakia

TECHNOLOGY FORESIGHT PANELS

9:30 – 12:00	**TF1: Experiences and Practices of Technology Foresight in the European Region (multi-country, national and regional levels)** *Issues:* - *Application of TF process at different levels to promote technology and innovation* - *Impact of TF in the decision-making process for technology/ innovation promotion* - *Methodologies and outcomes from selected experiences*
	Chairperson: Norbert Kroo, Hungarian Academy of Sciences (HUS) Key speakers: Karl Matthias Weber, ARC, Austria, and Attila Havas, HUS, Hungary Case presenters: 1. **Multi-country foresight** – Ana Morato, OPTI, Spain 2. **Regions foresight in Europe** – Francoise Warrant, Destrée Institute, Walonien Region, Belgium, and Alexander Sokolov, Institute for Statistical Studies and Economics of Knowledge, HSE, Russian Federation 3. **Foresight for national Science-Technology-Innovation strategy: the case of Romania** – Adrian Curaj, ROST, Romania 4. **Corporate foresight – Shaping new realities in urban mobility: A case study of foresight-driven innovation in the automotive industry** – Frank Ruff, Daimler, Germany Rapporteurs: Michael Keenan, PREST, UK, and Ricardo Seidl da Fonseca, UNIDO
12:00 – 13:30	**Lunch**
13:30 - 16:30	**TF2: Priority setting for future critical and key industrial technologies as driving forces for economic development and competitiveness** *Issues:* *According to existing TF exercises to discuss:* - *technology development trends and critical technologies* - *sectors that need critical technology change and*

	- *main directives for setting RTDI priorities for funding and implementing dedicated programmes*
	Chairperson: Fabiana Scapolo, JRC-IPTS, DG Research, EC, Spain Key speaker: Ron Johnston, Australian Centre for Innovation, University of Sydney, Australia Case presenters: 1. **Key technologies for Czech National Research Programme**: Karel Klusacek, TC, Czech Republic 2. **Scenarios and Road mapping for key technologies: UK Case Note – Scenario Analysis in Flood and Coastal Defence**: Ian Miles, PREST, UK 3. **RTDI priorities**: Elie Faroult, DG Research, European Commission Rapporteur: Michael Keenan, PREST, UK, and Ricardo Seidl da Fonseca, UNIDO
FAIR OF THE FUTURE	
9:30 – 18:00	**Exhibitions and presentations by companies and R&D institutes**
PLENARY SESSION	
16:30 – 18:00	**Foresight exercise on zero discharge** *Issues*: *Presentation of the results and recommendations of the study*
	Speaker: Henning Banthien, IFOK, Germany Rapporteur: Ferenc Kovats and Gabriella Eglesz, Hungary
Day 3: 29 September 2007	
MINISTERIAL ROUND TABLE	
9:00 – 10:00	**Presentation of conclusions and recommendations of the Summit** Speaker (main rapporteur): Lajos Nyiri, Hungary
10:00 – 12:00	**Ministerial consultations** Chairperson: Maria Rauch-Kallat, Austria Rapporteur: Grzegorz Donocik, UNIDO
12:00 – 13:30	**Working Lunch**
13:30 – 14:00	**Rapport on resolutions** Speaker (MRT Rapporteur): Grzegorz Donocik, UNIDO
14:00 – 14:30	**Closing ceremony** Chairperson: János Kóka, Minister of Economy and Transport, Hungary
17:00	**Closing reception**
FAIR FOR THE FUTURE	
9:30 – 15:00	**Exhibitions and presentations by companies and R&D institutes**

Agenda

Day 1 – 27 September 2007		Day 2 – 28 September 2007			Day 3 – 29 September 2007	
Plenary session	**Fair of the Future**	**Water Symposium**	**TF Panels**	**Fair of the Future**	**Ministerial Round Table**	**Fair of the future**
		9:00 – 10:30 W1: Saving water and increasing industrial water productivity	9:30 – 12:00 TF1: Experiences and Practices of Technology Foresight in the European Region (multi-country, national and regional levels)	9:30 – 18:00 Exhibitions and presentations by companies and R&D institutes	9:00 –10:00: Presentation of conclusions and recommendations of the Summit	9:30 – 15:00 Exhibitions and presentations by companies and R&D institutes
		10:30 – 12:00 W2: Matching water quality to use requirements			10:00 – 12:00 Ministerial consultations	
		12:00 – 13:30 Lunch	12:00 – 13:30 Lunch		12:00 – 13:30 Working Lunch	
14:00 – 15:00 Press conference	13:00 – 14:00 Opening ceremony of the Fair	13:30 – 15:00 W3: Water recycling and on-site reuse	13:30 – 16:30 TF2: Priority setting for future critical and key industrial technologies as driving forces for economic development		13:30 – 14:00 Rapport on resolutions	
15:00 – 15:30 Opening ceremony of the Summit	14:00 – 18:00 Exhibitions and presentations by companies and R&D institutes	15:00 – 16:30 W4: Using reclaimed water			14:00 – 14:30 Closing ceremony	
16:00 – 17:30 Plenary session		16:30 – 18:00 Plenary session: Foresight exercise on zero discharge			17:00 Closing reception	
18:00 – 20:00 Welcome reception						

Technology Foresight

Future of Foresighting for Economic Development

Luke Georghiou

Abstract

This paper describes the evolution of foresight and the potential for transition from technology to innovation foresight in view of the convergence of innovation and industrial policy. In the public sphere most nations have been engaged in foresight. Families of approaches have emerged. In the corporate sector there has been a trend to "open foresight" in terms of participation, scope and delineation and in the context of open innovation. Five generations of foresight have seen a broadening of scope and participation and more recently a shift to a distributed mode of activity and engagement with a broader policy focus. Foresight is itself a policy instrument used for example to promote networking but it is also a means to inform, develop and join up policy across domains. It is particularly helpful in supporting the new wave of demand side policies, which require shared visions between users and suppliers. For developing countries the creation of a neutral future space for debate and the opportunity to reduce exclusion from networked thinking about the future are key advantages.

Keywords

Foresight, innovation policy, corporate, demand-side, industrial policy, developing countries, transition economies

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Biographical Note

Luke Georghiou BSc, PhD is Director of PREST, a large research centre within Manchester Business School at the University of Manchester, and has been on its staff since 1977. His research interests include evaluation of R&D and innovation policy, foresight, national and international science policy, and management of science and technology. Other research interests include industry-science relations, policy for international scientific co-operation, evaluation of foresight, and changes in public sector research institutions.

Acknowledgement

This paper has been informed by the many fruitful ideas emerging from the UNIDO Expert Group Meeting on the Future of Technology Foresight held in Vienna on 29-30 May 2007.

1. Context of Technology Foresight

Technology foresight is a term which today encompasses multiple activities and purposes although all of them share a future orientation (between the immediate and the far horizon), an engagement with the science and innovation system, an interaction with the socio-economic dimension and an expectation that decision-making or policy consequences will result. Participation of stakeholders and the building of action networks or advocacy coalitions is an essential element. This paper begins by considering the existing domains of technology foresight more generally then considers an extended mandate to apply the potential for technology foresight in the wider domain of innovation and industry policy in the context of the knowledge economy. Within the context of this extended mandate the role of corporate foresight is also explored. Aspects of relevance to transition and developing economies are highlighted.

1.1. Content and Structure

Traditional uses for technology foresight may be divided between those with a "content focus" that is focused upon choices within the domain of science and technology, and "structural focus" that is addressing primarily the structures by which science and innovation achieve impacts upon the economy and society. Within the content focus category there are two main subdivisions:

- Priority setting; and
- Identifying ways in which future science and technology could address future challenges for society and identifying potential opportunities.

Typical manifestations of the structural focus include:

- Reorienting the Science & Innovation system;
- Demonstrating the vitality of Science & Innovation system;
- Bringing new actors into the strategic debate; and
- Building new networks and linkages across fields, sectors & markets or around problems.

It should be emphasized that content and structural goals may be addressed simultaneously. There is an increasing tendency for foresight to address structural or systemic issues directly – for example the French *Futuris* exercise, which was industry-led and focused upon reorientation of the national innovation system. Foresight also has a role in the social dimension. While the central focus of this paper is concerns foresight and industrial innovation, it should be remembered that societal trends condition the economic environment and would certainly feature in the foresight activity of major companies and industry support institutions.

We may also consider the role of foresight in carrying the input from future perspectives on science and technology into application across wider policy arenas. This has been an explicit aim of the Third Cycle of the UK Foresight Programme and has met with some success in environment, health and identity policies for example (PREST, 2006).

1.2. The Context – Public-Private Interaction

Identifying the setting for technology foresight is more complex. It may take place at organizational, local, regional, national or supranational levels. Most attention has been given to national and regional foresight activities in part because these are more visible but there is also a substantial body of organization level foresight, notably in the corporate world. However, even here it would be misleading to talk of purely "private" foresight as even corporate practitioners need to draw upon public networks to feed the visions they create and the trends that they identify. This is an inevitable consequence of the move to "open innovation" in which the assumption is abandoned that innovation happens within a single company based upon ideas generated in-house and developed, manufactured, marketed, distributed and serviced in the same way (Chesbrough, 2003). Instead open innovation recognizes the existence of an ecology of industry in which knowledge is shared and companies are actively engaged with their clients and suppliers and with knowledge providers in universities and elsewhere (Coombs and Georghiou, 2002).

1.3. Rationales – Shared Vision Linking Supply and Demand

It has long been recognized that technology foresight has a role in building such networks or "wiring up the innovation system" (Martin and Johnston, 1999). The United Kingdom's first technology foresight programme similarly addressed companies operating in the "network economy" which have to manage interfaces with customers, suppliers, collaborators, regulators and other stakeholders. Foresight here was seen as a means of creating a shared strategic vision which has the potential to reduce the uncertainty involved in innovation (Georghiou, 1996).

Building upon this one can consider the definition of foresight emerging from the eForesee project:

> "The foresight process involves intense iterative periods of open reflection, networking, consultation and discussion, leading to the joint refining of future visions and the common ownership of strategies, with the aim of exploiting long term opportunities opened up through the impact of science, technology and innovation on society....It is the discovery of a common space for open thinking on the future and the incubation of strategic approaches..."
>
> (Cassingena Harper 2003)

At the same time there is an emerging reorientation in innovation *policy* to reflect the realities of open innovation. One consequence has been a new emphasis upon the role of demand-side policies, broadly speaking the use of instruments such as public procurement and regulation to pull-through innovations but also encompassing measures such as clusters and platforms which seek to bring together demand and supply (Aho *et al*, 2006; Georghiou, 2007). In some ways these measures may be seen as a new industrial policy as well as a new innovation policy, but in this case an industrial policy which is fully compatible with the principles of competition.

These issues are equally valid for developing and emerging economies. The Interim Report of the Millennium Project Task Force on Science Technology and Innovation argues that a strong demand for technological solutions directed to local capabilities can be one of the strongest incentives to learning accumulation (Juma and Yee-Cheeong, 2004).

1.4. Extending the scope – from Technology to Innovation Foresight

The move from technology to innovation foresight explored in this paper means that it is important also to consider non-technological innovations in business processes and the service sector (for example low cost ticketless air-travel) or by government (for example congestion charging as a means to reduce traffic in city centres). The latter category is still relevant for industry since it opens up new opportunities for innovation.

It also means that means of accessing knowledge from outside the organization become as important as the direct promotion of R&D, even though R&D may be a necessary condition for the absorption of knowledge (Huston and Sakkab, 2006).

2. Existing Experience of Foresight

2.1. Foresight in Public Policy

Table 1 summarizes the evolution of national technology foresight programmes, mainly in developed countries. This is far from complete, the European Foresight Monitoring Network now has mapped well over 1000 foresight initiatives. Nonetheless the Table helps us to track the evolution of foresight. We may note the well known initial strong role for Delphi exercises modelled upon the Japanese approach and a switch of emphasis towards more interactive and mixed approaches. We may also see most countries in multiple engagement with foresight over time, though with the exception of Japan, little repetition of detailed approach. This can be interpreted both as continuing interest and as an indication that experimentation and adaptation are still under way.

Some other families of approaches may be detected. National critical technologies exercises have a very focused approach to technology priorities, normally on relatively short time horizons (critical technologies have also been addressed on a transnational basis by EU reports on Key Technologies and on Convergent Technologies). Another cluster in EU accession countries represented a wave of activity associated with the seeking to assist the specific transition of science and innovation systems. In the most recent period horizon scanning has emerged as a dynamic activity, normally focused on informing research policy decisions in the light of a broad range of both scientific and socioeconomic topics at the margins of current thinking. The issue of weak signals has also been engaged with by the COST A22 action.

Table 1. National Foresight Programmes and Exercises

Year	Delphi	Mixed	Panel/Scenario/Roadmapping etc
1971	1st 4 Japanese STA surveys		
1989			Ministry of Economic Affairs Netherlands
1990	1st German		
1991	5th Japanese		Critical Technologies USA
1992			Public Good Science Fund New Zealand
1993	South Korea		Technologies at Threshold of 21st Century Germany
1994	France Japan/Germany Mini Delphi		
1995		1st UK Foresight Programme	100 Key Technologies France
1996	Japan-German Delphi		Matching S&T to Future Needs Australia Foresight Steering Committee Netherlands
1997		ANEP Spain	Foresight Ireland
1998	Austria	TEP Hungary	South Africa; New Zealand; 1st Swedish Foresight; Brazil 2020
1999		ITC Foresight Thailand	2nd UK TF Programme; Futur 0 Germany; 2nd 100 Key Techs France
2000	7th Japanese; Prospectar Brazil	Technology Foresight Programme Brazil	ET2000 (Portugal); IPTS Futures EU
2001	Technology Foresight Chile		Futur 1 Germany; Technology Foresight Greece; TF Exercise Czech
2002			3rd UK Programme; eForesee (Cyprus, Estonia, Malta); 2nd Swedish TF; National Technology Foresight Denmark; NIH Roadmap USA
2003			Foretech (Bulgaria, Romania); 2nd Swedish Foresight; Norwegian Research Council 2020 studies
2004		8th Japanese	Futuris France; ANRT France; AGORA 2020 France; Nordic Hydrogen energy foresight;
2005		3 Moments Brazil	Finnsight Finland; 21st Century Challenges GAO USA
2006			SITRA Foresight Finland, Horizon scanning UK, Horizon Scanning Netherlands, Science Priorities Denmark, Navigator Network New Zealand

In addition to those exercises a strong tradition of foresight activity has also emerged in developing countries. Latin America has been particularly active. These can be summarized in a quote from Popper and Medina (2007):

> "Brazil, Chile, Colombia and Venezuela have National Foresight Programmes which focus on strategic sectors and themes and support capacity-building activities nationwide. Countries like Peru and Ecuador have constituted

Prospective Consortia linking universities to the industrial sector. Colombian and Venezuelan Regional STI Agendas (sub-national) have played a particularly special role in generating S&T priorities and achieving consensus and engagement of stakeholders. In terms of capacity-building, the region has benefited from the various regional UNIDO courses including: Venezuela (1999); Uruguay (2000); Colombia, Brazil and Peru (2001), Peru (2004) and Ecuador (2005). These activities inspired certain countries to organize national and sub-national courses, e.g. Colombia between 2001-6 organized numerous courses and seminars in collaboration with UNIDO, CAF, CAB, PREST, FUTURIBLES, CNAM, and CYTED. In Peru, CONCYTEC and the Consortium Prospective Peru (CPP) have promoted international congresses, and CGEE in Brazil is planning to have a role here too. As a result, it is possible to conclude that Latin America is working hard to develop a very strong Foresight Culture which, at the same time, helped to build a range of national experiences."

The policy challenge for Latin America has been characterized as taking place at three levels, with the macro level challenge being facilitation of the production of a State strategic vision for the knowledge economy, the meso-level challenge to promote policy coordination around the knowledge economy and the micro-level challenge to develop capacities in public policy managers.[1]

A similar dynamic activity is evident in Asia where Johnston and Sripaipan (2007) identify some engagement in most industrializing countries with the largest activity in China and Thailand. Turkey is another centre of activity, for example the 'Vision 2023: Strategies for Science and Technology' national project in 2003/4 aimed at providing Turkish stakeholders with a vision for the development of science and technology vision in Turkey over a period of 20 years and included a strong technology foresight strand.

Also not to be forgotten is the significance of multi-country foresight where sharing of resources and ideas can be one dimension but also the possibility of creating space for necessary dialogue about the linkage between long-term problems and opportunities, and actions in the here and now. This space may not always be available within countries and regions, and the involvement of an international organization or other third party can be vital here. This can be seen as helping to build the sorts of Foresight community of practice for developing regions that has become established in industrialized countries in the last decade. Ultimately, this could result in the lessons from and innovations in Foresight in developing countries entering the repertoire of those in industrial countries, to complement what is at present a rather one-sided flow of expertise.

Broader rationales for international cooperation in foresight rest upon potential gains from:

- Cost-reduction through shared efforts;
- Accessing technical expertise, training and experience in foresight approaches;

[1] J. Medina EGM.

- Accessing broader and/or complementary domain expertise through combining resources;
- Addressing transnational problems and issues including providing a gateway to broader regional cooperation in the sectors addressed by foresight.

2.2. Policy Transfer and Learning in Foresight

Given the large historical and current effort engaged in spreading good practice in foresight it is worth considering the issues involved in transferring foresight know-how from one country or setting to another. Policy transfer is a strong feature of the exercises shown in Table 1 above. One of the key rationales for launching a foresight activity has been the perception that it is a solution that has worked in other countries. In almost all cases exercises are preceded by a phase of reviewing international experience or drawing upon assistance from outside.

The need for this step to be carried out with the utmost care can be illustrated by reference to the literature on policy transfer between countries which enunciates several reasons for probable failure (Dolowitz and Marsh, 2000; Georghiou and Harper, 2007);

This can result from:

- Uninformed transfer
    - o borrowing country has insufficient information about the policy that is being transferred with the result the policy is imperfectly implemented.
- Incomplete transfer
    - o crucial elements of a policy or programme that made the policy or programme a success are not transferred.
- Inappropriate transfer
    - o insufficient consideration given to social, economic, political and ideological differences between the borrowings and the transferring country leading to programme failure.

All of these are issues that become more important still when the transfer is from a developed economy to one which is emerging, transition or developing. In this situation policy transfer needs to be contextualized and informed by previous relevant experience.

2.3. Corporate Foresight

The challenges faced by firms reflect the structural changes taking place in the economy and society. A new global setting of the world economy is defining the framework for operation of the industrial sector both inside the national boundaries and internationally. Such a setting can be characterized by several trends and discontinuities:

- Increased financial, trade and investment flows;
- Rapid and accelerating technological progress; in pervasive fields such microelectronics, ICTs, biotechnology, new materials, fuel cells and nanotechnologies;
- Responses to the sustainability challenge and changes in consumer and political values;
- Demographic and political change;
- New international regulations and standards, trade, quality, labour, environment, intellectual property rights;
- New systems to design, produce, distribute, and manage;
- Global value chains and production networks emerging in all types of industries managed by multinational companies and global buyers.

The corporate sector uses foresight (either in a formal or informal sense in terms of how it is labelled) to detect and prepare responses to such changes. Cuhls and Johnston (2006) in reviewing experience in this sector divide activity into two major categories: foresight in business, performed by companies for various reasons including foresight for innovation and predictive markets, and foresight for business performed by third parties but with the prime users being firms. Even inside the firm quite different models prevail, ranging from specialized dedicated units through to a close integration with strategic or design functions. Becker (2002) identified five major functions:

- Anticipatory intelligence, i.e. providing background information and an early warning of recent developments;
- Direction setting, i.e. establishing broad guidelines for the corporate strategy;
- Priority setting: i.e. identifying the most desirable lines of R & D as a direct input into specific (funding) decisions;
- Strategy formulation, i.e. participating in the formulation and implementation of strategic decisions; and
- Innovation catalysing, i.e. stimulating and supporting innovation processes between the different partners.

Daheim and Uerz (2006) detect a new trend of "open foresight" in the corporate sector, strongly linked to the open innovation theme discussed in this paper. This seeks to get beyond trend analysis and defines the term "open" foresight to refer to at least four aspects of openness: the involvement of relevant stakeholders from within and outside the client organization; open beyond a single sector environment; organized as an open process that does not end when a specific project has been achieved, but rather continuously overhauls and re-invents itself; and finally to act as an "irritant" for the organization.

A key issue in corporate foresight is the means by which the analyses interface with strategic processes within the firm. While impacts are of necessity intangible it is essential to find means for senior management to feel ownership of results through direct engagement rather than receipt of remote reports. As with other aspects of foresight stakeholder involvement is crucial as is the commitment of key personalities in positions of influence.

From the perspective of enterprises in developing countries a key objective for corporate foresight is a means to keep them in touch with trends which impinge upon their future technological and market prospects especially beyond their immediate national environment. Assistance may be needed both to build capability and also to connect to wider networks. Understanding of different cultures and practices is a pre-requisite for those who intend to engage with wider markets.

2.4. Development Pathways of Foresight

If we consider the reasons for emergence of the foresight activity described above we can see the types of motivation discussed in the introduction with foresight being driven by policymakers seeking to set priorities in face of restricted budgets and international competition & to strengthen networks. The emergence of foresight in the 1990s coincided with the biosciences revolution and consequences of ICT developments becoming manifest. As already noted the second wave of activity was associated with those responsible for research and innovation systems or organizations perceiving major strategic challenges such as EU accession, outdated missions and wanting to build commitment to new visions of the future. All of these motivations except the historical moment of EU accession remain valid and even there the challenges involved in achieving cohesion with more advanced EU Member States remain just as strong.

An earlier stylised characterization of the emergence of foresight used a generational model. Initially presented as three generations, we may now argue for five:

- *First Generation*: Foresight is here emerging from what are mainly technology forecasting activities, with the analyses driven mainly by the internal dynamics of technology and with ownership clearly in the hands of technical and foresight experts.
- *Second Generation*: Foresight projects seek to engage with technology and markets simultaneously. Technological development is examined in terms of its contribution to and influence from markets; and there is a strong emphasis on matching technological opportunities with market developments (and also with non-market needs such as environmental and social problems). Participation is across the academic-industrial nexus.
- *Third Generation*: Foresight's market perspective is enhanced by inclusion of a broader social dimension, involving the concerns and inputs of a broad range of social actors.[2] The need to take into account complicated issues concerning

[2] A similar concept has emerged in research policy more broadly, notably in the European Union's

social trends and alternative institutional arrangements means that the methods used and the knowledge bases drawn on have to be expanded to deal with such issues.

- *Fourth Generation*: Foresight Programmes have a distributed role in the science and innovation system, rather than being "owned" by a single policy sponsor. Multiple organizations sponsor and/or conduct exercises that are specific to their own needs, but are coordinated with other activities (e.g. sharing resources and results, having shared working groups).
- *Fifth Generation*: A mix of Foresight Programmes and exercises, also distributed across many sites. The principal concern of these activities is either (a) structures or actors within the STI system or (b) the scientific/technological dimensions of broader social or economic issues. Foresight here takes its place among a broader range of policy approaches.

In practice, these generations are not mutually exclusive and it is not uncommon for specific exercises to exhibit characteristics of more than one. What we can see is both a growing engagement with broader issues and a higher level of embedment in other policy and strategy developmental activities.

2.5. Understanding the Impact of Foresight

For foresight to become truly embedded it must be able to show impacts upon strategic behaviour either in the corporate context or in public policy. It is widely recognized that it is difficult to attribute decisions and directions uniquely to foresight. In part this is because the impact of foresight involves interaction of foresight outputs with the strategic behaviour of policy and economic actors and this behaviour is subject to a number of other influences. However we may also carry lessons from this observation. On the one hand it is possible to use foresight as a means to influence corporate/business strategy. On the other there is a need for foresight design to build in an interface with existing strategic processes where possible.

Keenan has observed that foresight not always tuned to the needs of recipients and that information needs to be presented in a way that policy/strategy mechanisms can receive and absorb it. For example, timing needs to synchronize with policy cycles and the level of recommendations needs to match the available funding or capacity for reform, allowing for the occasional need to introduce highly disruptive thinking.

Moving to the public sphere an evaluation of foresight needs to be accountable for the resources expended to support it. The approach hinges upon the *additionality* of foresight, summarized as the degree to which public support for foresight makes a difference and addressing questions such as:

- Would foresight have happened without the policy intervention?
- Is foresight done differently/better because of the policy intervention?

Fifth Framework Programme (Caracostas and Muldur, 1997) and its successors.

- Are the resulting actions better because of foresight?
- Have persistent changes been achieved (eg foresight culture)?

In the modern terminology of evaluation foresight promotion needs to demonstrate *behavioural additionality*, to become embedded in the behavioural routines of the organizations concerned (OECD, 2006). Priority needs to be given to building a foresight culture which is persistent beyond the original support.

3. Extending the Mandate to Innovation Foresight

3.1. Trend towards structural focus driven by knowledge economy focus

As noted in the introduction there has been a certain convergence of innovation and industrial policy in the context of the knowledge economy. This is evident for example in the emphasis given by the European Union's Lisbon strategy to the creation of a knowledge based economy and society and in many national economic strategies. However, in most countries innovation policy has not yet managed to move away from a strongly supply-side orientation – including support for the research system and a number of policies which aim to improve linkages especially across the science-industry interface. Beyond the conventionally understood market failures which provide a rationale for government to support industrial research and innovation it is today widely recognized that there are systemic failures such as lock-in to existing technologies preventing the adoption of new alternatives, and inadequate support infrastructure. For developing and emerging economies such systemic failures are often as major a barrier as lack of resources.

In such a context the Government role becomes one of ensuring that system has capacity to support the needs of innovating enterprises. This involves at a basic level the provision of the right framework conditions. Beyond the necessity for macroeconomic stability, this also involves creating a microeconomic climate conducive to innovation involving for example:

- An adequate supply of educated and entrepreneurially-oriented human capital;
- Supportive institutions for research and knowledge transfer;
- Policy coordination to create a favourable market and regulatory environment.

3.2. Addressing Needs and Deficiencies – Policy Mix and Foresight

One way in which policy needs can be defined is to consider the deficiencies and barriers that need to be remedied. At the level of the firm these broadly fall into four categories:

- Resources: Insufficient resources to undertake the work without public funds. Generally true for academic research & accepted for business R&D which is highly uncertain and/or where social returns justify an investment which does not meet private criteria.

- Incentives: Scientific structures or the market provide insufficient incentives for socially desirable behaviour, for example academic-industrial collaboration. Also fragmented or risk averse markets may obstruct innovation.
- Capabilities: Organizations lack key capabilities needed for the innovation process, eg ability to write business plans or raise venture capital.
- Opportunities: Generation of opportunities for innovation and provides one of the main justifications of public support of science. Need also to consider how firms can get hold of such opportunities through knowledge transfer/exchange.

Table 2 below shows how some typical policies correct these deficiencies. This emphasizes the need for a "policy mix" but also the opportunity for foresight to act as a balancing and linking mechanism.

Table 2. Deficiencies Addressed by Innovation Policy Measures

Policy measure	R	I	C	O
Support for basic research	✓			✓
Support for public research directed to industry	✓	✓	✓	✓
Support for training & mobility	✓		✓	
Grants for industrial R&D	✓	✓		✓
Fiscal support for R&D	✓	✓		
Equity support for venture capital	✓	✓		
Co-location measures		✓		✓
Information and brokerage support			✓	✓
Networking measures			✓	✓
Systemic policies		✓		✓
Public procurement of innovations	✓	✓		

R-Resources I-Incentives C-Capabilities O-Opportunities

Furthermore, if we consider the more comprehensive taxonomy of policies shown in Figure 1, we may see that foresight occurs as a policy measure itself in the category of promoting networking but foresight also has a role in informing and developing policy. Thus we may distinguish between Foresight *for* policy and Foresight *as* policy.

- For policy
  - Use as a tool to *inform and develop* policy in any area
  - Also for "joining up" policy across domains
  - In our domain normally areas of policy with a strong science/research input

- As policy
    - o Use as an instrument to *implement* budgetary, structural or cultural changes
    - o In our domain as an instrument of research and/or innovation policy

The role as policy includes making other policies function more effectively. Examples in the taxonomy include:

- Funding for science and Grants for Industrial R&D
    - o role in establishing funding priorities;
- Cluster policies
    - o forming the vision around which a knowledge-based cluster is formed;
- Procurement and Regulation
    - o developing a technology roadmap to inform procurers of the radical options which might offer innovative forms of supply (and build networks with conventional suppliers) and regulators of potential technological and/or socio-economic situations which regulation may promote.

As already noted, foresight may also be applied explicitly as an instrument to design the whole or part of an innovation support system. At a national level, we have noted the example of Futuris in France and there are further examples from Finland (Salmenkaita and Salo, 2002). Such work may also proceed at a regional level - for example it is currently being applied by the EU-funded Structural Funds Futurreg Project.[3]

3.3. Developing and Transition Economies

Considering the situation of developing and transition economies an important issue is the system capacity for strategic development. Again we may consider what deficiencies exist. These may include:

- Lack of conducive integrated policy and institutional framework;
- Under-developed technology and innovation promotion planning capabilities;
- Short-term thinking and reactive mode action;
- Implementation failures on strategies;
- System linkage failures and poor coordination;
- Disconnection of application of new technologies from socio-economic problems;
- Scientific institutions with strong and inflexible disciplinary focus;
- Low technology and innovation intensity in industry.

And resource deficiencies:

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[3] http://www.futurreg.net/.

- *Lack of funding for technology acquisition and diffusion*
- Lack of human capital and increasing human resources crisis (brain drain, demography)
- Absence of adequate equipment and infrastructure

This list of deficiencies was confirmed by a recent foresight exercise which aimed to assess the capacity for international scientific cooperation with the EU of four developing regions of the world: Latin America (excluding Brazil and Mexico); Former Soviet Union (excluding Russia and Ukraine); the Maghreb/Mashreq region; and sub-Saharan Africa (excluding South Africa). SCOPE 2015, as the project was called, was also an example of application of foresight in policy development.[4] One finding emerging from this study was that the often well-intentioned influence of donor organizations nonetheless created a fragmentation in national and organizational strategies as each donor attempted to impose their own priorities. With the strong financial influence they exerted in poorer countries the result could be to remove any space for effective strategy-making. Foresight could play a role in redressing this balance.

In seeking to engage foresight with the problems of underdevelopment it is necessary to highlight the diverse circumstances of developing regions and countries. Apart from geographical and cultural location, there are huge variations evident in such parameters as size and demographic composition, industrial output and economic structure, the development of technological capabilities and positioning in global value `chains, the characteristics of private and public actors and entrepreneurial and other attitudes – and the stability and openness of institutions of government and governance. The situation in the world's poorest nations bears little resemblance to hat in emerging or transition economies. As discussed in the EGM,[5] the *problematique* of underdevelopment cannot be reduced to one of the listed factors – it reflects the (varying) complex combinations of such factors in specific cases. There is not one solution to problems of development and while Foresight can often be part of the solution, it may not always be the policy instrument that is most urgently needed. Equally, "one size fits all" approaches have to be discounted: the sorts of Foresight practice, and the ways in which these are articulated into policy and governance, will vary from country to country, region to region. The ways in which questions of Science, Technology and Innovation (STI) are posed (whether they are central to the process or just one among several elements), the stakeholders involved (which agencies are or should be responsible for STI policy, what actors in Universities, firms, civil society need to be mobilized), the types of expertise and knowledge required – all these will vary.

How then to engage foresight with poverty reduction, competitiveness, sustainability, and the other goals. Long-term perspectives are necessary for much effective policy and strategy, especially as we confront rapid technological and geopolitical change,

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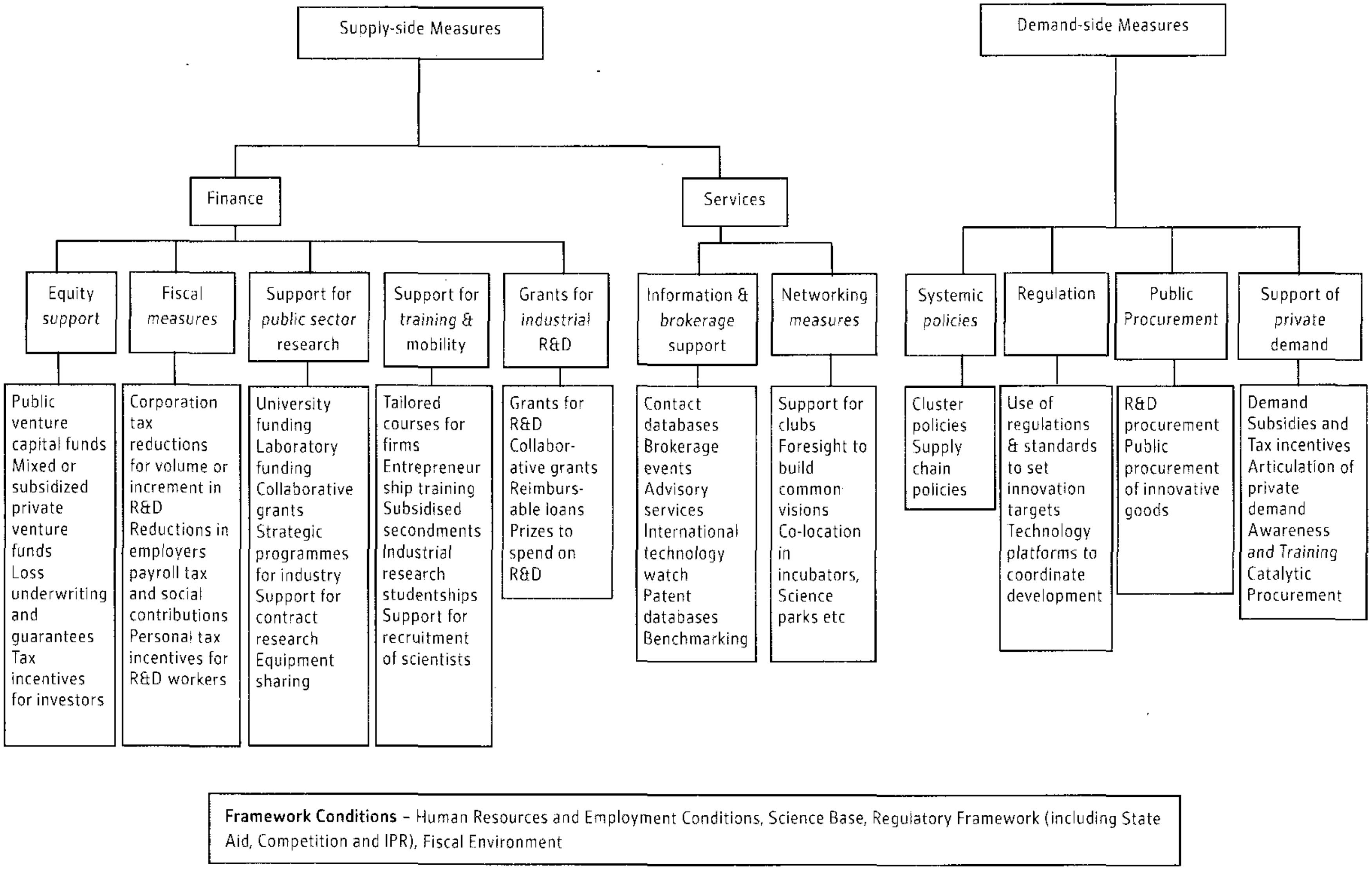
[4] http://prest.mbs.ac.uk/prest/SCOPE/.

[5] Thanks to the EGM rapporteurs for this section of the paper – Ian Miles and Jennifer Harper, as well as to all of those taking part in the discussion, notably Anthony Clayton and Tony Marjoram.

the challenges of climate change and globalization, and the like. These are issues that create a need for reform of many well-established STI systems – and that are particularly problematic for those countries and regions where such systems are barely functional. The multifaceted nature of these issues also demonstrates the need to situate STI analysis and foresight within a much wider context of thought and action.

Taking foresight to be the systematic combination of long-term perspectives, wide participation, and effective policy/strategy formulation and implementation, these general attributes have numerous potential benefits to offer. Across different contexts, they may help in risk management and raising awareness of impending problems and opportunities; inform and help structure planning and priority-setting; promote the establishment of the networks and exchange of knowledge that are vital to dynamic STI systems; diagnose the weaknesses in these systems and indicate areas of strength and those where remedial action is necessary; and play other roles that have been documented in case studies of foresight in Western industrial nations (and also in Japan and in a few more industrialized developing countries). One interesting point to arise from the discussion was that even in developing economies characterized by high levels of political polarization, foresight activities can play an important role in allowing actors to move beyond the patterns of thought and compartmentalized discourses that are grounded in immediate problems and short-term concerns. Common ground and new ways of framing issues could be established by longer-term approaches (the case was mentioned of moving away from the immediate crisis facing a specific agro-industry, to broader considerations concerning the scope for higher-value-added land use (planning). This coincides with experience in more developed countries, where Foresight has been used to break down professional and disciplinary barriers that reduce the effective use of expertise in STI decision-making.

Figure 1. Taxonomy of Research and Innovation Policies



Source: Edler, J. and Georghiou, L. (2007)

4. Conclusions

To draw towards a conclusion we may revisit the initial intention of this paper to explore the implications of a shift of emphasis from technology foresight to innovation foresight. This does not imply the neglect of technology as a driver but rather an opening up to the wider implications of the knowledge economy and society and the forces and trends that drive and impact upon innovation. In the economic sphere that innovation is most often effected by the business sector, though it may be in the course of the provision by that sector of public goods. Two key areas have been discussed in respect of this shift, its role in innovation and industrial policy and the promotion of foresight at the corporate level. In these two dimensions we may now conclude.

4.1. Innovation and Industrial Policy

Taking the first of these headings, we have identified a particular role for foresight in taking advantage of the trend towards what we may term new wave demand-side innovation policy. This means the use of foresight as an instrument of bringing together not only those responsible for the development of the technological or other knowledge needed for innovation, but also those who are likely to make use of the technology or to provide the regulatory environment in which it develops.

Along with promotion of cooperation between existing innovation actors, this fast-tracks the development of an open innovation system and new industrial eco-system in developing economies; systems which may otherwise continue to be dominated by traditional structures. This has the double advantage of making successful innovation more likely to occur and of channelling it towards solutions to some of the problems posed by the path towards sustainable development.

As discussed in previous sections, foresight is an essential component in addressing dimensions of innovation and industrial policy such as clusters and technology platforms built on base of common visions and in creating a pro-innovation culture that channels broader government such as public procurement towards the use of innovative goods and services again in a context driven by shared visions.

In practical terms this would mean that capacity building and assistance activities should also engage with sectoral ministries and agencies responsible for areas such as health, eco-innovation, food, housing and transport and to involve them in foresight activities, along with the relevant industrial sectors and their knowledge partners.

This approach combines elements of the emergent 4th and 5th Generation foresight approaches discussed in earlier sections with a shift from the monolithic national programme to a distributed, bottom-up model of foresight embedded at multiple levels within (increasingly distributed) innovation system. It also recognizes that knowledge acquisition by firms is as much about ability to scan and draw in external technology and manage partnerships as it is about internal R&D.

Multi-level governance provides many starting points for foresight which includes both sub-national and supra-national regional dimensions. Foresight is not about reaching a single solution and may in this context also be driven by diversity and competition.

Also important to emphasize is the need for more attention to be given to foresight on *structural issues, using it as a means of exploring and developing* new paradigms for themes such as industry-science relations, human resources for innovation and sectoral policies.

For those concerned with support for policy, practical realization of this shift of emphasis is largely not a matter of changing the instruments used. Capacity building and training remain key elements, awareness and foresight culture are core, identification and spread of good practice between countries through conferences, workshops, mobilization of experts and codification through guidelines and online resources are all important. Mobilizing finance is also essential for many countries.

The difference comes mainly in extending the content of such activities to a broader range of actors and themes within productive sectors. Partnerships for foresight then become the core for emergent knowledge-based economic initiatives. This also implies partnerships between international agencies. For developing countries we have seen that the chief benefits of foresight lie in two dimensions:

- Creation of a space in which "difficult" issues of the present may be properly aired by shifting to the future context; and
- Providing a means for transition which is designed to network with those who will not only provide future markets but also are the conduits of information about economic, social and cultural trends that may otherwise threaten to exclude actors in developing countries.

4.2. Corporate Foresight

The development of corporate foresight capability on emerging economies cannot be disassociated from the changes in the innovation environment which we have discussed with their emphasis on networks and linkages. Nonetheless, specific tasks exist to build the corporate culture and capability to sustain foresight activities in enterprises which may suffer both from lock-in to traditional thinking and markets and from difficulty in escaping the day-to-day pressures of business survival.

If we can take two key messages from the experience of corporate foresight to date these would be:

- Foresight is only worth doing (or commissioning) if the engagement of the principal stakeholders in the company is assured. This engagement is a function of the organizational positioning of foresight, the efforts made to secure involvement before, during and after each specific exercise, the skill of practitioners in presenting complex findings in a digestible format which nonetheless maintains the necessary detail, and the ongoing challenge of demonstrating relevance and impact even when it is one signal among many competing for attention in strategy-formulation; and

- The trend to open innovation has been matched by a similar move to open foresight and emphasizes the need for corporate practitioners to be willing to share ideas and approaches in return for gaining the necessary knowledge and insights needed to perform their own functions effectively.

The most likely prediction for foresight is that it will continue to adapt and reinvent itself both to keep pace with the changing structures in which technology and innovation are managed and to maintain the interest and attention of the most stakeholders that it needs if it is to have an impact either at the corporate level or on the policies and partnerships that create the environment for the business sector.

References

Aho, E., Cornu, J., Georghiou, L. and Subira, A., (2006) Creating an Innovative Europe. Report of the Independent Expert Group on R&D and Innovation appointed following the Hampton Court Summit. January 2006.

Becker, P. (2002), *Corporate Foresight in Europe: A First Overview*, Working Paper, European Commission, available at ftp://ftp.cordis.lu/pub/foresight/doc/st_corporate_foresight_040109.pdf.

Caracostas P. and Muldur U (1997) Society the endless frontier – a European vision of research and innovation policies for the 21st century, European Commission EUR 17655, 1997.

Cassingena Harper J. (2003) eForesee Report, Malta Council for Science and Technology.

Chesbrough H. (2003) The era of open innovation Sloan Management Review Vol 44 (3) Spring 2003.

Coombs R. and Georghiou L. (2002) A New Industrial Ecology, *Science* Vol 296 p.471 April 19 2002.

Cuhls and Johnston R, Corporate FTA (Future-oriented Technology Analysis) Anchor Paper for the International FTA Seminar, Seville, Sept. 2006.

Dolowitz, D, and Marsh, D., (2000) "Learning from Abroad; The Role of Policy Transfer in Contemporary Policy-Making", *Governance*, 13 (1), 5-24.

Daheim C and Uerz G (2006) Corporate Foresight in Europe: From Trend-based Logics to Open Foresight, International FTA Seminar, Seville, Sept. 2006.

Edler J and Georghiou L (2007) Public Procurement and Innovation – Resurrecting the Demand Side, *Research Policy* (forthcoming).

Georghiou L. (1996) "The UK Technology Foresight Programme", *Futures*, Vol.28, No.4, pp. 359-377.

Georghiou, L. (2007) Demanding Innovation – Lead Markets, Public Procurement and Innovation, NESTA Provocation 02: February 2007, London:NESTA.

Georghiou L and Harper J (2007)Policy Transfer and Learning in Foresight, in Georghiou L, Harper J, Keenan M, Miles I and Popper R (eds) International Handbook on Foresight and Science Policy: Theory and Practice, Edward Elgar, UK 2007 (forthcoming).

Huston L and Sakkab N (2006) Connect and Develop – inside Proctor and Gamble's new model for innovation, Harvard Business Review Vol 84 No 3 March 2006.

Johnston R and Sripaipan C (2007) Industrializing Countries: Case study China and Thailand, in Georghiou L, Harper J, Keenan M, Miles I and Popper R (eds) *International Handbook on Foresight and Science Policy: Theory and Practice*, Edward Elgar, UK 2007 (forthcoming).

Juma C and Yee-Cheeong I L (eds) (2004) Interim report of Task Force 10 on Science, Technology and Innovation, February 1, 2004, P51.

Martin B. and Johnston R. (1999) 'Technology foresight for wiring up the national innovation system', Technological Forecasting and Social Change 60,1: 37-54.

OECD (2006) Government R&D Funding and Company Behaviour: Measuring Behavioural Additionality, Paris: OECD 2006.

Popper R and Medina J (2007) Foresight in Latin America, in Georghiou L, Harper J, Keenan M, Miles I and Popper R (eds) International Handbook on Foresight and Science Policy: Theory and Practice, Edward Elgar, UK 2007 (forthcoming).

PREST (2006) Evaluation of the United Kingdom Foresight Programme Final Report March 2006 www.foresight.gov.uk//publications/publications.htm.

Salmenkaita J.-P. and Salo A., 2002. Rationales for government intervention in the commercialization of new technologies. *Technology Analysis & Strategic Management* 14, number 2, pages 183-200.

Experiences and Practices of Technology Foresight in the European Region

Attila Havas, Doris Schartinger & Karl Matthias Weber

Abstract

Foresight has evolved as a distinct prospective analytical tool: it considers alternative futures of various S&T fields or socio-economic systems by bringing together the representatives of various stakeholder groups, and thus assists the decision-making processes at different levels. In order to avoid the emerging of "hype – disappointment cycles", which could be observed in the case of new, initially promising technologies, the potential contributions to decision-making processes by foresight should be clearly understood. The paper puts foresight into this broader context of policy (decision) –making processes: it describes the evolution of different policy rationales since the 1950s, develops a framework to classify the impacts of various types of prospective analyses, and reviews the evaluation results of several national foresight programmes by using this framework.

Keywords

Foresight, innovation policy, impact assessment, evaluation, policy learning, policy coordination, distributed policy-making, Europe, Central and Eastern Europe, emerging economies

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Biographical Notes

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Dr. Matthias Weber has been the head of Technology Policy Department at Austrian Research Centres, systems research division, since 2000. He has been working for almost fifteen years on foresight and strategy development, on transformation dynamics of innovation systems, and on governance matters in relation to research, technology and innovation policy. Among other activities, he has been involved in and led a range of foresight projects at European, national and regional levels. As managing director of a joint research undertaking between the City of Vienna and Austrian Research Centres, he is involved in a foresight and strategy process to inform the future research and innovation policy of the city region. Matthias Weber is currently Chairman of the Scientific Steering Committee of ETEPS (European Techno-Economic Policy Support Network) and a member of the EC high-level expert group on ERA Rationales.

1. Introduction

The evolution of foresight since its inception in Europe in the 1990s is a success story; it has acquired prominence as a process aiming to support forward-looking opinion formation in decision-making, both for public policies and businesses. This is reflected, for instance, in the range of domains to which the initial national technology foresight approach has been transferred over the past few years: (i) multi-country; and (ii) regional levels, as well as (iii) sectoral perspectives; and (iv) various policy areas, beyond STI policies.

In spite of this apparent success, the perspectives for the future are far from clear. The notion of "hype –disappointment cycles", which has been developed to describe the patterns of attention paid to emerging technologies, might be applicable to foresight, too: initial enthusiasm has given way to a significant deal of scepticism in several countries, and more recently to a more realistic assessment of the strengths and the weaknesses of various types of prospective analyses.

There are two main reasons for this: (i) embedding foresight in the decision-making processes is a far from trivial task; and (ii) the requirements from the new application domains where foresight is used, are not only challenging, but also different from science, technology and innovation policies.

In this paper, we will look specifically at one of the policy areas where foresight has become more prominent: innovation policy. The paper will proceed along three main steps. First, we position foresight in the context of political decision-making and implementation processes. Second, we analyse to links between foresight and innovation policy. Third, we summarize the insights into the actual and expected impact of foresight gained from several evaluation exercises, with a particular emphasis on policy impacts.

2. Policy Challenges: Why to Conduct Foresight

2.1. Policy rationale for running foresight programmes

A number of technological, economic, societal, political and environmental trends affect all countries and most areas of policy-making, thus a new *culture of future-oriented thinking* is needed. Foresight can assist policy processes in various ways. It stresses the possibility of different futures (or future states), as opposed to the assumption that there is an already given, pre-determined future, and hence highlights the opportunity of shaping our futures. Further, it can enhance flexibility in policy making and implementation, broaden perspectives, and encourage thinking outside the box ("think of the unthinkable").

The increasing number of national foresight programmes suggests that foresight can be a useful policy tool in rather different national innovation systems. As a growing body of literature analyses this surge, the major factors explaining the diffusion of foresight can be summarized here in a telegraphic style:

- Globalization, sweeping technological and organizational changes, as well as the ever-increasing importance of learning capabilities and application of knowledge have significantly altered the 'rules of the game'. Thus, policymakers have to take on new responsibilities (as well as dropping some previous ones), while firms must find new strategies to remain, or become, competitive in this new environment.
- Given the above factors our future cannot be predicted by any sophisticated model. Planning or forecasting of our future becomes more and more ridiculed in light of rapid and fundamental changes. History also teaches us valuable lessons about the (im)possibilities of planning and predicting the future. Therefore, flexibility, open minds for and awareness of possible futures are inevitable. Diversity is a key word: diversity in scope (in terms of possible futures, differing analyses etc), as well as diversity in solutions or policy options.
- Decision-makers face *complex* challenges: socio-economic and technological factors interact in defining issues of strategic importance, e.g.

- ➢ education and life-long learning (new demands on education systems; new, mainly IT-based tools and methods for teaching and learning; the growing need for interaction and co-operation with businesses);
- ➢ environmental issues;
- ➢ quality of life (health, education, demographic changes, especially the growing share and special needs of elderly people, living and working environment, social conflicts, crime prevention, etc.);
- ➢ competitiveness (at national and EU-level for attracting talents and capital, at firm level maintaining and increasing market shares nationally and internationally, etc.);
- ➢ regional disparities,[1] especially in large countries.

- Most policy problems no longer have 'self-evident' solutions. Governments are forced to make use of 'evidence-based policies', policies based on knowledge/insight into what works and what does not. This does not mean that values are no longer of importance. Values are still very important, but have to be considered in the context of a given issue.
- Policymakers have to learn to cope with growing complexity and uncertainty of policy issues themselves. Thus the precautionary principle is of a growing significance.
- New skills and behaviour are required (e.g. problem-solving, communication and co-operation skills in multidisciplinary, multicultural teams meeting more often only "virtually", as well as creativity) if individuals or organizations are to prosper in this new setting. This, in turn, creates new demands on the education and training system (see above).
- Clusters, networks (business – academia, business – business, both at national, international levels) and other forms of co-operation have become a key factor in creating, diffusing and exploiting knowledge and new technologies, and therefore in satisfying social needs and achieving economic success.
- There is a widening gap between the speed of technological changes and the ability to formulate appropriate policies (which requires a sound understanding of the underlying causes and mechanisms at work).
- Given the growing political and economic pressures, governments try hard to balance their budgets, while cutting taxes, and hence they need to reduce public spending relative to GDP. In the meantime accountability – why to spend taxpayers' money, on what – has become even more important in democratic societies. Public R&D expenditures are also subject to these demands.
- Policymakers also have to deal with intensifying social concerns about new technologies (mainly ethical and safety concerns in the case of biotech or nuclear

[1] In this particular point, regional disparities are to be understood as intra-country ones.

technologies, and fears of unemployment and social exclusion caused by the rapid diffusion of information and communication technologies).

- Even the credibility of science is somewhat fading. Scientific research no longer stands for 'true' in itself. The 'objectiveness' of policies based on scientific research is questioned (by citizens, interest groups, etc.) as scientists themselves are known to have different opinions and come to different conclusions on the same issue.
- More generally, individualization, as a major recent trend, has several repercussions. The ever more mature and independent citizens want to be catered to their needs; this calls for 'mass customization' not only in manufacturing and services, but to some extent also in policy-making. They are also more and more informed about possibilities, possible negative effects, and will not hesitate to voice their preferences. On top of this the social bases for decision-making are quickly eroding. The 'usual', erstwhile social groupings to which people belonged (e.g. churches/ religions, socialists, entrepreneurs, workers) no longer provide relevant, sufficient guidance for all areas of decision-making. People can, and nowadays do, belong to a multitude of different interest groups; they are not bound by the traditional 'pillars'. Thus, the role of the traditional intermediaries (political parties, unions etc) is becoming less dominant. More and more specific interest groups (new intermediaries, e.g. NGOs) have sprung up, and become increasingly important. This can be seen as a supplement to democracy; citizens are exercising 'voice' in new ways (not just once in 4-year election periods). Therefore decision-making is becoming ever more complex. Coalitions (not those of political parties, but of stakeholders) are not fixed, they tend shift issue by issue. All this calls for openness on possible futures, flexibility, and room for diversity as mentioned above.

Besides the above trends, there are other specific, policy-relevant methodological reasons to apply foresight. First, it can offer vital input for 'quantum leaps' in policy-making in various domains. Usually policies evolve in a piecemeal way, in incremental, small steps. From time to time, however, a more fundamental rethinking of current policies is needed. In other words, policymakers occasionally need to ask if current policies can be continued: do they react to (early) signs of changes, block or accommodate future developments?

> The parable of the boiling frog illustrates this point 'vividly': put a frog in a cooking pot with cold water, and start heating the water. The frog will not jump out, because it does not alerted by the slowly rising temperature. It will boil alive.

Second, foresight can also help in picking up *weak signals*: weak but very important signals that a fundamental re-assessment and re-alignment of current policies are needed. In other words, foresight can serve as a crucial part of an *early warning* system, and it can be seen as an instrument for an adaptive, 'learning society'.

In sum, participative, transparent, forward-looking methods are needed when decision-makers are trying to find solutions for the above challenges. Foresight – as a systematic, participatory process, collecting future intelligence and building medium-to-long-term visions, aimed at influencing present-day decisions and mobilizing joint actions – offers an essential tool for this endeavour. (EC DG Research, 2002) It helps in making choices in an ever more complex situation by discussing alternative options, bringing together different communities with their complementary knowledge and experience. In doing so, and discussing the various visions with a wide range of stakeholders, it also leads to a more transparent decision-making process, and hence provides a way to obtain public support. The process, in which stakeholders communicate and share ideas concentrating on longer-term issues, generate consensus, and co-operate with increased commitment in devising and realizing a national strategy, has been deemed so crucial in several countries that it has become one of the explicit objectives of running a foresight programme. The foresight process can reduce uncertainty, too, because participants can align their endeavours once they arrive at shared visions. Many governments have already realized the importance of foresight activities, and thus this relatively new, and innovative, policy tool is spreading across continents.

2.2. Relevance of Foresight for policy in CEE and other emerging economies

The above general considerations apply in catching-up countries in the Central and Eastern European and NIS region, too. Quite a few pressures – especially the need to change attitudes and norms, develop new skills, facilitate co-operation, balance budgets – are even stronger than in the case of advanced countries. Moreover, most of these countries also have to cope with additional challenges: the need to find new markets; fragile international competitiveness; relatively poor quality of life; brain drain. These all point to the need to devise a sound, appropriate innovation policy, and even more importantly, to strengthen their respective systems of innovation. Foresight can be an effective tool to embark upon these interrelated issues, too, if used deliberately in this broader context.

Foresight can also contribute to tackle yet another challenge of emerging economies: most of them are struggling with 'burning' short-term issues – such as pressures on various public services, e.g. health care, education, pensions and thus severe budget deficit; imbalances in current accounts and foreign trade; unemployment; etc. – while faced with a compelling need for fundamental organizational and institutional changes. In other words, short- and long-term issues compete for various resources: capabilities (intellectual resources for problem-solving); attention of politicians and policymakers who decide on the allocation of financial funds; and attention of opinion-leaders who can set the agenda (and thus influence discussions and decisions on the allocation of funds). These intellectual and financial resources are always limited, thus choices have to be made. A thorough, well-designed foresight process can help identify priorities, also in terms of striking a balance between short- and long-term issues.

Further, foresight can offer additional "process benefits" in the CEE/NIS region. By debating the various strengths, weaknesses, threats and opportunities of a country posed by the catching-up process, and the role of universities and research institutes in replying to those challenges, the process itself is likely to contribute to realign the S&T system (including the higher education sector) to the new situation. An intense, high-profile discussion – in other words, a wide consultation process involving the major stakeholders – can also be used as a means to raise the profile of S&T and innovation issues in politics and formulating economic policies. (Georghoiu, 2002)

To conclude, foresight can be a useful tool in the CEE region and other emerging economies, too; in spite the fact that these countries can only exceptionally push the frontiers of S&T progress. A number of factors seem to contradict this conclusion at the first glance. Foresight is costly in terms of time and money. Further, advanced countries regularly conduct foresight programmes, and their reports, Delphi-survey results, etc. are readily available. Yet, only a national programme can position a country in the global context and stir up dialogues on how to react to major S&T, business, societal and environmental trends. Similarly, strength and weaknesses of a given country would not be discussed by other programmes, let alone broad socio-economic issues. Process benefits cannot be achieved without a national programme, either. Without these, a country would not be able to improve the quality of life of her population and enhance her international competitiveness.

There are even stronger needs for strategic thinking in CEE countries and other emerging economies than in the advanced countries, given their specific challenges, in particular their transition processes and major changes in their external environment. Yet, long-term thinking is discredited across the region. Policymakers do not rely on modern decision-preparatory tools to a sufficient extent, and quite often do not realize the close interconnections between RTDI processes and socio-economic development. Thus, in many cases, they are only willing to spend on R&D when "we can afford" – although it should be the other way around: "we spend on promoting RTDI processes, because we want to foster wealth creation". Science, technology and innovation policies are isolated from each other – if not "fighting" for the same, limited set of resources – and major economic policies are not coordinated with STI policies.

Foresight may change these attitudes, but exactly because of these factors, foresight programmes are only scattered in the region. One cannot observe strong commitment for profound foresight programmes, that is, serious consideration and determined implementation of policy recommendations, accepting/introducing a new decision-making culture, along with a new way of thinking, with more emphasis on communication, co-operation, consensus among the major stakeholders, and joint commitments to take action.

However, foresight should not be conducted for its own sake – just because it is becoming "fashionable" throughout the world, and currently being promoted by international organizations. On the contrary, there should be a strong link between foresight, decision preparation and policy-making: foresight should be used as a policy tool to address major socio-economic and political challenges. It is not a panacea, however; it cannot solve all the problems listed above, and cannot solve any of them just on its own. Obviously, other methods and tools are also required, as well as an assiduous implementation of the strategies devised either at national, regional, sector or firm level.

3. From Technology Foresight to integrated policy strategies

3.1. Positioning foresight in the policy process: towards policy integration

In the 1960s, government policies in relation to research and technology were predominantly inspired by an approach that today is often labelled as "picking winners": promising technologies, sectors and large players were selected as being of particular public or strategic interest and were thus doted with significant amounts of financial and other types of support. With the recognition of the limitations of government's ability to actively plan and shape future developments in an efficient and fully informed manner, the late 1970s saw the emergence of new paradigm in research, technology and – then also – innovation policies, which was characterized by a focus on shaping framework conditions that are conducive to innovation. This 'hands off' approach was subsequently evolving into what is nowadays called the systems approach to research and innovation, which not only deals with framework conditions but also with the institutional and structural settings for R&D and innovation (RTDI). In line with these concepts, the 1990s were also characterized by a great reluctance of government policy to prioritise and select technologies and research themes in a top-down manner. In recent years, and driven by fiercer competition at global level for, especially, private investment in RTDI processes, we can observe a shift in policy-making practices from shaping framework conditions and structural settings towards strategic decision-making. Strategic means here that the thematic portfolio of a country and region and the medium- to long-term perspectives are given a greater weight in science, technology and innovation (STI) policies again. However, the growing complexity of innovation processes is also recognized, by stressing the bottom-up component of networking and clustering as important instruments for enhancing the innovative performance in emerging areas of specialization. (OECD, 2002)

Similar to this shift in approaches to innovation processes and STI policies, there has been a shift in the conceptual understanding of policy processes. Taking into account insights from strategic planning and complex social systems thinking, recent developments in policy-making processes go beyond earlier cycle models and stress interactivity, learning, and the decentralized and networked character of political decision-making and implementation. Earlier technocratic and linear process models of policy making in terms of 'formulation – implementation – evaluation' phases were replaced by cycle models, where evaluations are supposed to feed back into the policy formation and implementation phases. Already in these cycle models, policy learning is seen as an essential ingredient of political governance. Recognizing the fact that in view of the complexity and the ever changing character of the object of policy – which strongly applies in the case of innovation policy – there is neither a clear-cut recipe for, nor an overarching theory, of policy. From a different angle, we should acknowledge a fervent need for continuous adaptation and re-adjustment of policies and related instruments.

More recently, it has been recognized that the effectiveness of policy depends also on the involvement of a broader range of actors than those formally in charge of policy decisions. The concept of distributed policy-making and intelligence (Kuhlmann *et al.*, 2001) draws our attention to various policy practices relying extensively on the knowledge, experience and competence of the different stakeholders concerned. From this network perspective, policy making is not just about government, but about the joint impact of public and private decision-making having an impact on society's course of change and the networked interactions that precede formal decision-making. For government policy to be effective, this implies the participation of stakeholders. Further, the role of government is shifting from being a central steering entity to that of a moderator of collective decision-making processes, that is, the principles of modern democracy have an effect in these fields, too.

With such an open and distributed model of policy-making in mind, it is now increasingly recognized that an opening of political processes is necessary to ensure the robustness and the effectiveness of its outcomes. This is also reflected in the EC's White Paper on Governance (EC, 2001), which stresses five principles of good governance: participation, accountability, openness, effectiveness, coherence.

The complexity and the interdependencies involved in policy-making are also recognized in the need for policy coordination, if not integration, in four different respects:

- horizontal policy coordination, i.e. between different policy areas;
- vertical policy coordination, i.e. between different administrative layers;
- multi-level policy coordination, i.e. between different levels of governance (European, national, regional);
- temporal policy coordination, i.e. between different phases of policy making processes. (OECD, 2005)

In this context, foresight assists increasingly interdependent and partly autonomous decision-making processes in a systematic manner. Foresight looks well beyond current day-to-day decision-making concerns. It uses a participatory approach to generate insights on future challenges, directions of change, and thus devises alternative visions with the aim of informing decision-making processes, either in general terms of open debates or more specifically in support of specific issues that are up for decisions.

The aforementioned shift in conceiving of policy-making processes is reflected in the evolving practices of foresight. First of all, it has emerged as a distinct approach as opposed to forecasting exercises on science and technology. Historically this trend is linked to the adoption of the term 'technology foresight' as distinct from 'technology forecasting' and the like.[1] The underlying difference is that foresight is a participatory activity, involving representatives of different stakeholder groups, while forecasting activities are solely based on S&T expert opinion.[2]

As a second important trend, several foresight programmes have incorporated market and business aspects, while yet another group of them considered societal issues. This broadening of the scope of forward-looking exercises can be interpreted as a reflection of the abandoning of simplistic models of technological change, and the adoption of a systemic understanding of innovation processes, including the co-evolution of social, economic, and technological changes.

Thirdly, we can see a strong emphasis on, and belief in, the contribution of foresight activities to shaping rather than predicting and controlling the future. The Delphi surveys in the 1970s and 1980s were strongly influenced by the linear idea that the consensus achieved given the Delphi exercise could serve as a forecast, and thus as a foundation for taking preparatory actions to exploit emerging technologies. A similarly linear perspective, but from a different angle, holds for the critical technology studies conducted in the US, in France and the Netherlands. They also relied largely on a predictive approach and combined it with the idea of being able to secure through national policy a leading edge in selected technologies. (Andersen *et al.*, 2007) Subsequently, new forms of Delphi have been developed that do not strive to achieve consensus on future forecasts, but rather to map diversity of opinion. (Best *et al.*, 1986) In the meantime, countries that until the 1990s were relying on Delphi surveys to support their research and technology policies have recurred to complementing their tool box by other methods to promote more intense participation (e.g. direct communications among the participants); the cases in point are, for instance, the German Futur process or the French FutuRIS project.

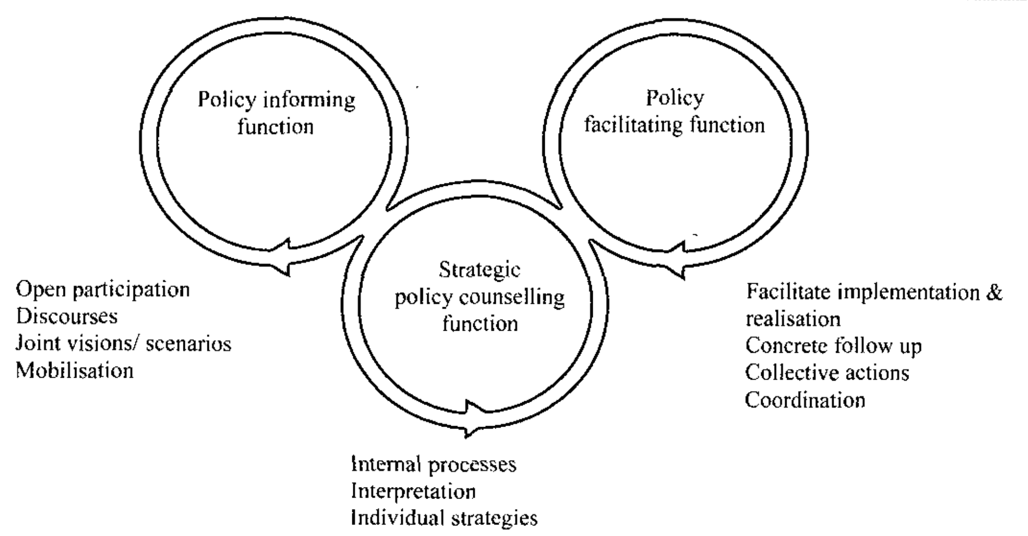
Foresight processes bring together not only experts, but also decision-makers from research, industry, policy-making and society, and thus a shared understanding of current problems, goals and development options can be expected to emerge among those actors that have an important role to play in shaping the future. This converging understanding of the issues at play is likely to contribute to improving implicitly the coherence of the distributed decisions of these actors, in line with the shared mental framework developed. In other words, the future is being shaped by aligning expectations and thus 'creating' a self-fulfilling prophecy. These so-called process outputs are often regarded as more important than the actual substantive (or tangible) outputs like reports and websites.[3]

Finally, and most recently, we can observe an increasing interest in foresight activities that aim at supporting strategy formation both at collective level and at the level of individual organizations, e.g. "Adaptive Foresight" (Eriksson and Weber, 2007), or "Sustainability Foresight" (Truffer *et al.*, 2007). This interest is fuelled by the recognition that there is a translation problem apparent in foresight approaches that predominantly rely on broad participatory processes, namely the translation of shared collective problem-perceptions, expectations and visions into concrete decisions of individual actors and organizations. From this perspective, Foresight can be interpreted as an integral element of networked and distributed political decision-making by providing three crucial functions (da Costa *et al.*, 2007; Eriksson and

Weber, 2007; Weber, 2006), which – in line with the network-type distributed model of policy-making processes – are provided simultaneously rather than in distinct phases:

- First, *policy informing* by generating consolidated findings concerning the dynamics of change, future challenges and options and transmitting it to policymakers as an input into policy conceptualization and design. This function is an important incentive for policymakers to initiate a foresight programme in the first place.
- Secondly, *policy strategic counselling* by merging the insights generated in the context of policy informing foresight activities with perspectives on the strategic positioning and options of individual actors, to support their internal decision-making processes.
- Thirdly, *policy facilitating* by building a common awareness of current dynamics and future developments as well as new networks and visions among stakeholders, thus facilitating the implementation of policy strategies.

Figure 1. Adaptive Foresight



Source: adapted from Eriksson and Weber (2007)

Against this background, it is now possible to systematize the potential policy impacts of foresight, by drawing first of all on the three main functions of foresight in relation to policy-making processes, secondly on the range of impacts that have been assigned to foresight in the corresponding literature and thirdly on the time lag at which an impact occurs.[4] (Table 1)

Table 1. A Framework to Classify Impacts of Foresight Activities

Function	Time lag	Targeted and/or unintended impact
Informing	**Immediate**	• Increased recognition of a topic area • Awareness of science, technology and innovation among players, creating debate • Awareness of systemic character • Training of participants in foresight matters • New combinations of experts and stakeholders, shared understanding (knowledge network)
	Intermediate	• *Articulation of joint visions of the future, establishing longer-term perspectives*
	Ultimate	• Integrate able new actors in the community
Counselling	**Immediate**	• Make hidden agendas and objectives explicit
	Intermediate	• Devising recommendations and identifying options for action • Activate and support fast policy learning and policy unlearning processes • Identify hidden obstacles to the introduction of more informed, transparent, open participatory processes to governance
	Ultimate	• Influence on (research/ policy) agendas of actors, both public and private (as revealed, for instance, in policy strategies and programmes) • Incorporate forward-looking elements in organizations' internal procedures
Facilitating	**Immediate**	• Effective actions taken
	Intermediate	• Formation of action networks • Creation of follow-up activities
	Ultimate	• Adoption of foresight contents in the research and teaching agenda of organizations; Foresight spin-off activities in various disciplines • Improved coherence of policies • Cultural changes towards longer-term, holistic, and systemic thinking

Source: ARC sys, building on Cassingena Harper and Georghiou (2005), PREST (2006) and ForSociety (2007)

3.2. Different application areas

The various benefits of foresight in the policy-making processes can be enjoyed at the level of national economies, as well as at multi-country, or regional levels, or in industrial sectors. Moreover, policy-oriented foresight exercises have been addressing a wide range of fields. Thus, a rough categorization of foresight exercises can be made in terms of its focus on:

- A certain geographical territory (i.e. local/regional, national, transnational, international)
- A certain socio-economic domain (a specific industrial sector, SMEs, clusters, etc.)
- A certain policy field (transport policy, innovation policy, etc.)
- A certain topic (women entrepreneurship, crime prevention, etc.)

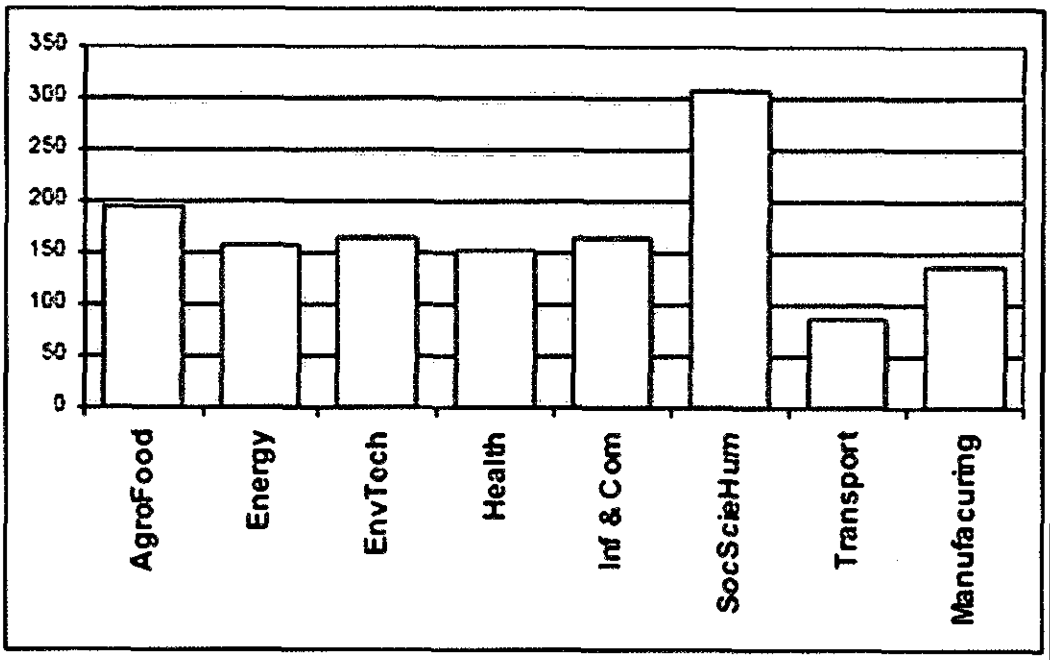
In all these respects, the recent years have witnessed a broadening coverage of foresight programmes. The initial focus on predominantly national foresight exercises has been complemented especially by regional foresight (Gavigan *et al.* 2001), but also by a growing interest in European Union level and/or multi-country foresight exercises, where appropriate. The three latter 'thematic' categories have received fast growing attention, often in combination with one of the geographic levels. While initially, *technology* foresight was the dominant thematic focus of foresight initiatives, we have recently seen the emergence of topics that have hardly any link with technology, covering subjects such as poverty, social security systems, cultural heritage, etc. Not the least the regional wave of foresight has contributed to substituting the technology focus by the much broader concepts such as innovation and regional development.

These arguments are supported by the findings of the European Foresight Monitoring Network (EFMN), which has conducted a systematic scanning and analysis of foresight exercises worldwide (though with a strong emphasis being put on the European Union). It shows that out of about 800 exercises analysed (as of September 2006), a fairly even coverage of the eight thematic areas can be observed, with exercises focusing on social science and humanities perspectives standing out a particularly important.[5] (Figure 2a)

Over time, there has been quite some fluctuation in terms of the relative importance of these thematic areas (Figure 2b), with socio-economic issues (in the database, and hence in the figure labelled as social sciences and humanities), ICT and energy growing significantly in importance over the past three to five years. Environmental, energy and transport-related themes turned out to be the most important concerns cutting across the entire set of EFMN exercises (i.e. they were frequently mentioned in the EFMN exercises with a different focus), whereas projects on social sciences and humanities tend to be conducted rather as stand-alone activities with little reference to other areas. (Keenan *et al.* 2006, p.9; Figure 3)

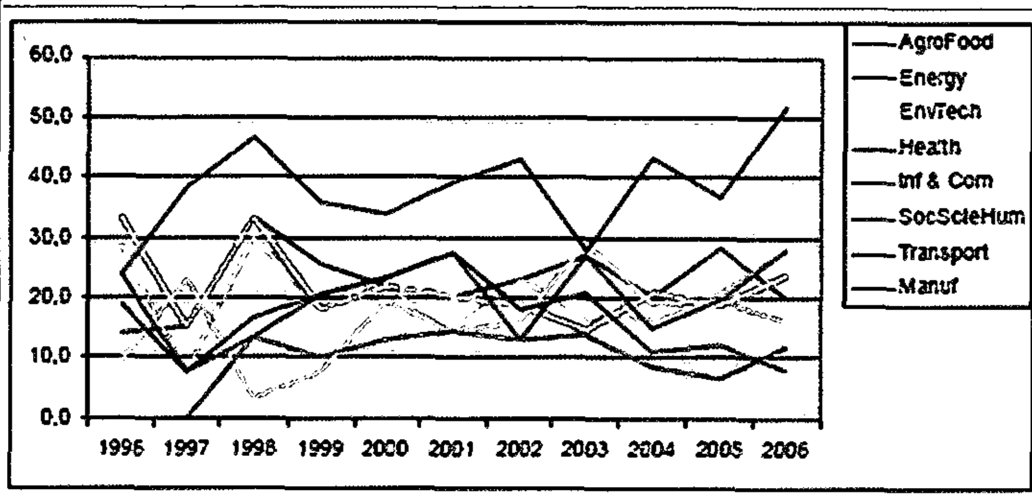
This quantitative evidence on the broadening of the thematic orientation of foresight work is further reinforced by looking at some of the specific themes that were addressed in the most recent generations of national foresight programmes, with subjects such as crime prevention (UK Mark 3), flooding (UK Mark 3), sustainable infrastructures (German socio-ecological research programme).

Figure 2a. Importance of different thematic areas



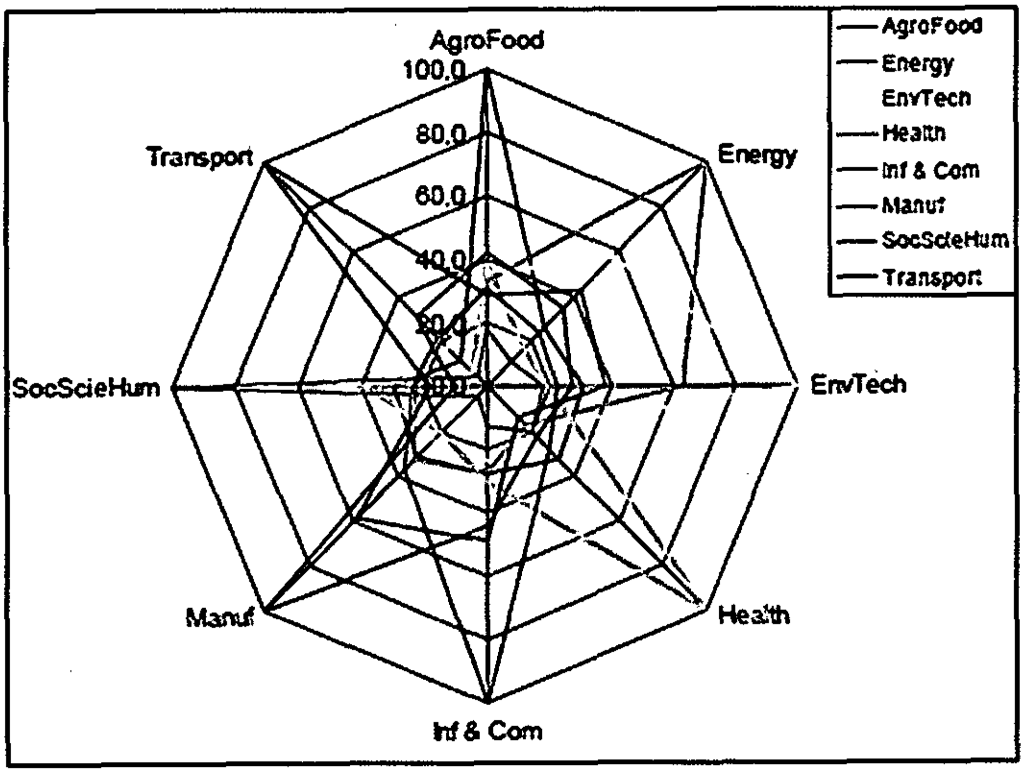
Source: Keenan *et al.* (2006)

Figure 2b. Evolution of the importance of different thematic areas 1996-2006



Source: Keenan *et al.* (2006)

Figure 3. Consideration of main thematic areas in foresight exercises



Source: Keenan *et al.* (2006)

While this first statistical analysis of recent developments in foresight/ prospective activities reflects the changes in importance that is assigned to different thematic areas and issues, it does not say much about the actual results that have been generated. In fact, a comprehensive and thorough analysis of the content of foresight exercises has not been conducted so far, not even for foresight in Europe. Cross-cutting analyses of foresight activities in Europe have focused on specific themes and areas.[6]

Foresights reports and policy strategy documents from seven EU countries have been analysed by Mahroum *et al.* (2004). The study identifies both major emerging socio-economic challenges and the potential contributions of main current and expected future developments in major fields of scientific and socio-technical research to tackling these challenges. Six main challenges were identified:

- Pervasive globalization: Globalization is widely regarded as an unavoidable trend that is creating major social and structural challenges for societies. The world's economies are bound together by trade, investments, financial flows and the growing mobility of highly trained people. Globalization does not only make collaboration and openness between countries imperative, but also within societies. The rapid expansion of globalization is literally transforming the European region into a borderless area with massive opportunities and enormous challenges.

- Transition to a knowledge-intensive economy and society: All countries are preparing for the knowledge-intensive society, as knowledge has become the most important competitive factor. The emergence of the knowledge-intensive (learning) society is identified as a main challenge in the vast majority of foresight reports analysed. In fact, the Finnish foresight report is even entitled *The Future is in Knowledge and Competence.*

- Growing regional disparities and social marginalization: In a globalizing and urbanizing world, in which cities compete with each other to attract inward investment, local politicians are seeking to create high quality, healthy, attractive living environments for their own citizens, and to attract businesses from elsewhere. Businesses with high value-added and complex, knowledge-intensive activities are located in regions with good development conditions including strong knowledge infrastructure, a good business climate, availability of skilled labour, and a good living environment. All industrial countries are competing to create dynamic regions that provide these or similar conditions. However, this competition creates not only winners, but also losers, and growing disparities can be observed at the level of regions as well as at the level of individuals.

- Transformation of health care: The various foresight/prospective reports indicate a clear need for a substantial overhaul of the health care systems, as Europe (and the world) embarks on a new dawn of preventive and pervasive health care services and delivery. Those will be primarily driven by a number of forces, technological advances, aging, and changing lifestyles. Europe will be further challenged to harness its research capabilities to increase its ability to deal with, and prevent, health crises. The challenge is thus for European health care systems to move from curative to preventive health care systems. Preventive health care systems will require focusing on new ways of life (diet, drinking and smoking habits, sports, etc.), delivering health services, the development of new pharmaceuticals, diagnostics and treatments and also the development of healthy and functional foods and materials.

- Management of environmental resources and energy supply: The environment, high quality of life, and stable and efficient energy sources will increasingly become 'values' that people are interested in taking care of and that they are willing to pay for. The values are visible in investment patterns, consumer behaviour and legislative changes.

- Consolidation of the information society: The development enabled by digital solutions and the Internet will continue to have a crucial impact on the development of all industries and social sectors as well as on the lives and practices of individuals according to all reports surveyed. The digital revolution, with its new communications and information technology, has changed society and our way of living and it will continue to do so. The digital dimension is everywhere. These new applications will continue to help improve productivity in the traditional sectors of industry. They will also continue to change the workplace and the ways we work, providing us with greater independence in terms of time and space.

While these six challenges reflect the most important future concerns many European countries share, the reports analysed also underline the crucial importance of five existing and emerging areas of science and technology development for addressing these six challenges.

- Complex systems management is a critical scientific field. In almost all the challenges mentioned above, issues of a complex (as opposed to a merely complicated) nature at are play. In fact, the transformation of large-scale socio-technical systems can only be handled on the basis of a consolidated understanding of how mechanisms of complexity work.
- Information and Communication Technologies have obviously a key role to play when dealing with the problems of globalization, with the realization of the knowledge-intensive society, for reducing regional and social disparities, for environmental management and for health care. It is this pervasive character of ICT which makes it so critical.
- Nanotechnology is equally a pervasive technology, though not yet to the same extent as ICT. As an enabling technology, it also has an impact on the advancement of ICT and other ground-laying technology areas, which then find their application in health products and services, or various types of advanced products in a knowledge-based society/economy. Furthermore, due to its - contested - impacts on resource consumption, nanotechnology will have a direct impact on environmental resources, whether this impact will be positive or negative.
- Biotechnology and genetic technology are repeatedly mentioned as S&T areas of strategic importance. However, as their importance grows, they raise a number of important risks and contentious issues with respect to social disparities (e.g. access to advanced genetic cures), globalization (investment in genetic technology with lax regulation) and knowledge-intensive economy/society (who benefits economically from genetic technology), let alone environmental resources (e.g. impact of genetically modified organisms and food).
- Energy systems have a rather clear prime challenge to address, i.e. environment and energy, but it is also of importance of globalization (global energy supplies of oil, hydrogen, electricity), knowledge-based economy (economic impacts of cheap energy, external costs) and regional disparities (the energy rich vs. the energy poor, adapted technology to poor countries).

While this may be a sketchy representation of what is regarded in Europe as major challenges and S&T developments of the future, it is a first approximation. Obviously, the level of attention paid to these issues differs by country and depends on their specific socio-economic situation and cultural context.

4. Innovation policy and foresight

Similar to foresight, innovation is a horizontal, cross-cutting policy matter that affects many other policy areas, most notably energy, environment, transport, regional development, industrial change, health, education, and others ("horizontalisation"). These policy areas, in turn, can have quite important impacts on innovation processes and innovation performance, too. This implies that the requirements of these policy areas need to be taken into account in innovation policy and vice-versa. The growing inter-dependence of policy areas is one of the motivations for stressing the need for better policy coordination with respect to innovation-related issues, and it has been one of the drivers behind the emphasis put on systemic innovation policy instruments in order to complement classical policy instruments such as direct research subsidies and public procurement. Systemic instruments are meant to enhance the capability of innovation systems for self-organization and therefore address innovation policy at a system level.

These insights also contributed to the emergence over the past two decades of a more 'humble' perception of what policy-making can actually do and deliver with respect to innovation: (i) policymakers cannot be seen as perfectly informed social planners, but at best as mediators and initiators of collectively negotiated decisions, and (ii) the formation of policy strategies must be seen as a continuous, interactive learning process.

From this perspective, *foresight* on innovation policy issues can be interpreted as a systemic coordination mechanism that not only mediates between policy actors and different stakeholder communities, but also between different policy areas (and their respective stakeholders) affecting innovation. In other words, foresight activities contribute to an infrastructure of distributed intelligence that is enabling the whole system to better address future challenges, and especially also link RTDI processes more closely to socio-economic needs by offering a forum for exchange between RTDI demand and RTDI supply perspectives. It is also reckoned that foresight actors develop a stronger inclination towards long-term strategic thinking and better access to relevant knowledge for developing their internal strategic planning. As a consequence, combining foresight practices with the establishment of other intelligence competences helps ensure the tight embedding of forward-thinking and policy learning.

These observations may serve to underpin the potential for synergies between innovation policy and foresight, but the actual effectiveness of foresight depends to a significant extent on its neat embedding in the innovation system and innovation policy context ('contextualization'). Subsequently, four important dimensions of this contextualization shall be briefly discussed: governance culture, policy attention, socio-economic dynamics, and resource availability.

Governance culture

In countries that already have a set of elaborated innovation policies in place, these tend to be underpinned by a whole set of strategic intelligence instruments, ranging from innovation research and monitoring to impact assessments and evaluations. Within this portfolio, foresight often acquires a special role to inform debates, support strategy formation and facilitate the implementation of policies, but its influence on innovation policy depends on the role of the other instruments of innovation policy intelligence and learning. This kind of situation is characteristic of most Western European countries, where more or less differentiated governance mechanisms have been established to develop, monitor and re-orient government policies, In countries, where the innovation policy culture is less developed, such as in most transition economies, in developing and/or industrializing countries, foresight as a participatory approach can be much more prominent ('visible') in contributing to the coordination of policies and actors, not the least due to the absence of other intelligence approaches. In these countries, it seems to have the potential to structure catching-up processes in assembling new actors, integrate them into a consensus-oriented dialogue and thereby effectively support policy-learning and unlearning processes. Moreover, it provides the ground for setting up and exploiting the potential of other intelligence approaches by contributing to the shaping of an innovation and strategy culture. (The obvious examples are: CEE countries, Malta, and a number of developing countries).

Policy attention

Still, the governance culture alone does not explain major differences in the effectiveness of foresight. In countries with a highly developed innovation policy culture, the importance of foresight as compared to other instruments depends very much on its positioning and the support enjoyed by high-ranking policymakers. The British Mark I Foresight experience and its impact on agendas was not the least due to the high-level of policy attention it received, and to the close link to the responsible Minister's office. In Sweden, the existence of a well developed range of other policy support mechanisms made foresight one instrument among others, and without gaining priority, it left much less room for impact. The on-going innovation policy foresight by the City of Vienna is closely tied to a process of re-positioning its STI policy, even if this close link may not have been intended right from the outset. However, one should also note the risks involved in a close link with, and attention of, policymakers. Policy attention is often closely tied to issues that are high on the policy agendas, a situation that may give rise to an instrumental use of foresight results for political purposes rather than to an open-minded discourse about challenges and options for the future. The framing of a foresight exercise, e.g. in terms of time horizon, objectives and ownership is crucial to ensure the right balance between attention and openness.

Socio-economic dynamics

The timing of a foresight exercise is also very important for the contribution it can have to innovation policy. In countries that are facing major structural changes and expecting new developments to emerge in the coming years, the need for orientation and forward-looking information is much more pressing than in countries that are in a comparatively stable economic and social development phase. The transition economies in Central and Eastern Europe are examples in case (Havas 2003b), as well as many industrializing countries. However, also in the so-called advanced countries, characterized by apparently stable socio-economic structures, foresight can be highly relevant to discuss alternative futures. In the light of strong pressures stemming from globalization and major social and techno-economic forces, quite fundamental and structural changes are required (e.g. in terms of business practices, economic structures and incentive mechanisms, skills development, attitudes, etc.), but are difficult to introduce due to strong path-dependencies inherent in the dominant socio-technical regimes.

Resource availability

Closely related to the dimension of socio-economic dynamics, the availability of resources and finance can reinforce the interest in and the impact of foresight. Economic standstill or even recession tends to lead to resistance to change and makes it very difficult to allocate resources to new future-oriented activities. Yet, even under such unfavourable circumstances, shared visions can reduce uncertainty, facilitate priority-setting or at least the acceptance of the need for priority-setting, and thus lead to a more effective use and exploitation of scarce public money.

The horizontal nature of both innovation (policy) and foresight, and the embedding of foresight in its wider socio-economic and political are key aspects to be taken into account when discussing the impact of foresight, and its likely future(s).

5. The impact of foresight on policy

5.1. Assessing the impact of foresight in the context of innovation policy

The assessment of impacts of foresight must rely on a consolidated understanding of the policy processes it is embedded in, taking into consideration the three functions outlined above. The policy facilitating function has been highly stressed among foresight experts. However, the first methodological attempts to grasp not only the direct but also the indirect impacts of foresight exercises on the shape and course of government policies have been made only relatively recently. The empirical basis on which to draw is thus rather scarce. The analysis can only be based on the evaluation of four recent foresight exercises, the second rounds of the UK and Swedish foresight exercises, the eFORESEE project in Malta, and the experience with the Hungarian foresight exercise (TEP), with a fifth evaluation, i.e. the one of the German Futur process, not being publicly available.[7]

Table 2. International Foresight Activities and their Evaluations

Country	Dates of Foresight Process	Date of Evaluation Report/ Analysis	Years in Between	Public R&D Expenditures (2003, % of GDP)
Hungary	1997-2001	2004	3	0,62
Malta	2002-04	2005	1	0,19
Sweden	2002-04	2005	1	1,02
UK	2002-now	2006	0	0,68

Source: ARC sys, public R&D expenditures from the European Innovation Scoreboard 2005[8]

As regards the various functions of foresight, little is known so far in terms of impact assessment. While the informing function is generally acknowledged (though little hard evidence provided), the policy counselling and policy facilitating functions are still comparatively novel, and have thus not yet been subject to deeper investigations.

In this chapter, the various evaluation reports are analysed in terms of the impacts the foresight programmes had with respect to the three main functions of foresight according to the process model and the impact assessment framework outlined in Section 3: policy informing, policy counselling, and policy facilitating. Some key issues resulting from this analysis of assessment results are discussed thereafter, aiming at highlighting contextual factors that strongly influence the likelihood of having an impact on policy (or not).

Assessment of the Policy Informing Function

Results of the foresight process constitute a 'reservoir of knowledge', which is available for policymakers over the following years. They unevenly find their way as active inputs in the political discourse, either through personal networks or simply because there is a conclusive text available 'off the shelf' when policies are being drafted. (Georghiou *et al.*, 2004. p. 5)

With respect to the policy informing function, the quality of the reports produced during the foresight exercise is crucial. To simply make a report of the unstructured musings of a panel is seen as very negative and significantly undermines the effects such reports can have in decision-making processes. This is especially true, if the choice of the panel members, which consequently strongly determines the outcomes of the entire foresight programme, is neither transparent nor systematic. The information provided in the reports must not be perceived as party-political or partial either, as this clearly impairs the confidence in their quality. Instead, the trust in the quality of the reports (and thus their legitimacy as foundation for policy decision) increases if i) high-level independent experts are involved and carry the exercise (e.g. in the UK); and ii) the exercise is highly inclusive in terms of participation, which means that the knowledge of a large number of interested and informed people is tapped (e.g. Malta). In order to achieve this, foresight may need to be done in parallel at different levels, with different customers. (Arnold *et al.*, 2005, p. 33)

Assessment of the Policy Advisory/Strategic Counselling Function

There are clear difficulties in assessing the policy advisory function, the most obvious of which is the time lag between the foresight exercise and the emergence of results in political decisions. The impacts of foresight activities on policy-making are likely to occur and become visible only some time after the foresight process for several reasons. First, it often takes time for the 'reservoirs of knowledge' to be found and absorbed, so they tend to shape decisions only after some time – although there are exceptions from this general tendency, see e.g. the Irish case. Secondly, the negotiation and bargaining processes associated with policy formation, interpretation, and implementation also take their time and lead to a decelerated perception of actual foresight impacts. (PREST 2006, p. 17) This holds for both the products and the process benefits of foresight.

The situation is slightly different in those cases where foresight elements are closely linked to processes of policy formation, like for instance in the context of the Dutch Transition Management experiences. (Kemp and Rotmans, 2005; the recent review of the Austrian technology and innovation policy strategy, BMVIT, 2006) In these cases, the impact on policy formation is quite immediate, but they require a balance between open participatory and closed internal phases of opinion formation.

Assessment of the Policy Facilitating Function

There is very little known about the continuing contact of major stakeholders after the end of a foresight exercise. In Sweden, at the individual level nearly everyone found that participating in TF2 was an immensely enjoyable and learning experienced and [...] that their personal networks were greatly expanded, in a number of cases they also argued that this would boost their careers. (Arnold *et al.*, 2005, p. 30) The adherence of distinct networks on the whole, formed during the foresight process, seems to depend to a great extent on financial support after the end of foresight exercise; see, e.g. the UK experience.

5.2. Special features of the evaluation of recent foresight exercises

5.2.1. The Second Foresight Round in the UK

The evaluation report of the UK Foresight round launched in 2002 found as immediate effects the increased recognition/profile for the topic area, and new combinations of experts and stakeholders brought together. Both may be attributed to the policy informing function. (PREST, 2006, p. 17ff)

Intermediate effects include (i) the articulation of visions of the future, and (ii) the formulation of recommendations and options for action. These first two intermediate effects may be summarized under the policy advisory function, and were clearly achieved through the reports generated by the various projects launched in the course of the UK foresight round 2002. A third intermediate effect is the formation of action networks, which already points towards impacts in terms of policy implementation. However, evidence is less conclusive concerning the formation of action networks, which seems to be highly dependent upon the sponsor agency, and hence much more needs to be done to render them self-sustaining.

Ultimate effects include influence on research agendas of both public (the UK Research Councils, UK government policy) and private actors (industry), and may be observed in the range of policy counselling and policy implementation. Effects in the public domain are evident in the stimulation of new areas of work within existing programmes and fora, rather than the formulation of whole new programmes. Ultimate effects are a lot more difficult to trace in the private sector. First, the private sector features less prominently in the current UK foresight round. Second, foresight impacts in industry do not manifest themselves in publicly accessible documentation. What remains is anecdotal evidence of participants from industry that foresight activities are perceived as successful and interesting events.

A Brief Overview of Policy Impacts in the UK

The second round of foresight in the UK was organized in different projects, which vary considerably in their impacts on policy making.

The foresight project on cognitive systems (CS) was not intended to directly exert influence on policy (other than research policy, by offering funds for cross-disciplinary proposals building on the CS project). (PREST, 2006, p. 37)

The flood and coastal defence (FCD) project was used heavily to inform the sponsoring ministry's (Defra) long-term strategy on flooding. It has provided a route map as a result, a map for Defra to use in policy development and decision making. Furthermore, the HM Treasury stresses the important contributions of the project for the Spending Review (SR) 2004, which ensured the high level of funding for flood management allocated in SR 2002. (PREST, 2006, p. 43ff)

In the one-year-report of the project on cyber trust and crime prevention (CTCP) on its impacts on government policy making, mention is made of workshops using the project scenarios of CTCP, also of CTCP contributing to the definition of fraud and to the Cabinet Office's development of a Strategy for Information Assurance. The DTI Innovation Group's newly forming priority on cyber security presumably relies to a large part on CTCP. However, some interviews suggest that the policy impacts of CTCT may be limited or delayed due to factors outside CTCP e.g. the turnover of the responsible minister. (PREST, 2006, p. 49ff)

The foresight project on exploiting the electromagnetic spectrum (EEMS) was aimed at assessing the research field in terms possible commercialization. It exerted some influence on the calls of the Research Councils and of DTI's Technology Programmes, but Foresight in general is just one of the many inputs DTI uses to identify areas to support. Yet, the response from the community to the calls was below expectation, which suggests that it is an area still someway off readiness for commercialization. (PREST, 2006, p. 56ff)

The project on brain science, addiction and drugs (BSAD) identified possible contradictions in the current policy, with current a possible future developments. The responsible ministry has already used the outputs. However, as the project was launched in 2005, the views of those interviewed were that it was still too early to speculate on longer-term impacts on policy. (PREST, 2006, p. 61ff)

5.2.2. eFORESEE in Malta

The foresight exercise carried out in Malta in 2002-2004 was conducted in the context of a political system undergoing fast pressures of change in the critical phase of pre-accession to the European Union. The assessment of the exercise revealed that the impacts that are particularly elaborated on are the ones related to the project *Malta's Knowledge Futures in ICT and Education Pilot.* The main targeted output here was a vision of Malta in 2010. Furthermore, the pilot used five edged and well identifiable success criteria as objectives and measures of achievement.

In the domain of policy informing, the objectives were to develop high quality scenarios worthy of publication and the involvement of new actors beyond the established players in the field. Concerning policy counselling, the objectives were to identify textual modifications or inputs in the National Development Plan, a specific reference and follow-up activities in the NDP, resulting from the foresight exercise. With respect to policy implementation, the objectives were the development of action plans worthy of publication, bringing to the table in the form of a 'core group', the main high-level visionaries and strategic planners in Malta, and the formation of new public-private partnerships that would take action on business opportunities identified via this exercise.

An evaluation has concluded that the objectives have been met, the main policy development being the launch of an updated RTDI Strategy (2003-2006) and its implementing tool, the RTDI programme. The foresight exercise has been instrumental in identifying the key weaknesses in the national system of innovation, which, in turn, have been targeted by the RTDI programme. (Cassingena Harper and Georghiou, 2005, pp. 94 ff)

Several major unforeseen impacts that came to the fore during the implementation phase have also been identified:

- Activation and support of fast policy learning and policy unlearning processes.
- Engaging able new actors and integrate them in a consensus-oriented dialogue.
- Identification of hidden obstacles to the introduction of more informed, transparent, open participatory processes to governance.
- A shift from the targeted set of objectives set at the beginning of the exercise to the informal or societal goals, which also formed part of the task. The shift was made when in the course of the exercise it became clear that in achieving the objectives targeted in the outset, work had also to be addressed the set of goals related to the socio-cultural context.
- Increased awareness of science, innovation and technology policy concerns among local players. This impact was accelerated as the exercise was highly inclusive and sought to engage actors at all levels (strategic players, politicians and policymakers as well as experts in the fields of social and natural sciences).

- Increased awareness of the need for consensus-building approaches in long-term vision-setting exercises if policies are to prove sustainable.
- Foresight spin-off activities in various disciplines, as some of the panel members responded proactively to the issues under discussion and embarked on their own foresight activities. (e.g. FutureChild, theatre foresight, tourism foresight, etc.)
- Investments in foresight training in order to ensure the quality of foresight processes and results.
- The adoption of foresight contents in the research and teaching agenda of the University of Malta. (Cassingena Harper and Georghiou, 2005, p. 99ff)

5.2.3. The Technology Foresight Programme in Hungary

The Hungarian Technology Foresight Programme (TEP) proceeded from 1997 to 2001, as the first experience of a full-scale national foresight activity in a transition economy. The Steering Group and the seven thematic panels assessed the current situation, outlined different visions for the future, and devised policy proposals. The thematic panels analysed the key aspects of the following areas: human resources; health and life sciences; information technology, telecommunications and the media; natural and built environments; manufacturing and business processes; agribusiness and the food industry; transport. Their main concern was to identify major tools to improve the quality of life and enhance international competitiveness, and thus they emphasized the significance of both knowledge generation and exploitation.

TEP was evaluated by an international panel in 2004. (Georghiou *et al.*, 2004) It was Central part of the evaluation was a survey which produced 62 responses. According to the survey respondents, the most important effects were mainly in the area of cultural changes – establishing longer-term perspectives, and introducing greater inter-disciplinarity were the effects which stood out most in their rating of importance. Both effects may be interpreted as part of the policy informing function, the first effect also as part of the policy facilitating function. However, the effects achieved in terms of the original objectives were seen as quite weak, particularly influencing the research directions of industry or the public sector. It also had an effect on the climate of thought as it introduced longer-term holistic thinking in a period when the country was dominated by a short-term agenda (partly because of economic challenges but also as an opposition to the long-term planning in the political past). (Georghiou *et al.*, 2004, p. 4 ff)

With respect to policy counselling, the effects of the Hungarian foresight on public policy are apparent now, but they took much longer than expected to materialize. (Havas 2003a) The process behind this materialization was a "slow and non-linear process". (Georghiou *et al.*, 2004, p. 5) In various policy areas (e.g. strategic documents by the Prime Minister's Office, transport policy, the national health programme, environmental policy, IT policy) do statements, recommendations, sometimes exact passages, reflect results from TEP. It seems that the reservoir of knowledge created by TEP unevenly entered the policy making processes, either through personal networks or simply because there was a conclusive text available when policies were being drafted. (Georghiou *et al.*, 2004, p. 5)

A few more impacts can be observed since the evaluation exercise was conducted. The broad visions presented in the first National Development Plan (2004-2006) have relied heavily on the so-called macro visions published in the Steering Group report of TEP. Further, the first ever STI policy strategy, approved in March 2007by the government, is also making explicit reference to these macro visions.

5.2.4. The Second Technology Foresight Programme in Sweden (TF2)

In Sweden, the foresight process took place in 2002-2004, and it was evaluated by an international team in 2005. The evaluation report states that organizations (research organizations, consulting agencies, and foundations) appear to be the main winners and users of the results. (Arnold *et al.*, 2005) There is little sign of direct influence at the decision-making or political level (in our terminology: the policy counselling function). However, there has been a considerable overlap between various undertakings in the domain of research and innovation policy: TF2, the Research Bill and the national innovation strategy *Innovativa Sverige* were all devised in the same time. (ibid, p. 23) In their interviews, civil servants argued that the results of TF2 were not well marketed in the policy-making system, and that the synthesis report was produced well after the 'window of opportunity' to influence the Research Bill. Concerning the policy informing function, it was argued that the synthesis report was perceived to be party-political, which undermined its credibility. (ibid, p. 28) The most obvious impact of TF2 was the organization of a series of fora for young people to debate the future.

5.3. Key issues from the foresight impact analyses

As an overall assessment of its impact, Foresight is a useful decision-preparatory tool, as suggested by its wide-spread use across continents, as well as by theoretical considerations. Foresight can assist decision-makers in tackling a number of complex challenges: it can reduce technological, economic or social uncertainties by identifying various futures and policy options, make better informed decisions by bringing together different communities of practice with their complementary knowledge and experience, obtain public support by improving transparency, and thus improve overall efficiency of public spending. (Havas 2006) However, network-building effects are at least as important as the actual results of the process. The added-value of foresight increases when it is possible to overcome traditional sectoral/disciplinary barriers and to succeed in engaging able new actors beyond the established and well-known players in the field. This forges novel linkages within the innovation system and increases the recognition of the foresight topic area among the various players.

The results of evaluation exercises conducted so far also indicate that there are a number of key issues that can either hamper foresight from being effective in exerting an influence on policy-making, or significantly enhance their impact.

Enrolment of Able New Actors and Formation of Actor Networks

According to the participants of many foresight processes, the network-building effects are at least as important as the actual results of the process. The added-value of foresight increases when it is possible to overcome traditional sectoral/ disciplinary barriers and to succeed in engaging able new actors beyond the established and well-known players in the field. This forges novel linkages within the innovation system and increases the recognition of the foresight topic area among the various players.

Interested customers with absorptive capacities

A key problem experienced was the linkage between the foresight activities and its clients. Interested customers with absorptive capacity are a precondition if foresight is to affect policy. In Sweden, the foresight results seem to have difficulty to compete with the abundance of other reports, as civil servants do not have the resources to work themselves through quantities of reports. (Arnold *et al.*, 2005) In the UK the responsible minister was personally involved, which provided a focus and a clear indication of priority and importance of the exercise, and quite likely this factor increased the time resources civil servants devoted to the absorption of the results. (PREST, 2006, p. 19)

Ownership of results

The more path-breaking and revolutionary the results of the foresight process are, the more likely their implementation interferes with the competences of several departments or even ministries. This seems often to be the reason why recommendations derived from the foresight process lack commitment to acting upon them. In Hungary, TEP produced a long list of recommendations, which are sparsely implemented. (Georghiou *et al.*, 2004, p. 4 ff.) In Sweden, implications of the synthesis report were so wide-ranging that they were beyond the scope of individuals, units or even ministries. (Arnold *et al.*, 2005, p. 28)

Time horizon

A time horizon slightly beyond the concerns of even strategic policy decisions allows more "out-of-the-box" thinking and creativity in exploring the future and its implications. There is obviously a trade-off between creative, long-term thinking and the likelihood of having an immediate impact on decision-making.

The Congruence of Actors in Foresight and Political Advice

The actors, individuals and groups, who inform and advice ministries in their decisions and priorities are often the same that take a lead part in the foresight processes. This makes it especially hard to judge the impact of the foresight activities, even if political programmes and resolutions obviously reflect foresight results. In the extreme, this leads to the conclusion of OST about the UK foresight activities that "in the absence of Foresight, some or all of the successful outcomes might very well have transpired in part or at a later date." (Keenan, 2000) This argument presupposes that the ideas expressed in the foresight exercises "were around" anyway. Yet, there is a difference between ideas of visionary individuals that somehow find their way into opinion-forming or decision-making processes and the development of a vision in a foresight exercise, a vision that has been created jointly and that is shared by a broader constituency. This difference has major implications with respect to the ownership of results, and thus with respect to the likelihood, efficiency and efficacy of implementation.

6. Conclusions and recommendations

Foresight is a useful decision-preparatory tool, as suggested by its wide-spread use across continents, as well as by theoretical considerations. Foresight can assist decision-makers in tackling a number of complex challenges: it can reduce technological, economic or social uncertainties by identifying various futures and policy options, make better informed decisions by bringing together different communities of practice with their complementary knowledge and experience, obtain public support by improving transparency, and thus improve overall efficiency of public spending.

Foresight can be applied for all sorts of decision-making processes (businesses, research institutes, professional associations, NGOs, etc) – but our paper has been mainly concerned with the role of foresight in shaping public policies.

Foresight should not be conducted for its own sake – just because it is becoming "fashionable" throughout the world, and currently being promoted by international organizations. It is crucial to prove the relevance of foresight for decision-making: its timing and relevance to major issues faced by societies, as well as the quality of its 'products' – reports and policy recommendations – are critical. Only substantive, yet carefully formulated proposals can grab the attention of opinion leaders and decision-makers, and then, in turn, the results are likely to be implemented. Otherwise all the time and efforts that participants put into a foresight programme would be wasted, together with the public money spent to cover organizational and publication costs. The so-called process results – e.g. intensified networking, communication and co-operation among the participants – still might be significant even in this sad case, but they are less visible, and much more difficult to measure. Thus, the chances of a repeated programme – when it would be due again given the changing environment – are becoming really thin.

Foresight can be a useful tool in a number of policy fields – well beyond science, technology and innovation. It is time to embrace this broader notion of foresight, and especially in the CEE countries and other emerging economies, facing daunting tasks in a number of fields of socio-economic development.

International cooperation in foresight can raise awareness among the stakeholders, and also enhance the chances of success by sharing lessons, easing the lack of financial and intellectual resources through exploiting synergies and economies of scale. International organizations can also facilitate foresight programmes in emerging economies, and in particular collaboration among them. It is crucial, however, to maintain the commitment of local actors, e.g. in terms of time and funds devoted to the programme, willingness to implement the results. In other words, the main forms of foreign assistance should be the provision of knowledge-sharing platforms and other fora to exchange experience (among emerging economies as well as with advanced countries), monitoring and evaluating foresight initiatives in the CEE region and other emerging economies.

References

Andersen, P.D., Borup, M., Borch, K., Kaivo-oja, J., Eerola, A., Finnbjörnsson, Th., Øverland, E., Eriksson, E.A., Malmer, Th, and Mölleryd, B. (2007): Foresight in Nordic Innovation Systems, report for the Nordic Innovation Centre, Oslo, forthcoming.

Arnold, E., S. Faugert, Eriksson, A. and Charlet, V. (2005): *From Foresight to Consensus? An Evaluation of the Second Round of Swedish Technology Foresight*, Technopolis Report.

Best, G., Parston, G. and Rosenhead, J. (1986): Robustness in practice: the regional planning of health services, *Journal of the Operational Research Society*, 37, 463-478.

BMVIT (2006): Forschung, Technologie und Innovation für Wohlstand in gesellschaftlicher Verantwortung. Strategische Leitlinien [Technology and Innovation for Wealth Creation and Societal Responsibility. Strategic Guidelines], report to the Austrian Federal Ministry for Transport, Innovation and Technology BMVIT, Vienna.

Cassingena Harper J., L. Georghiou (2005): The Targeted and Unforeseen Impacts on Innovation Policy: the eFORESEE Malta Case Study, *Int. J. of Foresight and Innovation Policy*, 2, 84-103.

Cuhls, K. and Georghiou, L. (2004): Evaluating a Participative Foresight Process: "Futur - the German Research Dialogue", *Research Evaluation*, 13, 143-153.

Da Costa, O., Warnke, P., Scapolo, F. and Cagnin, C. (2006): Contribution of the FOR-LEARN project to the study of foresight impacts on policy, paper presented at the second international FTA Seminar, Sevilla, 27-29 September 2006.

Decker, M. and Ladikas, M. (eds) (2004): *Bridges between Science, Society and Policy Technology Assessment – Methods and Impacts*, Berlin: Springer.

EC (2001): *European Governance: A White Paper*, Brussels: European Commission.

Eriksson, E.A. and Weber, K.M. (2007): Adaptive Foresight: Navigating the complex landscape of policy strategies, *Technological Forecasting & Social Change*, forthcoming.

ForSociety (2007): Self-Evaluation Tool for Foresight Project Managers, http://www.eranet-forsociety.net, forthcoming.

Gavigan, J.P., Scapolo, F., Keenan, M., Miles, I., Farhi, F., Lecoq, D., Capriati, M., di Bartolomeo, T. (2001): *FOREN Guide - Foresight for Regional Development Network - A Practical Guide to Regional Foresight*, IPTS: Sevilla.

Georghiou, L. (2001): Third Generation Foresight - Integrating the Socio-economic Dimension, in: *The Proceedings of International Conference on Technology Foresight*, Tokyo, March 7 and 8, 2000.

Georghiou, L. (2002): Policy rationales, sponsors and objectives, presentation at the eFORESEE Workshop on Foresight Basics, Malta, 24-26 July 2002.

Georghiou, L., Acheson, H., Cassingena Harper, J., Clar, G., Klusacek, K. (2004): *Evaluation of the Hungarian Technology Foresight Programme (TEP)*, Report of an International Panel, http://www.nkth.gov.hu/main.php?folderID=159&articleID=3826&ctag=articlelist&iid=1.

Havas, A. (2003a): Evolving Foresight in a Small Transition Economy: The design, use and relevance of foresight methods in Hungary, *Journal of Forecasting*, 22, 179-201.

Havas, A. (2003b): The Relevance of Foresight for Accession Countries and Possibilities for Co-operation, IPTS *Report*, No. 73, 4-11.

Havas, A. (2006): Developing UNIDO TF Programme for the CEE/NIS Region, http://www.unido.org/file-storage/download/?file_id=57728.

Joss, S. and Bellucci, S. (eds) (2002): *Participatory Technology Assessment: European Perspectives*, London: CSD.

Keenan, M., Butter, M., Sainz, G. and Popper, R. (2006): Mapping Foresight in Europe and other Regions of the World: Highlights from the Annual mapping of the EFMN in 2005-2006, paper presented at the second international FTA Seminar, Sevilla, 27-29 September 2006.

Keenan, M (2000): *An Evaluation of the Implementation of the UK Technology Foresight Programme*, PhD thesis, PREST, University of Manchester.

Kemp, R. and Rotmans, J. (2005): The Management of the Co-evolution of Technical, Environmental and Social Systems, in: *Towards Environmental Innovation Systems*, M. Weber and J. Hemmelskamp (eds.) Springer, Berlin.

Kuhlmann, S. (2001): *Management of innovation systems: The role of distributed intelligence*, Maklu Uitgevers N.V., Antwerpen.

Mahroum, S., Steindl, C., Weber, K.M. (2004): Future-oriented analysis of the main socio-economic challenges in Europe: the potential impact of research, Part I: A comparative analysis of Austria, Denmark, Finland, Germany, Ireland, Sweden and the UK, ESTO Research Report, Sevilla/Vienna.

Martin, B.R. and Irvine, J. (1989): *Research Foresight: Priority-Setting in Science*, London and New York: Pinter Publishers.

OECD (2002): *Dynamising National Innovation Systems*, OECD: Paris.

OECD (2005): *Governance of Innovation Systems, Volume 1: Synthesis Report*, OECD: Paris.

PREST (2006): *Evaluation of the United Kingdom Foresight Programme, Final Report*, Manchester Business School, University of Manchester.

Rip, A., Misa, T., Schot, J. (1995): *Managing Technology in Society. The Approach of Constructive Technology Assessment*, London: Pinter.

Rhomberg, W., Steindl, C., Weber, M. (2006): *Neue Entwicklungen im Bereich der Wirkungsanalyse und -abschätzung FTIpolitischer Maßnahmen*, report to the Austrian Council for Research and Technology Development, Vienna.

Truffer, B., Voss, J.-P., Konrad, K. (2007): Sustainability Foresight. Towards a Coupled Analysis of Socio-Technical Transformations and Expectation Dynamics, *Technology Forecasting & Social Change*, forthcoming.

Weber K.M. (2006): Foresight and portfolio analysis as complementary elements in anticipatory policy-making, in: Voß J.-P., Bauknecht D. & Kemp R. (eds.): *Reflexive Governance for Sustainable Development*, Cheltenham: Edward Elgar.

Notes

1 This understanding of foresight builds on the UK foresight tradition as begun by Martin and Irvine (1989). Today, earlier technology forecasting approaches like the large Delphi surveys introduced in Japan in the early 1970s and later on adopted by Germany and other countries are often subsumed under the 'foresight' heading. For our purposes, however, the distinction between foresight and forecasting is useful.

2 Participatory and constructive approaches are increasingly applied in technology assessment activities, too, given the growing prominence of social, economic, environmental and ethical concerns related to scientific and technological developments. (Decker and Ladikas, 2004; Joss and Bellucci, 2002; Rip et al., 1995) Here, the aim is to negotiate consensus on risks and opportunities or at least achieve transparency about conflicting viewpoints, in order to contribute to a normative debate on desirable future development paths.

3 Obviously, there are also certain types of foresight exercises that have a less pro-active intention by concentrating on the identification of future challenges and issues only rather than aiming at solutions.

4 See the study on methods and dimensions of impact assessment by Rhomberg et al. (2006) and in particular the still ongoing work on self-evaluation tools for foresight in the context of the ForSociety ERA-Net (ForSociety 2007).

5 It should be noted, however, that not all exercises included in the EFMN database would qualify as "foresight" in the sense of the definition used in this paper – quite a few of them would be other types of presopective or strategic analyses.

6 This is the case, for instance, for cognitive sciences and energy in the context of the European Foresight Monitoring Network (EFMN), but also for ICT (see the analysis conducted in the context of the FISTERA project) and other sectorally focused foresight projects at the European Union level.

7 An evaluation of the German Futur process has been conducted, but not published. A short account can be found in Cuhls and Georghiou (2004).

8 http://trendchart.cordis.lu/scoreboards/scoreboard2005/docs/EIS2005_database.xls.

MULTI-COUNTRY FORESIGHT

Ana Morato, Jesus Rodriguez Cortezo and Ricardo Seidl da Fonseca

Abstract

Over the last decade, the framework in which decisions are taken has transcended the borders of the states in various different ways. There is a regional concept of a more geo-strategic significance and which is formed by various border countries or group of countries that, in light of their social, economic, and geo-strategic peculiarities need to set up actions and superstructures with a multi-country scope in order to improve competitiveness and the living conditions of its population.

Multi-country foresight is used to analyse common problems, detect opportunities for cooperation, identify complementary attributes, and deal with the subject of possible infrastructures at a regional level, which could not be set up at national level. The most important consideration at this stage is not to lose sight of the two levels: National and Regional and also the participation mechanisms at the political and operating level.

Keywords

Foresight, multi-country, supra-national, regional, Research-Development-Innovation (RDI), technological trends, technology transfer, strategic decision making, productive chain, expert panel, Delphi method, road-mapping.

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1. Introduction

A collaboration research between the Foundation OPTI and the United Nations Industrial Development Organization (UNIDO) was established in 2000 with the aim to disseminate the foresight as a tool of technological policies and to elaborate and carry out foresight exercises in which various countries participate with common interests and issues. The use of foresight to groups of countries, which, geographically or politically, constitute a single "region" with the same or similar resources and capacities, was expected to be an effective tool in identifying synergies and complementary attributes, and in setting up actions assisting further development of national and supra-national interests. The present paper makes a balance of the application of the concept of multi-country foresight in different exercises and indicates opportunities for its use in the future.

1.1. From regional dimension to multi-country scope – UNIDO foresight approach

UNIDO by launching the technology foresight initiative, proposed as a special feature the regional dimension for its foresight approach, meaning in this context addressing common issues of macro-regions such a Latin America and the Caribbean, Central and Eastern Europe, Asia, Arab countries and Africa. This approach has been evolving to the present one where the organization concentrates efforts in promoting and applying foresight methods at the supra-national, pluri-country or multi-country scope. The core idea is to use the foresight process as a tool for establishing multi-country research, development and innovation (RDI) policies and programmes as well as for industrial policies and strategies.

The regional concept used in this paper refers to geographical and political space formed by: (a) more the one country, being direct neighbors or belonging to a common macro-region; or (b) areas extending over more than one national border, such as a river basin. In this case, it is use as interchangeable notion the supra-national scope. By contrast, regional concept can also be used to characterize an area inside a national boundary, such as provinces, oblast, states or municipalities.

Nevertheless, it has to be considered that technology foresight exercises, by their own definition, are undertaken with the assumption that the specific technological development takes place within a well-defined social and economic framework and its effects should be beneficial to the related society and economy. This means that final results of a foresight exercise will always have a national (or even local) character, since it is at that level that strategic political or business decisions are made.

However, there are several reasons that justify the multi-country approach. The value of a technology foresight exercise depends on the one hand the strength of the achieved expert opinions and consensus building, and on the other hand the capacity of the involved stakeholders to influence future trends and events.

According to UNIDO, for most developing countries, conducting sub-regional (regions inside a country) and multi-country or supra-national foresight exercises is more realistic, to reach both the necessary quality and representative size of experts' opinions collection as well as to form multilateral groups able to realize their visions of the future by joining efforts, economic and political forces. Moreover, multi-country foresight initiatives can build a solid consensus basis for corporate and public investments in applied sciences and technology development by enlarging the productive capability and markets. They can also provide guidelines for cooperative research programmes in the private and the public sector, and they can vastly improve national and international collaboration and networking. At the very least, different national technology foresight exercises could be networked, whenever possible, into regional initiatives for common awareness building and training. In this sense, regional foresight exercises contribute to create a more comprehensive perspective that will help to better define national policies on a higher level of quality and implementation capability.

Notwithstanding the advantages of the multi-country (or supra-national) approach, it can be only applied in a demand-driven manner and in regions or group of countries where its implementation is feasible, the socio-economic situations among the related countries are relatively comparable and/or the region or group has experiences in integration processes.

Additionally, multi-country initiatives could help to overcome potential difficulties and excessive costs that constrain developing countries to undertake full-scale technology foresight exercises at the national level. The multi-country approach of the UNIDO technology foresight initiative facilitates less developed countries and small countries to be aware of global and regional trends, which could bring advantages or challenges to their economies.

In summary, the aim envisioned by UNIDO technology foresight multi-country initiatives is to facilitate a process of joint reflection, brought in by international experience, on key issues that may affect several countries and extract consequences for national exercises in strategic decision processes. For this purpose, certain production chains and/or areas of knowledge, that present a common interest for different countries, are very interesting subjects for foresight projects. The result to be achieved is the identification of the broad trends of technological evolution capable of influencing these production chains over the medium and long-term, so as to facilitate strategic decision-making in relation to these tendencies in each country involved.

However, it is necessary to take into consideration that:

- Multi-country or supra-national foresight study serves as a support for, but does not substitute the national exercises, and
- The exchange of knowledge in both directions implied by the relationship between the national and supra-national levels of the foresight exercise constitutes an effective mechanism of international collaboration among the countries involved.

In consequence, one of the greatest achievements of the multi-country foresight approach is its contribution in structuring and networking the technological and industrial communities of the target region or group of countries. Based on current experience, the UNIDO multi-country initiatives have been instrumental for creating the basis for national foresight capabilities.

1.2. Production chains

As already cited above, an interesting field of application for multi-country foresight is on shaping the future of production chains, which in the course of the globalization process are spread throughout various countries. This is also the case of large countries, where nodes of production chains are located in different areas or provinces.

The application of foresight methods for production chains involves the following steps:

- Modelling the production chain as an industrial system, composed by successive and interlinked nodes and the segmentation of each node;
- Analysis of the institutional and organizational environment encompassing the target production chain;
- Identification of needs and expectations of each segment and the whole chain;
- Analysis of the performance of the chain and identification of the critical factors for enhancing its performance;
- Prognostics of the future behaviour of the critical factors, and in consequence of the expected performance of the chain;
- Creation of future scenarios and visions affecting the chain and its environment;
- Identification of actions and key technologies to reach the future visions.

As a result, such an exercise would be able to identify:

- Technological demands and therefore orientations towards search for innovations, and
- Non-technological demands, indicating opportunities, threats and actions to be taken inside the chain and related to its institutional and organizational environment envisaging the enhancement of its performance in the future.

This approach, developed and applied in the UNIDO-promoted foresight exercise in Brazil for four production chains has been the basis for further exercises conducted or coordinated by the organization, namely for the fishery industry and medicinal plants in South America and food industry and water zero discharge in Eastern Europe. Two of these exercises will be presented in more detail later in this paper.

2. Application of foresight at the multi-country scope

2.1 Contribution of the multi-country foresight to policy making

The multi-country foresight contributes in various aspects to strengthen the capacities for strategic decision making at different levels. First of all, it is a platform for mutual learning by sharing knowledge between professionals, both from academy and business, from a particular area of knowledge or activity sector as well as sharing knowledge between public and private decision-makers.

Multi-country foresight is also useful to promote joint analysis of common problems, detect opportunities for cooperation, identify complementary attributes, and define needed infrastructures at a regional level, which are not feasible at the national level. All this enables to develop a region on common basis and create the consensus necessary to meet threats and opportunities from other regions.

2.2. Motivations of the participating countries

In spite of these advantages, to mobilize the active participation of countries in multi-country foresight exercises awareness and demonstration efforts are needed. The main motivation arguments could be in two ways:

- Showing the existence of structural deficiencies, where development process is difficult or non feasible to implement at the national level
- Demonstrating that specific constraints for economic growth can only be removed through joint formulation of medium- and long-term policies

In this connection, the success of this type of foresight exercise will depend on knowledge of the situation, realities and commonalities of the countries involved with regard to the topic being tackled.

Another key aspect relates to the identification of the appropriate stakeholders, amongst two main groups. On the one hand, it is necessary to mobilize public institutions to carry out the exercise and subsequently use the results. On the other hand, it is necessary to involve those who experience the problems in concrete terms, including scientists, technologists, and industrial professionals, as well as social actors, the latter being fundamental to projects in developing countries.

2.3. Organizing multi-country foresight processes

For the formulation and organization of multi-countries foresight, it is a key element the consideration of the two interconnected levels: *national and regional (supra-national)*. It is necessary to formulate the methodology and the execution process of the exercise closely taking this concept into account, and knowing which aspects are of an exclusively national nature and which are exclusively regional. A point that should be made about the multi-country scope is that the results of such a foresight exercise are never the sum of the results achieved at the national scope for each country, as only the common issues among the countries are addressed.

Secondly, it is necessary to formulate effective participation mechanisms at two levels: *the political level*, which is essential for the project to succeed and for the subsequent commitment to the implementation of results; and the *operating level* (realizing the work packages), essential for the smooth development of the exercise in each of the participating countries.

The following are some basic considerations when formulating the exercise, including actions to overcome eventual obstacles:

- To draft Terms of Reference for national teams participating in the project, which are clear and common to all the countries.
- The correct choice of a national work team, knowing how to combine technical and methodological capabilities. On this point, added value is provided to these projects by technology transfer carried out in the area of foresight and the control of its methodologies. These types of exercises are often accompanied by methodological training courses.
- The need to organize Regional Conferences throughout the project, not only to fulfil the different phases of the established methodology but also because they constitute a forum to meet and debate the future of the group of countries.
- These types of projects work if it is possible to organize proper working in a network. Working in a network is very useful, both from the point of view of effectiveness and efficiency, but is not free of limitations and difficulties. The technical project coordinator is a key actor in overcoming these obstacles.
- Finally, another large obstacle to be overcome in multi-country foresight exercises relates to ensuring that the multilateral cooperation takes into consideration the determining factors of the local interests of each country.

2.4. Basic methodology

One of the main contributions of these type of foresight exercise, both from the point of view of methodology and of the obtained results, is the way in which it works on two levels: national and regional (supra-national). What does this double focus mean? Firstly, it means that the different countries separately diagnose their specific problems and obtain results regarding the future of a given sector. Secondly, it means that projects for cooperation, synergies, and opportunities for development are identified, that transcend national borders and give rise to regional (supra-national) policies.

Foresight exercises at multi-country level, about a productive chain, would start with:

- *Diagnostics of the national situation of components of the productive chain*: the starting point of the work is the preparation of diagnostics in each target country on the status and possible development of specific sectors in the content of the subject productive chain, as well as the surrounding framework.

- *Identification of the regional (supra-national) landscape*: on the basis of the above-mentioned diagnostics prepared for each target country, information is integrated with the aim to extend the diagnostic to the regional level. An analysis of strengths and weaknesses is used as a starting point for the design of scenarios for the future.

- *Regional conference*: a conference is organized with three objectives:

    - To identify foresight methodology for regional productive chains

    - To present results of the work done

    - To launch the foresight exercises at the national level

- *Foresight studies at the national level*: there are different methods, as Delphi questioners, Road Maps and Key Technologies surveys to develop foresight studies where expert panels in each country identify technological and economic challenges faced by the country and consult to identify critical issues for developing the sector. The methodology applied by the panels, as well as the type of consultation, is defined in the methodology workshop at the regional conference. For the subject productive chain, this exercise generates national foresight studies in the target countries.

- *Final report on the multi-country foresight for the productive chain:* a final report is elaborated for the basis of the national foresight studies, which identify, inter allia, the following aspects:

    - Strengths and weaknesses in the region

    - Critical issue for development

    - Future technologies

    - Industrial development trends

    - Markets

    - Tools and mechanisms of action

    - Decision making processes.

2.5. Opportunities

It can be concluded that the various types of multi-country foresight exercises offer the following opportunities:

- They enable a shared vision of the future to be created.
- They boost the position of a country group in facilitating the implementation of projects and joint infrastructures.
- They help to compare different states of development in relation to a sector and facilitate benchmarking.
- They identify synergies.
- With the implementation of joint actions, they strengthen the competitive position of a region.
- They create an instrument for dialogue, exchange of opinions, and creation of networks.
- They allow joint consideration of future tendencies and a self-diagnosis of the starting capacities.
- They establish consensus on future visions and opportunities for development at the national and multilateral levels.

3. Experience and results of UNIDO-OPTI cooperation

UNIDO and OPTI joined effort to develop and apply the approach of multi-country foresight to specific regions and production chains. The first exercise ever in this field was the foresight project Future of the Fishery Industry in the Pacific coast of South America. The exercise involved the four countries of this sub-region: Chile, Colombia, Ecuador and Peru. Other exercises under implementation are Medicinal plants in the Andean region, involving Bolivia, Ecuador and Peru; Future of the Food Industry in six countries of CEE; Future of zero discharge for industrial water in the CEE countries. A briefing on the exercises dedicated to the fishery industry in South America and the food industry in Central and Eastern Europe is presented in the following sections.

3.1. Future of the Fishery Industry in the Pacific Coast of South America

3.1.1. *Project description and methodology*

The purpose of this multi-country foresight project was the consideration of possible futures for the fishery industry, conceptualized as a production chain extended to four countries in the Pacific coast of South America: Chile, Colombia, Ecuador and Peru. As a first step, an analysis was made in each of the countries involved to diagnose the present condition of the production chain in each country. These analyses were to serve as a starting point for the foresight study for each country, but in parallel a regional synthesis was undertaken, with the aim of bringing out characteristic features, potentialities and common problems in the broader regional framework.

The principles of the methodology and the basic criteria used in its application are as follows:

a. The complete production chain of the fishery industry was taken as the subject of study, including aquaculture in it. The nodes in this production chain are, in a highly simplified form:

- The inputs for fishing and aquaculture activities
- Fishing
- Aquaculture
- The processing of the products of fishing and aquaculture
- Marketing
- Consumption

b. National teams were set up, one in each country, under common technical and operational supervision;

c. The distinguishing feature of the project is articulation between the two levels, national and regional;

d. The basic principle of foresight studies was applied, namely collective thinking by as broad as possible a range of experts on hypotheses drawn up regarding the future in a particular field.

3.1.2. Participants

The project relied on a somewhat complex organizational network consisting of the following categories of participants:

- UNIDO, as general coordinator
- A high-level political counterpart in each country
- A national coordinator in each country
- OPTI as an agency with foresight expertise
- Technical advisers

UNIDO was responsible for the design and management of the project, coordination among the participants, the preparation of and updating of information, a database and the website, final evaluation and the preparation of reports.

The political counterparts, at deputy minister level, ensured the commitment of the participating countries to the project.

The national coordinators were the executive officials in charge of the tasks to be carried out in each country.

The agency with foresight expertise, the Spanish organization OPTI, was responsible for technical direction of the project.

Lastly, different experts participated as technical advisers.

3.1.3. Structure of the project

The project was implemented in various stages, such as:

a. A diagnostic study of the fishery production chain in each country, with an analysis of the status of its components;

b. A regional diagnostic study, in which the characteristics of the region were identified, and which was to serve as a basis for the regional foresight study;

c. A regional conference, where all the project participants met for the first time and the national teams had an opportunity to exchange their experience and concerns;

d. Foresight studies at the national level;

e. Final regional-level report;

f. Final regional conference for the presentation and discussion of the results of the project.

Figure 1 sets out the reports drawn up in the course of the project.

Figure 1. Structure of the project

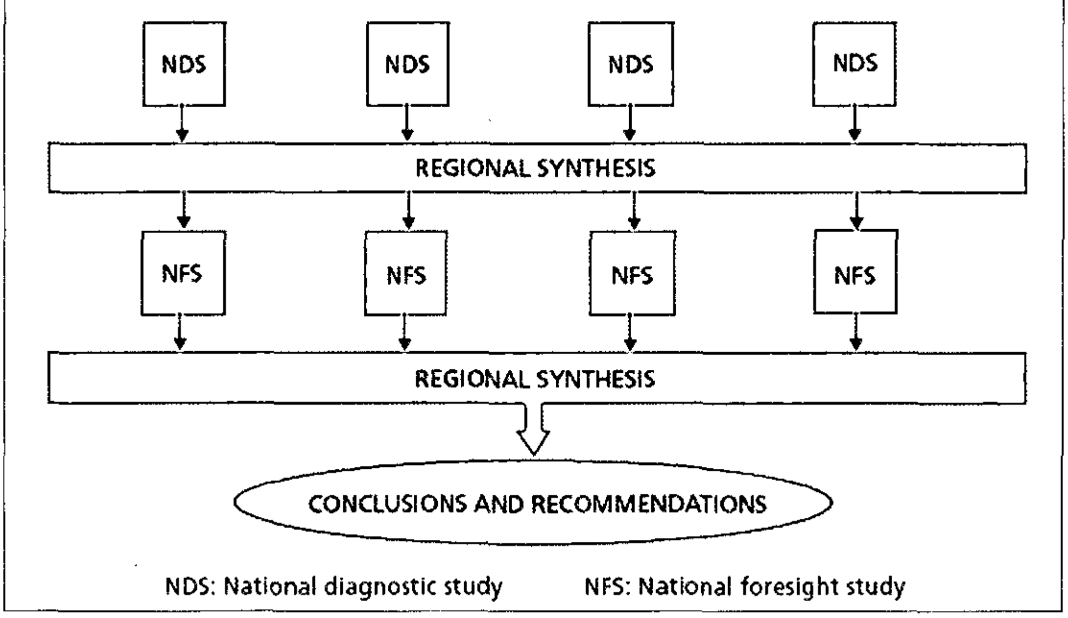
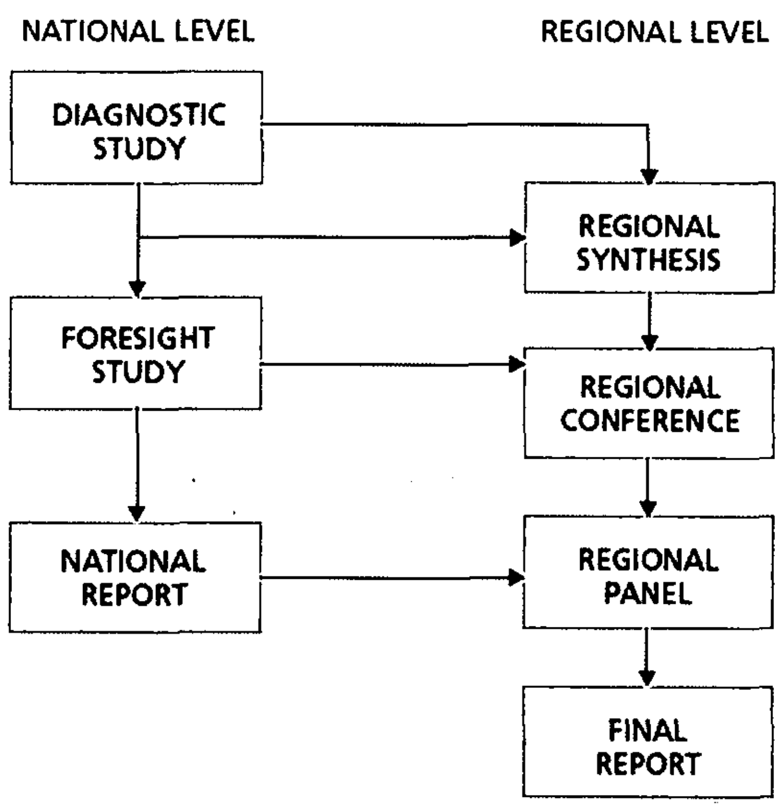


Figure 2 shows the activities at the two levels, national and regional (supra-national).

Figure 2. Implementation of the project at the national and regional levels



3.1.4. The results: technology related trends – a common vision of the future

The countries of the region (South American Pacific coast), taken together, constitute one of the world's largest suppliers of fishery products, and they are potential protagonists on the world stage in a scenario of greater demand for fish. For this purpose, it will be desirable for them, going beyond their present very valuable capacities, to give priority attention to rationalizing their area of operations, to guarantee, in the first instance, its sustainability and to obtain the maximum advantage from their catches. Taking into account the trends observed in the exercise, the first condition for achieving this result will be an effort by the countries of the region to organize fishery activities jointly, making the protection of their resources a common objective and a basis for cooperation. Such cooperation should extend to prospecting work and the exchange of experience and technologies. The capacities of the various countries differ greatly and are, in many respects, complementary, and it would seem reasonable to hope that points of convergence can easily be identified so that all can benefit.

Common objectives in the sphere of fishing are those identified in the foresight exercise:

- Diversification of operations to include new species found in the exclusive economic zone, adjacent national and international waters and deeper waters where fishing operations take place at the present time. This will require exploratory commercial fishing cruises to ascertain the potential for these species, in order to be able to guarantee their rational and sustainable exploitation with adequate organization and management measures by countries.
- Better detection of and prospecting for resources, to permit a reduction in discards and to provide a basis for the subsequent traceability of the products. This will call for the incorporation of advanced technologies–i.e. considerable investment in modernization of the fleet and fishing equipment and the training of crew members in the efficient use of the new facilities.
- Fleet modernization which will allow improvements in techniques for handling, storage and processing on board, including the necessary reconversion of fleets now devoted to fishing for indirect human consumption, for the purpose of direct human consumption. Governments will need to establish long-term soft credit lines to guarantee the operationality and profitability of this initiative. An effective training programme for crew members will also be required, taking into account the different needs and activities to be developed.

In the area of aquaculture, the first conclusion relates to the strengthening of this activity in Ecuador and Colombia, and the need for a strong expansion in Peru. In the latter country, the introduction of a national plan for the development of aquaculture is being proposed, with the participation of the public and private sectors. Ecuador and Colombia have offered cooperation, in view of their greater experience in this domain.

The objectives suggested by the trends identified in this field are:

- An effort to improve feeding patterns, a notable area of research being the possibilities for replacing totally carnivorous diets by diets including vegetable foods, of great importance for the future of shrimp cultivation, for example;
- The eradication of viral diseases through diagnostic methods and vaccination;
- The production of new species and the development of reproduction methods permitting the selection of progenies;
- The availability of seeds in adequate quantity and quality for efficient operations;
- The utilization of genetic research and development to ensure greater productive efficiency and an improved yield.

In the processing industry, the following objectives are foreseen:

- The incorporation of advanced conservation technologies, such as modified atmosphere, "active" packaging or, potentially, irradiation technologies. All these developments, especially the last-mentioned, are subject to external conditions that may hinder their materialization. In any event, conservation technologies are a key factor for competitiveness in this sector.
- The development and introduction on international markets of new products, among which mention may be made of those resulting from the use for human consumption of species previously utilized for the production of meal and oils, fish derivatives with a higher value added and degree of handling and products related to the use of the different parts of the fish and of residues for other sectors, such as tanning or the chemical or pharmaceutical industry. This will significantly improve the economic efficiency of marine products, but there will also be very positive effects for the environment.
- The modernization of production processes through the incorporation of new equipment and new methods. This will give rise to needs for financing and the training of human resources.

Together with these sectoral aspects, there are certain topics, which affect the whole productive chain and are of great importance in guaranteeing its overall competitiveness and efficiency.

The first aspect is the quality necessary for access to international markets and the product traceability that these markets require or will require in the future as a result of the international standards established, inter alia, by the Codex Alimentarius and FAO.

Secondly, there is a need to protect the environment at all stages in the production of fishery and aquaculture products.

Thirdly, there is the need for the training of the personnel involved in the production chain, who must adapt to the use of new techniques and also (and more important) be made duly aware of the delicate questions of safety, for themselves and for others, and of respect for the environment.

Lastly, both in Ecuador and in Colombia a desirable objective is considered to be increasing the consumption of fish products among the population so as to reach at least the average level for Latin America, which in any case is considerably below the average world consumption level.

3.1.5. The results: policy and strategies to implement this common vision

The study resulted in the identification of trends of evolution, possible and probable, with a view of defining objectives and making decisions for medium and long-range actions. The final report of the study, corroborated by the Second Regional Conference of the Technology Foresight study on the fishery industry productive chain in the South American Pacific coast, 25-26 May 2005, Manta, Ecuador, identifies a series of recommendations for follow up actions and projects for the development of the fishery industry in the sub-region. The Technology Foresight study at the regional level has contributed to raise awareness and build consensus and agreement among the key stakeholders to conduct these transformations in a sustainable manner. The high authorities from the countries participating in the foresight study on the fishery industry indicated their commitment in applying the results and recommendations in their policy framework, both national and international.

The participant countries agreed to follow the recommendations of the study in their strategic decisions and specifically to pursue:

- Definition of a regional policy for strengthening the competitiveness and sustainability of the fishery production chain
- Technology up-grading and investment promotion for re-conversion and modernization of the industrial fishing and fish-processing vessels
- Creation of new regional center for capability building on fishery industrial technologies and technology watch/road mapping
- Implementation of policy and infrastructure for establishing a quality mark of origin for the fish products of the region, taking into account tradability and traceability.

3.2. Future of the Food industry in six countries of CEE – towards higher food quality and safety

Project title: Healthy and Safe Food for the Future - A Technology Foresight Project in Bulgaria, Croatia, Czech Republic, Hungary, Romania and Slovakia (FutureFood6)

3.2.1. Project description

Food quality and safety are crucial aspects of human life and are, therefore, prime policy objectives of the EU. Food quality and safety have to be secured through regulations with regard to inputs, production processes, outputs, transportation, storage, packaging, labelling, documentation of origin and the like, for creating an adequate infrastructure for food markets and their smooth development. The food industries in the CEE are undergoing sweeping ownership, technological, organizational and financial changes. The new decision-making processes should put a strong emphasis on safety and quality standards. Substantial changes in financial services, wholesale markets, commodities exchange, price information, transportation facilities and infrastructure are also needed.

A foresight process is highly instrumental to tackle these complex issues. By bringing together the relevant stakeholders with their wide range of expertise and accumulated skills it is possible to identify emerging technological and market opportunities and threats, consider S&T and socioeconomic factors in their entirety, and thus devise appropriate policies and strategies, based on consensus among these stakeholders.

The objectives of the project are as follows:

a) To promote a new decision-making culture among managers and policymakers in order to put quality and safety issues into the centre of the total food chain management.

b) To identify future key technologies and new business models to promote the quality and safety requirements in food production, by establishing a Food Quality and Safety Platform in CEE countries.

The ultimate goal of the project is to assist the total food chain in Central and Eastern European countries to reach international quality and safety standards, and in turn, to enhance European competitiveness as a whole by developing an industry, which is synonymous with safety, diversity, sophistication and products of high quality.

3.2.2. Methodology

The methodology used in this project is based on different foresight tools. The key axes of this methodology are:

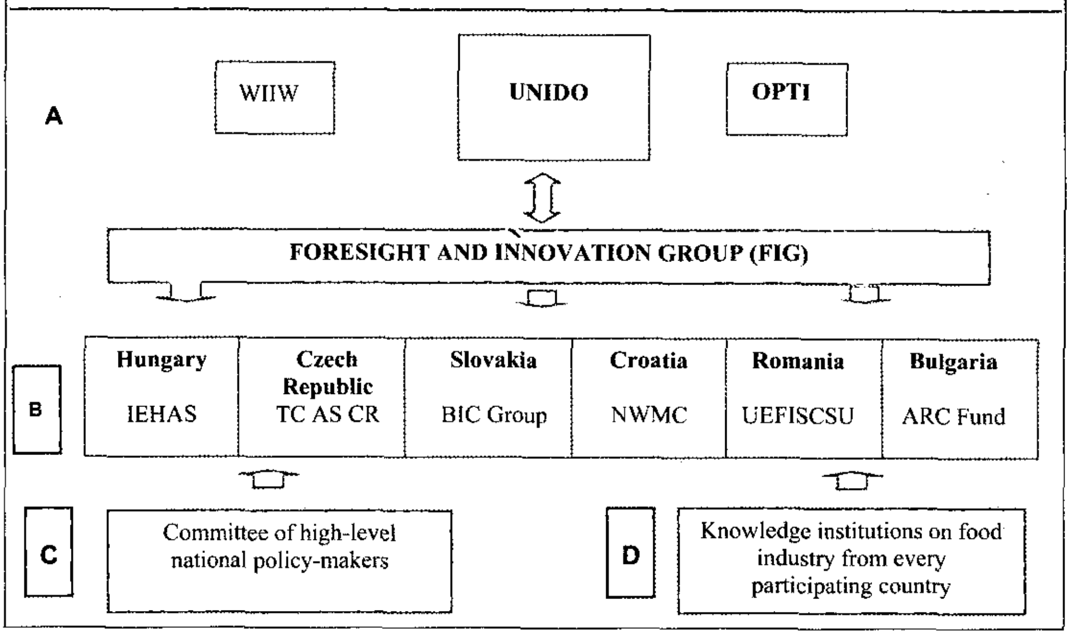
- *Mobilization* of a variety of stakeholders groups with experience in relevant science and technology fields, business, societal issues and policymakers from Bulgaria, Croatia, Czech Republic, Hungary, Romania and Slovakia to share their assessment and expectations of the future of the total food chain in these countries.
- *A socio-economic scenario building exercise* to collect the views of consumers and other societal groups concerned with the food industry and the impact of different technologies. This exercise also identifies the major drivers for the food chain.
- *Interviews* with specialists from different disciplines and affiliation (industry, academic institutions, public authorities, etc.). The goal of these interviews is to gather information about the current situation of the sector, the industry needs, problems and future prospects.
- *A survey on key technologies* to address challenges associated with the future of the industry. A special attention is devoted to identify and analyse all aspects relevant to food quality and safety. Traceability and sustainability issues are of specific concern throughout the project.
- *Vision building exercise* to depict multiple possible future states, based on the views, experience and aspirations of stakeholders, consumers and other societal groups, business people, researchers and policymakers.
- *Technology road mapping* to consider in the detail S&T implications of possible future states and identify appropriate actions to exploit opportunities and alleviate threats.

3.2.3. Project implementation

The project is fully financed by the European Commission through the Sixth Framework Programme (FP6).

The project team consists of the different participants as seen in Figure 3. Participants at level A and B are consortium members (partners).

Figure 3. Project Team



A. The project coordinator is the United Nations Industrial Development Organization (UNIDO). The project coordinator counts on with the support of two advisors:

- Methodological Advisor: *Fundación Observatorio de Prospectiva Tecnológica Industrial* (OPTI).
- Economic Sector Advisor: The Vienna Institute for International Economic Studies (WIIW)

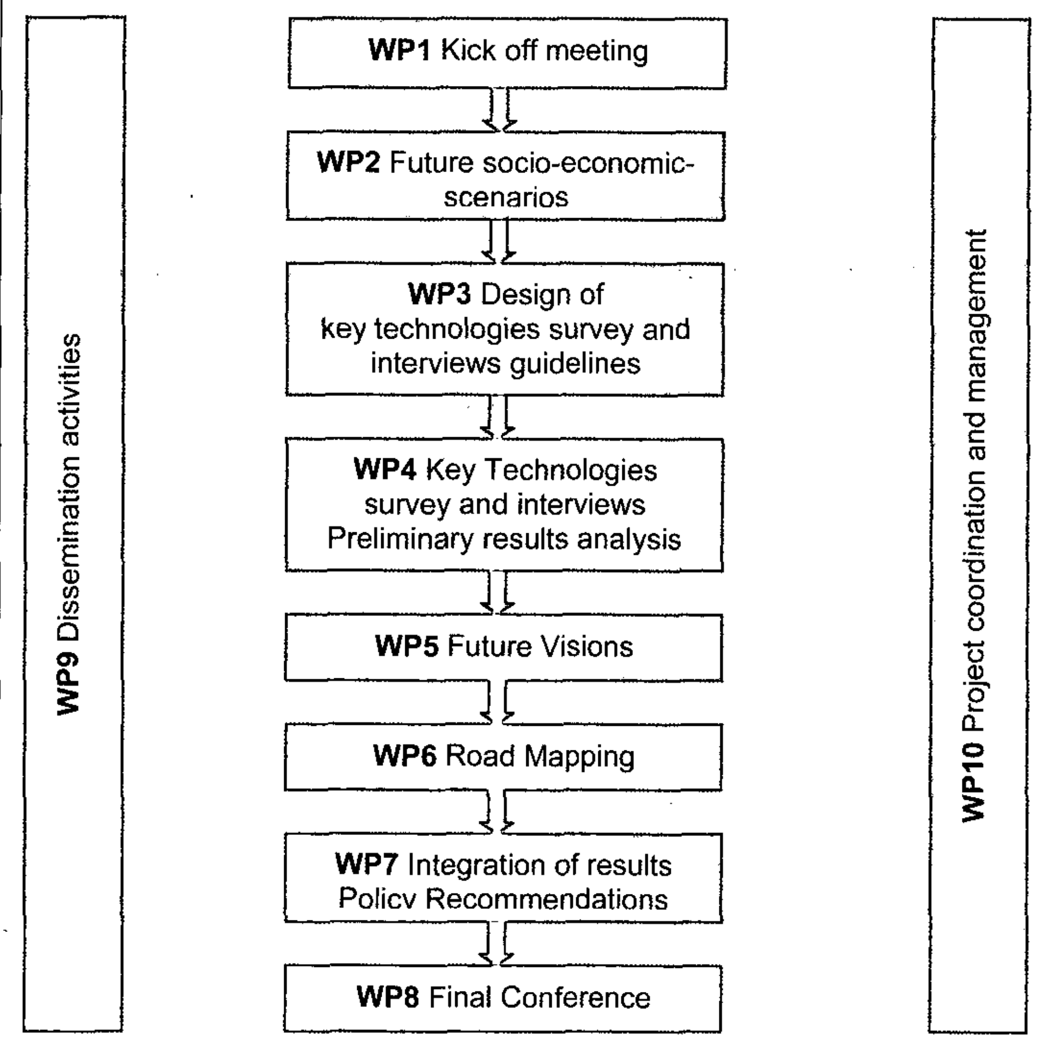
B. A group of partners constituted as the Foresight and Innovation Group, experts in Technology Foresight and Innovation, are responsible for the core project activities. The institutions of this group are also responsible for the implementation of the project in their own country. The following institutions constitutes this group: The Vienna Institute for International Economic Studies (WIIW), Austria; Institute of Economics, Hungarian Academy of Sciences (IEHAS), Hungary; Technology Centre of the Academy of Sciences CR (TC AS CR), Czech Republic; BIC Group, s.r.o. (BIC Group), Slovakia; National Wholesale Market Company Inc. (NWMC), Croatia; Executive Agency for Higher Education and Research Funding (UEFISCSU), Romania; and Applied Research and Communications Fund (ARC Fund), Bulgaria.

C. Committee of high-level national policymakers is set up with one representative from each participating country. This committee advises the partners on major policy related issues and guarantees the use of the project findings in policy formulation exercises.

D. A knowledge institution on food industry from each participating country supports the national FIG member in all phases of the project. They provide expertise and assist in the identification of experts for the consultation exercises (questionnaires and interviews).

The implementation plan consists of a set of work packages that are closely linked with each other. A responsible partner, either the project coordinator or other partner within the Foresight and Innovation Group, leads each work package. The duration of the whole project will be 24 months until the final conference, including the final reports. Figure 4 represents the work packages and their sequence and linkages.

Figure 4. Workplan flowchart



3.2.4. The results – socio-economic scenarios building

The project is under implementation and is expected to be finalized on January 2009. The interim deliverables can be found at the project web page: http://www.futurefood6.com.

As an important result at the present stage, for illustration, it could be presented the *basic construction of socio-economic scenarios. Through scenarios building* workshop and expert consultations, the project defined the four scenarios which will be used for the definition of the key technologies to be further exploited in the project.

The scenarios building exercise used four sets of future trends: social, macroeconomic, technological and geopolitical, to be evaluated in terms of their impact on the agrifood industry of selected countries and their uncertainty level with regards to their final materialization. With this information, the project developed four future scenarios for the sector: A. Consumer paradise; B. multinational golden pond; C. consumer nightmare; D. Same old story. Figure 5 and 6 indicate the graphical distribution and content of the scenarios, which will be further elaborated.

Figure 5. Definition of the scenarios axis selection

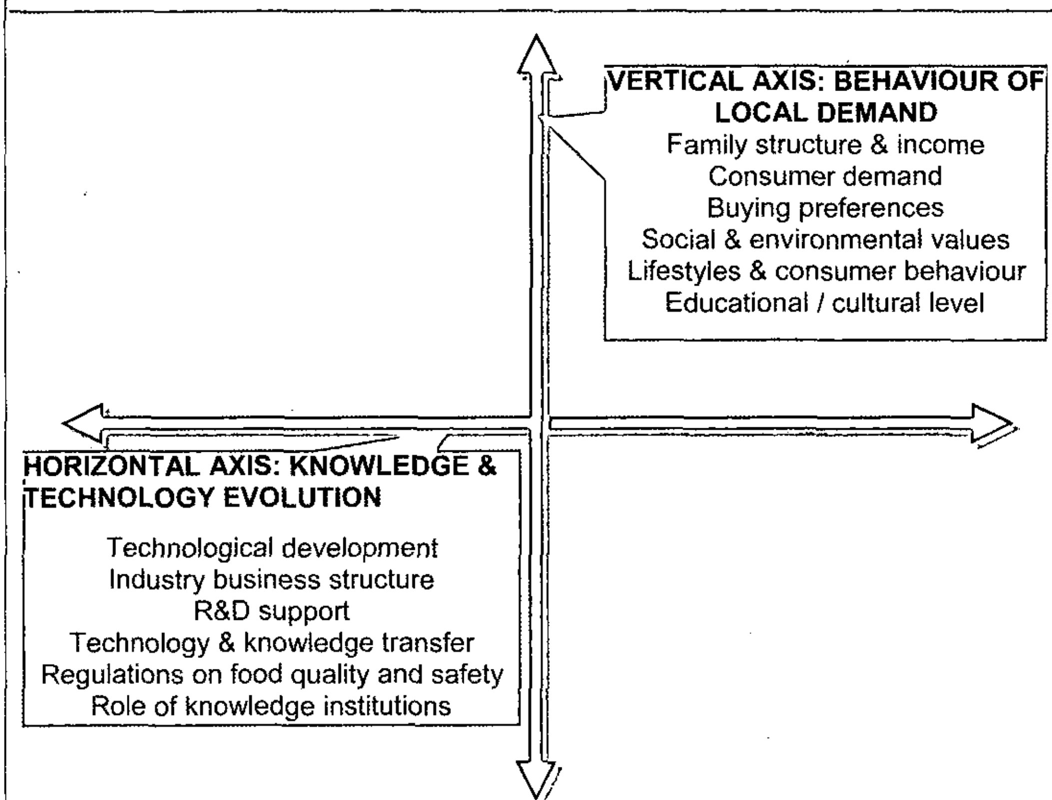
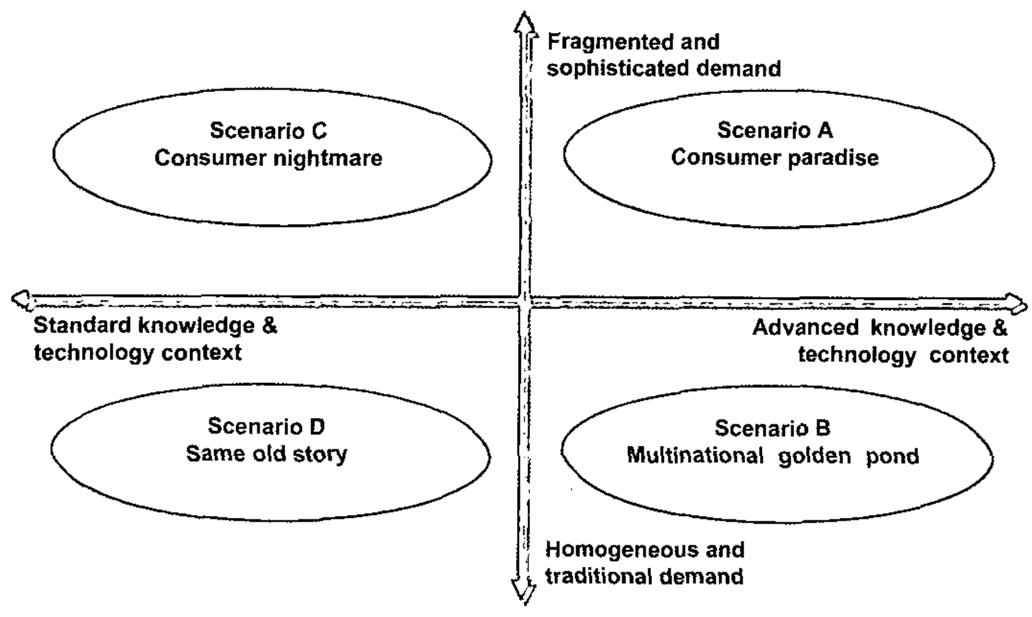


Figure 6. Scenarios design



The scenarios defined in the project can be characterized as follows:

<u>Scenario A: Consumer paradise</u>

- Technological dynamism expands the supply of food products.
- Development of disruptive technologies leads to advanced products concepts which are introduced in the market.
- Technology levels within the industry are rather high.
- Advances in process technologies increase food quality and safety and makes sustainable production feasible.
- Industry is structured in a flexible way allowing a rapid reaction to changes in demand.
- Trust between enterprises.
- Strong public and private R&D support creates a favourable environment for innovation.
- Highly fragmented and sophisticated demand. Demand-driven markets. Stronger sensitivity to quality than to price. Deep understanding of consumers choice behaviour.
- Wide acceptance of ethnic food and cuisine. Food expenditure linked to social status.
- Diverse lifestyles with specific food preferences. Industry develops new and personalized food. Awareness towards balanced diets and healthy lifestyles. Dietary diversification.

- e-commerce practises in widespread use among consumers.
- Personalized self-relevant nutrition information is available to consumers. Complete traceability of products is a must. Effective interaction with consumers.

Scenario B: Multinational Golden Pond

- Technology breakthroughs in several fields of knowledge. Innovation mainly driven by costs reduction. Competitive low-cost producing and processing food. Low product diversification.
- Controlled expenditure of consumers. Price concerns win the battle against quality issues. Consumer requirements for food quality, health & safety exist but not to very strict levels.
- Low penetration levels of ICT into consumers. Low levels of interaction with consumers. Traditional distribution channels.
- Environmental awareness only arises during climate crisis.
- Supply-driven markets dominated by big multinational corporations. Companies have the power to induce behavioural change in consumers.
- Available critical mass for undertaking extensive global food & nutrition research.
- Diverse but mass segments of consumers.
- Strong public role in regulatory affairs.

Scenario C: Consumer nightmare

- High consumer awareness about environmental and social issues. Strong requirements for food quality and safety.
- Absence of a regional regulation. Increased production costs and slow procedures.
- Failure of tech. breakthroughs. Mismatch between technology demand and supply.
- Lack of funds for food & nutritional research.
- Scarce technological innovations hinder wide access to innovative food products.
- Weak product diversification. Consumer needs are not satisfied.
- Consumers mobilization to stop multinational dominance of food markets.
- Industry has not quick reaction capacities to changes in demand.
- *Satisfaction of local demands through local production.*
- Proliferation of small food business operating as isolated islands.

Scenario D: Same old story

- Failure of disruptive technologies development.
- There are only incremental innovations which do not solve critical issues within the industry. Low technological levels in the sector.
- Very homogeneous demand in large parts of the world. Supply-driven markets. Low product diversification. Business models based in mass production procedures.
- No interaction between the industry and consumers.
- Price driven consumer buying preferences.
- Weak implementation of sustainable systems for food production.
- Industry pays little attention to small consumers groups and focus marketing strategies in large segments.
- Traditional distribution channels. Proliferation of intermediates. Increased prices to the end user.

References:

Foresight Study on the productive chain of the fishery industry in the region of the South American pacific coast- Final summary report. United Nations Industrial Development Organization, 2006.

The future of Medicinal plants in the Andean area (http://www.unido.org/doc/56615).

Healthy and Safe Food for the Future - A Technology Foresight Project in Bulgaria, Croatia, Czech Republic, Hungary, Romania and Slovakia (FutureFood6) (http://www.futurefood6.com).

Regions Foresight in Europe – The Case of Wallonia

Françoise Warrant

Abstract

Where, when, with whom and in which temporal horizon is technology foresight organized in Wallonia? What are the results of technology foresight exercises ? To answer to those questions, this paper offers an insight on the most relevant practices related to technology foresight during the last years in three different fields of the regional policy (R&D policy, industrial policy and employment policy). Even if pure technology foresight is rather limited in Wallonia, the paper indicates its function and also its distribution and embeddedness across many initiatives. Technology foresight tends to become progressively a transverse concern, cross-cutting several regional administrations and agencies, as well as different sectors. Nowadays, technology foresight also reaches regional industrial and employment policies. By the same time, the process of technology foresight becomes also fairly decentralized.

Beside technology foresight practices, Wallonia has also accumulated a huge experience in territorial foresight which offers an interesting complement to technology foresight in order to provide solutions to relevant problems for a region.

Keywords

Regional policies; technology foresight; territorial foresight; key technologies; clustering.

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Biographical Notes

Françoise WARRANT, director of research at the DESTREE INSTITUTE, holds a master degree in Law. She is specialized in evaluation of R&D and innovation policies. She has professional experience from academia and European administration (DG Research- FAST Programme in the early '90). Her research and publications address technology assessment, technology foresight, innovation in services, and sustainable innovation. Françoise WARRANT is the (co-)author of several books, notably : with Valenduc G., *La société à l'épreuve de la technologie, dix ans de sensibilisation aux enjeux de la recherche et du changement technologique,* (FTU, 2002); *Favoriser l'innovation dans les services, un rôle pour les pouvoirs publics* (Paris, L'Harmattan, May 2001); with Thill G., *Plaidoyer pour des universités citoyennes et responsables,* (coed. Presses Universitaires de Namur and FPH, 1998 – translated in

Greek); *Le déploiement mondial de la R&D industrielle, facteur et garant de la globalisation de l'économie*, (Office for official publications of the European Communities, 1993.

1. The Multidimensional Role of Technology Foresight

As a preliminary remark, we would like to point out the broad scope of technology foresight. As mentioned in 2002 by a high level group of experts working for the European Commission[1] on the role of foresight, "the term of "Technology Foresight" can be - and has been - misunderstood as dealing only with specific technologies in a very narrow sense. This report, however, uses the term "Foresight" to emphasize that the future is determined by interaction between technology, science and society."

In 2005, the European Commission (DG Research) has also commissioned another expert group to explore the issues of Key Technologies for Europe (at the horizon 2015/2020). This group highlighted foresight's multidimensional role:[2]

- "Foresight provides a new arena/space where policy and investment decisions are discussed and in which futures are contested (...);
- Foresight's outreach role of bringing about broader stakeholder participation, engagement and learning in the communication of longer term issues and the building of consensus on the most promising areas;
- Foresight plays an important role as "coordination device" of collective strategy development for realizing system innovations in society, by aligning the individual strategies of the variety of industrial, research, policy and societal actors when they are geared towards long-term objectives that cannot easily be achieved through market mechanisms;
- Foresight provides the tools (scenario-building, road mapping) for tackling key problems and issues by developing different plausible scenarios against which R&D action and roadmaps are tested (...);
- Foresight provides insights into decisions related to strategic funding of R&D in relation with emerging opportunities and niche areas;
- Foresight helps to identify the major trends and drivers (technical, political, societal and economic) shaping the future and influencing the medium to long-term environment of key technologies (...)".

The importance of deliberation is also stressed by von Schomberg, Guimarães Pereira and Funtowicz.[3] For these authors, the quality of foresight-knowledge depends on deliberative procedures. These deliberative procedures at the interface between science and policy ensure an adequately balanced knowledge input.

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[1] High Level Expert Group for the European Commission (September 2002), *Thinking, debating and shaping the future : Foresight for Europe, Final report prepared by a High Level Expert Group for the European Commission*, European Commission, Directorate-General for Research, Unit RTD-K2, , p.17

[2] Key Technologies Expert Group (2006), *Creative system disruption towards a research strategy beyond Lisbon*, synthesis report, Directorate-General for Research, Scientific and Technological Foresight, Luxemburg, Office for Official Publications of the European Communities, EUR 21968, p.49.

[3] Von Schomberg R., Guimarães Pereira A. and Funtowicz S. (November 2005), *Deliberating Foresight Knowledge for Policy and Foresight Knowledge Assessment*, Luxemburg, Office for Official Publications of the European Communities, EUR 21957.

Table 1. Multiple functions of technology foresight

Multiple functions of technology foresight
- Provision of tools
- *Provision of insights related to emerging opportunities and niche areas*
- Identification of trends and drivers shaping the future
- Arena for discussion and deliberation
- Bridge between several stakeholders
- *Coordination device of collective strategy development*

One has to keep in mind all these functions of technology foresight when considering at the case of Wallonia (Belgium). Wallonia is a Region of 3,380 millions inhabitants, located in the Southern part of Belgium, between the German and French borders. It covers 16.844 km2 whereof 87,7 per cent consist of rural areas and forests.

2. The Regional Context

2.1. Regional competencies

Wallonia is one of the three Regions that make up the Federal Belgian State, the other two being the Flemish Region and the Brussels-Capital Region. The French Community is one of the three Communities which compose the federal Belgian state, the two others being the Flemish Community and the German-speaking Community. The regional competencies consist of : regional aspects of the economic policy, scientific research relating to regional matters, employment policy, environmental policy, agriculture, regional aspects of the energy policy, spatial planning, housing, public works, transport, foreign trade, supervision of the local authorities, property belonging to the various religious groups, international relations relating to regional matters. The Community matters concern education, social affairs, cultural matters, and language use.

Within the highly federalized Belgian research system,[4] governmental competencies in the STI area are arranged as follows:

- the Regions (Flanders, Wallonia, Brussels-Capital) have authority on research policy for economic development purposes, thereby encompassing technological development and applied research;
- the Communities (French-, Flemish-, and German-speaking) are responsible for education and fundamental research in universities and Higher Education Establishments;

[4] For more details, see *Erawatch Research Inventory Report for Belgium*, European Communities, 2006, <http://cordis.europa.eu/erawatch/>.

- the Federal State retains responsibility for research areas requiring homogeneous execution at national level, and research in execution of international agreements (e.g. space research).

The main responsibility for R&D policy and funding lies therefore within the Regions and the Communities.

2.2. Regional economy at a glance

Belgium is a highly-industrialized country that has long had one of the most open economies in the world with extremely high export rates reaching 70 per cent of GDP[5]. Belgium preserves its position of 10th exporter of goods in the world. In addition, the share of foreign direct investment or control on domestic production exceeds 50 per cent in most parts of the country. Its geographic position at the heart of the European Union has allowed it to benefit from inflows of business- and government-related services.

In Wallonia, perhaps more than everywhere else in Europe, innovation and technological development constitutes a major challenge of the redeployment of regional economy. During decades, our products were recognized as being highly technical, although they concerned to a large extent sectors now considered as traditional.[6]

The regional economy is also heavily and increasingly based on services (at more than 70 per cent).

2.3. Regional innovation system

In mid-2006, the Science Policy Council of the Walloonian Region[7] published an evaluation report[8] focused on the situation of R&D and innovation in the region. Interestingly, it shows that nearly three-quarter of research is conducted by companies. The share of the public sector as an operator of R&D is particularly weak in Wallonia. Industrial research is strongly concentrated in some large High Tech sectors (life's sciences, chemistry-pharmacy, aerospace, telecommunications, computer operations). It is financed in major part by the companies themselves, although relatively important public appropriations are devoted to that. An important proportion of industrial research is carried out by some (very) large companies. This concentration could be seen as a weakness of the Walloonian system of research. The

[5] Service public fédéral Economie (novembre 2006) , P.M.E., Classes moyennes, *Panorama de l'économie belge 2006*, Brussels.

[6] van Overbeke M.(2005), *Les politiques de recherche et d'innovation aujourd'hui*, Working Paper 05-01, Federal Bureau of planning, Brussels.

[7] The CPS is a consultative body linked to the Economic and Social Council of the Walloon Region. The CPS advises the Walloon Government on science, research and technological development. It is composed of the social partners and representatives of various research groups (universities, high schools, public research centres, etc) and the regional administration DGTRE.

[8] Graitson D.(June 2006), *La R&D en Wallonie: état des lieux et perspectives*, Conseil wallon de la Politique Scientifique.

more traditional industrial branches, which still constitute an important side of Walloonian productive system, are lagging behind from this point of view.

The report also pinpoints as an area of concern the trends in terms of science and engineering graduates: currently Wallonia has a relatively good potential regarding the share of R&D personnel in the active population,[9] showing figures above the EU average. However, trends in graduates and registration for science and engineering courses are negative or stagnating and life-long learning participation is insufficient.

Commercialization of research, notably in the form of high-tech spin-offs, is also an acknowledged weakness despite some recent improvements, the causes may be due to insufficient seed and start-up capital, according to the Science Policy Council's report Over the last years, regional public RTD policy has put emphasis on the exploitation of public research outputs in the economic sector and enhancement of technology diffusion in companies. The process of transferring technologies to more traditional SME's has required more attention. Recent initiatives to create a more effective system of science and technology intermediaries, e.g. through the creation of the Walloonian Agency for Technology Stimulation may help in this respect.

In Wallonia, the main instruments for R&D policy include:[10] support for R&D activities within enterprises through R&D subsidies and loans, specific subsidies for SME's including for feasibility studies and for hiring innovation personnel, the "FIRST" programmes with the aim of improving human mobility between universities and enterprises. On the public research side, instruments include: funding grants for research on initiatives within universities and research centres, subsidies for technology development activities in research centres, notably through the support of technology guidance activities. Furthermore, there exist grants under the "mobilizing programmes" for R&D in enterprises, research centres and universities in areas of specific regional importance. New type of support for research-industry consortiums is organized around key sectors (see infra). University interfaces are funded by the Region in their role of "research valoriser" and with respect to their activities in IPR management. A significant additional effort has been made by the government of Wallonia since 2005 through the so-called "Marshall Plan" which injected some 270 million € of additional funding for R&D and innovation over a four-year period 2006-2009.

2.4. Regional governance

Since 1999, the intensity and the quality of policy-making practices in Wallonia has undoubtedly improved through the development of a strategic and region-wide planning process within the framework of the "Contract for the future of the Walloons". This planning and consultation process has gone through several rounds[11] and the latest version was adopted on 20 January 2005 by the Government

[9] See Fiers J.(2005), « Innovation et R&D dans les régions belges dans une perspective européenne », *Working Paper* 13-05, Bureau fédéral du Plan, Juin 2005.

[10] For a detailed description, see *Erawatch Research Inventory Report for Belgium*, European Communities, 2006, p.6.

[11] The Contrat for the future of Wallonia (Contrat d'Avenir pour la Wallonie) adopted in 1999 and

of Wallonia. The Contract is structured around six broad objectives (each with a quantified target) and nine broad measures. Moreover, the Government has followed one of the recommendations of the evaluation of the previous round by structuring the implementation in the form of four strategic cross-cutting plans: creation of activity, maximizing human potential, social inclusion and balanced territorial development. The first and second of these strategic transversal plans (*'Plans stratégiques transversaux'* - PST is the French acronym), are more directly relevant for innovation policy.

3. Technology Foresight in Wallonia

Where, when, with whom and in which temporal horizon is technology foresight organized in the Walloon Region? What are the results of technology foresight exercises? To answer to those questions, let us investigate three different fields of the regional policy: R&D policy, industrial policy and employment policy. In these three areas, what have been the most relevant practices related to technology foresight during the last decade?

3.1. R&D Policy

3.1.1. 40 Key technologies for Wallonia – Prometheus I

The Regional Innovation Strategy programme called PROMETHEE I, co-funded by DG REGIO under Article 10 of the ERDF, was an important opportunity to conduct a foresight exercise. Within the framework of the Prometheus project aiming at stimulating the dynamics of innovation in Wallonia, the Directorate-General of Technologies, Research and Energy[12] (*Direction Générale des Technologies, de la Recherche et de l'Energie* –hereafter called DGTRE), launched several programs simultaneously over these last years. First of all, it was carried out in 1999-2000 as an exploratory study on the technological fields of the future for Wallonia which led to the identification of the "40 key technology fields for Wallonia by 2010". The foresight study,[13] led by the consortium ECCE (F)/ LENTIC (B), was based on a methodology developed for international work having similar objectives (in particular in France) as well as on a broad interactive consultation of the Walloon actors and with the help of international experts.

The exercise, primarily based on the needs and the potential of the Walloonian companies, did not claim to cover the entire scope of the field of research. This approach was considered indeed as not adapted at the stage of fundamental research. The creativity of the researcher and the exploration of completely new fields cannot be limited by too targeted policies.

the updated version adopted in 2002 (the "CAWA").

12 One of the 6 directorates of the regional administration.

13 Ministère de la Région wallonne (2001), *Les 40 technologies-clés pour la Wallonie, Les domaines technologiques du futur pour la Wallonie à l'horizon 2010*, étude réalisée dans le cadre du projet RIS/Prométhée avec le soutien de la Commission européenne, Direction générale des Technologies, de la Recherche et de l'Energie, Jambes.

This analysis was carried out in technological terms of fields. The goal was to position technological competences which are often transverse and to find applications in several sectors. Nevertheless, the sectoral analysis remains an essential tool to highlight existing economic opportunities in these sectors of application. This is why work relating to the key technologies was supplemented by an examination of the growth potential of the Walloonian sectors, based on the study of performances of our economy in terms of production, employment and export during last years. This work revealed the existence of branches already well established or in emergence, offering promising prospects and located in the following sectors: food industries, pharmacy, chemistry, materials, equipment goods, textile, edition and printing works, transport and computer operations.

The crossing of the results of these two studies, by offering a thorough vision of the technological and economic aspects of regional productive fabric, made it possible to identify strategic fields in which specific actions are desirable. A matrix, specific to Wallonia, has been built on this basis, which highlights the regional strategic sectors, identified by the analysis of the structure and the recent dynamics of economic base and of the key technologies which referred to it. These interactions were numerous, several key technologies being potentially applicable in each sector. It offered a synthesis of what could (or would have) be the technological request of Walloonian industry during the next ten years, in the same manner that it highlights certain elements of its capacity of technological offer. In addition, it clearly emphasized technologies which play a part in the development of basic, essential sectors and those which find applications in sectors carrying growth.

The purpose of this stage was to provide a tool for decision-making to all the actors concerned with research and innovation: public authorities, companies, research centres and universities. There was no question of leading the research projects. Creativity remains the driver, particularly at the stage of fundamental research (not covered by the exercise). Afterwards, it was the task of the various interested parties to seize these results, to analyse them and to draw some conclusions for their own action plans. At the level of the Walloonian Authorities, the fields identified as key are expected to constitute a source of inspiration for the setting up of 'mobilizing actions'.

The identification of the 40 key technologies has three ambitions:

1. Being a tool for positioning for the whole of the actors of research and the innovation;
2. Being a window for the Walloonian technological potential;
3. Being a foresight tool to highlight public policies of regional development.

Table 2. 40 key technologies for Wallonia 2010

40 Key Technologies for Wallonia 2010
MATERIALS - CHEMISTRY
Non polluting surface treatments
Cleaning and scouring without effluents
New intelligent glazes
Technologies of chemical decontamination purification
Recycling of materials in the building and public works
Recycling of refractors
Materials with layers added and assembled to surface
Technologies of absorbing materials
New applications of wood material in the BTP and industry
Systems in aqueous phase
EQUIPMENT GOODS
Technologies of quality control
Eco-design and dismantling of the products at the end of their lifetime
Rapid prototyping
Intelligent sensors
Micro- and nanotechnologies in the equipment goods
Metrology applied to the environment
Technologies limiting radio electric pollution
Technologies of reduction of the noise of the transportation means
INFORMATION TECHNOLOGIES
Voice's recognition
Programming tools
Micro- and nanotechnologies in the ICT
Techniques of transmission of information
Treatment of the signal
New multi-media products
Bio-informatics
LIVING ORGANISMS TECHNOLOGIES AND AGROALIMENTARY TECHNOLOGIES
Automated sequencing of the DNA
Vaccines resulting from the genetic engineering
Recombining systems of production of proteins
Gene therapy
Microphone and nano - manufacturing in the medical sector and the diagnosis
Bio-engineering
Technological revival in the food industries
ENVIRONMENT – ENERGY – TRANSPORTATION –CITIES
Smart house
Management of water resources
Treatment and control of drinking water
Biological purification of water and treatment of muds
Techniques of waste processing
New and renewable energies
Telecommunications for the control and the management of road flows
Techniques for construction, disassembling and rebuilding

For these 40 key technologies, the consultants devoted themselves to a work of analysis and characterization, which relates to the following aspects: technology itself (description, nature, degree of maturity, sectors of application, investments); interactions with other key technologies belonging to the five groups; the current and potential market development (its size, its growth, the field for competition and intensity of competition, the identification of the actors already present on the market at the European level, the foreseeable tendencies); the position of Wallonia in the field (degree of implication, degree of autonomy of the providers and of the users of technology at the level of research and at the level of the applications, the identification of the industrial and different actors). The widespread dissemination of the results of this study took place in particular through a conference organized in the beginning of 2000, allowing for a debate between the actors mobilized throughout the study, and also through the edition of a work.

3.1.2. Technology clusters Program ('grappage technologique')

The DGTRE used the result of the Regional Innovation Strategy programme (Prometheus I, co-funded by DG REGIO under Article 10 of the ERDF, as already mentioned), and in particular, the regional technology foresight exercise which had led to the identification of 40 key technologies, to define and launch a pilot action aiming at encouraging firms to co-operate in order to develop joint research and innovation actions related to these key technologies.

The Technology Clusters programme is an experimental pilot action of the DGTRE. The overall objectives are to promote partnership and synergies amongst groups of enterprises and between the business and scientific communities; and to reinforce the innovation dynamic in enterprises through the support of new forms of partnership allowing for exchange of knowledge and undertaking of joint actions, training and commercialization, notably in terms of new product development. Two calls for proposals have been organized. The ten elected projects concern the following technology fields: Integrated and secure management of electronic documents; multimedia; industrial applications of software engineering; friction stir welding; rapid prototyping; mechatronics; recycling of refractors; digital signal processing; nutrition; application of ICT to the graphics industry.

The financial intervention of the region is extremely limited and is essentially intended to part-fund an expert or an animator for each of the clusters with the aim of putting organizational procedures into place in order to identify the interested stakeholders and assess the market and technological trends.

3.1.3. Prometheus II

Through the ERDF, the European Commission decided to co-finance the innovating Action plan of the Walloonian region named Prometheus II. This project was approved in 2003 and its implementation started at the beginning of 2004 and is continuing until the end of the year 2007. Three operators were involved: the

DGTRE, the centres of competence[14] and the Walloon Agency for Telecommunications.[15]

The DGTRE was entrusted to implement the actions focused on technological innovation. In fact, it has carried out evaluation exercises rather than foresight exercises. The programme comprises a analytical part on three aspects: identification of the fields of competence of the Walloon laboratories in applied research; evaluation of the Walloon system of scientific and technological intermediation; assessment of the means to promote quality management in the activities of research.

3.1.4. Mobilizing programmes

In Wallonia, the choice of areas to be supported, notably, through the 'mobilizing programmes' is usually made by consulting the Science Policy Advisory Council, CPS, rather than through explicit Delphi-like or other types of formal analysis and surveys.

Since 2000, through mobilizing programmes, the region follows two objectives: to reinforce the scientific potential of its universities and high schools and to develop it in Walloon industrial base. This double goal is pursued by financing applicable research projects, i.e. likely to lead in the long term to an exploitation of their results in existing or future companies. The programmes contain generally sets of themes and are focused on fields which are of great interest for Walloonian industrial base. The evaluation and selection of each project are made by two independent foreign experts. Moreover, they stress interdisciplinary collaboration between teams of research and privilege, even impose, the implication in the projects of several research institutions.

3.1.5. Collective research centres & excellence hubs

The mission of the collective research centres is to carry out applied research activities in their sector of competence and provide training, technological assistance, technological watch and dissemination of technologies to firms. In addition to those collective research centres, a number of new research and technology transfer centres[16] (*'pôles d'excellence'*) have been created, notably with the support of the Structural Funds in the Objective 1 - province of Hainaut during the

[14] Recently set up (from 2000 until now), the centres of competence are training infrastructures: they are vectors of a new technical culture for the workers, the work applicants, the companies' managers, the students, the teachers. A first series of projects aims at reinforcing accompaniment to the ICT for the (very) small enterprises. Other projects aim to develop targeted sensitizing actions related to the ICT for the work applicants and of the workers.

[15] Created in 1999, the Walloon Agency of Telecommunications (AWT) is a public agency which aim is to promote the universal access to the ICT and their generalized use. The AWT has developed within this Prometheus II programme methodological tools necessary to the reinforcement of the appropriation of the ICT by the Walloon companies and citizens, i.e. a multi-media guide, methodologically and technically innovating, available on line and suitable to the needs for Walloon SMEs and the educational sector.

[16] They differ from the collective centres on two main points: they originate from universities and not from industry; they are originally 100 per cent publicly financed – 50 per cent by EU ERDF funding and 50 per cent by the Walloon region.

period 1994-99. With respect to the existing collective research centres, the aim here was to develop and strengthen existing know-how in additional fields, namely: biotechnologies, chemistry, information technologies, telecommunication, new materials and extractive industries. Alike the collective research centres, their mission is to carry out applied research activities in their area of competence and provide technological assistance, technological watch and diffusion of technologies to firms (including training...). They are consequently an essential tool of the economic and industrial redeployment of Wallonia insofar as they contribute to the diffusion and the integration of emergent technologies in industrial base.

3.1.6. Involvement of stakeholders in R&D policy debates & Technology Assessment

During the last decade, broad consultations on R&D issues have become a more usual practice through a series of Research Meetings (1996-1997) and the Prometheus programme (1999-2001). From June 1996 to November 1997, the Council for Science Policy (CPS) and the regional administration (DGTRE) organized a series of ten one-day conferences-debates,[17] opened to the wider public. About 900 participants attended at least one of the meetings. This group was composed of members from industry, universities, public agencies and administrations, government, education, trade unions and other social organizations. Each conference was organized on the same pattern: keynote speeches, including some made by foreign experts; roundtable discussions with representatives of concerned stakeholders; discussion with the audience. The subjects of the debates were: research listening to the civil society; organization of the research system.; scope and means of R&D public financing in the region; industrial cooperative research centres; sectoral and thematic orientations of regional public research; valorisation of research results; evaluation of the impacts of R&D on society; social and cultural conditions of innovation; internationalization of R&D; role of the researcher in society. The CPS published a synthesis of the contributions and debates and issued key policy recommendations for the future of research and of technological development in the Region. The Prometheus I project described above can be considered as a follow-up initiative of this broad consultation and discussion process.

In addition, during the last ten years, the region has significantly increased its promotional efforts in scientific and technical culture, particularly focusing on young people.

In the Walloonian Region, technology assessment (TA) capacities are not that well-established. In 1994, the Region of Wallonia decided to institutionalize a consultative TA mission at the level of the Walloonian Council for Science Policy (CPS). The TA mission consisted of two tasks: to prepare opinions of the CPS on TA-related topics and to manage an experimental research programme, granted by DGTRE and subcontracted by way of calls for proposals to universities and research centres, by way of calls for proposals. A small team for TA coordination was set up under the

[17] Graitson D., *Les rencontres de la recherche*, Bulletin Athéna, no 136, décembre 1997.

authority of the CPS. Until now, the technology assessment assignment granted to the CPS has not yet reached the visibility or impact that one might have expected from a regional body experienced used to institutionalizing technology assessment.

In Wallonia, EMERIT[18] has been an original long term TA experience. EMERIT is the acronym of *'Expériences de Médiation et d'Evaluation dans la Recherche et l'Innovation Technologique'* (Experiments of Mediation and Evaluation in Research and Technological Innovation). The project started in 1992. It consisted of a mission entrusted by the Walloonian Minister of Research to a not-for-profit research called 'Technology to the Work & Technology Research Centre[19] at the *Fondation Travail-Université* (FTU). The assignments were to promote awareness and to create a favourable climate towards technology assessment (TA) in the Region of Wallonia, and to support initiatives of mediation between research and the civil society. These assignments resulted in a pluri-annual programme of activities: exploratory studies, publications, organization of public events (conferences, workshops).

As Valenduc and Vendramin stated, "the Walloon situation is paradoxical today because whilst expertise is growing in several research centres in the "technology and society" field, regional initiatives on TA institutionalization are more or less at a standstill".[20]

3.2. Industrial policy

Competence for innovation policy matters within Wallonia is shared between the R&D policy on the one hand (industrial research and technological innovation) and economic policy on the other (investment support to enterprises, foreign investment, start-ups and cluster policy, etc.). Let us have a look on the technological component of the clustering policy and on the competitiveness policy.

3.2.1. Economic clusters

In January 2000, the Government of Wallonia fixed support to the development of networks of companies among the priority measures of its *Contract for the Future* for the Region. At the same time, awareness and support actions to clustering were included in the 2000-2006 programmes of the phasing out of Objective 1 (Hainaut), Objective 2 urban (Liège) and Objective 2 rural (Namur and Luxembourg).

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18 Valenduc G., Vendramin P. et Warrant F., *La société à l'épreuve de la technologie, dix ans de sensibilisation aux enjeux de la recherche et du changement technologique*, FTU avec le soutien de la Région wallonne, mars 2002, ISBN 2-9300062-18-5.

19 FTU was selected as the host institution of EMERIT because of its experience in research on technology and society, and its close cooperation with social organizations.

20 See Felt U. (ed.) and alii, *Opening public understanding of science and technology - Final report*, European Commission, June 2003.

The Clusters programme was launched[21] between July 2001 and March 2002 and extended in 2003, on the basis of an initial positive assessment of the pilot actions. These 'economic clusters' have been defined as: "an organizational approach of the production system based on the initiative of the companies (with, if need be, the participation of research centres) and characterized by a co-operation framework encompassing related activities; the voluntary development between the companies of a complementary relationship, vertical or horizontal, profit or non-profit, the promotion of a common vision of development". A recent decree formalizing the relationship between the regional authority and 'clusters' as beneficiaries of support measures has been adopted by the region on 17 January 2007.

Between 1999 and 2004, The Destree Institute has conducted an important foresight exercise on behalf of the Government of Wallonia and its Administration. The *Foresight Mission Wallonia 21*[22] was conducted with the task of encouraging the study and production on a regional scale of foresight views and action programmes in the framework of Wallonia's *Contract for the Future*.

Twenty actions were identified in this context to make of Wallonia an area of knowledge, learning and creativity, described here, constitute a result of the Foresight Mission Wallonia 21. The setting up of an economic cluster of creativity was strongly recommended. This would have to associate partners of cultural industries, designers, artistic teachers, etc. One of the most productive axis of innovation consists of uniting people or teams which generally do not work together. This cluster of the economic creativity is intended to generate new employment and to reinforce the economic activity by the development of the growth, the vitality and the competitiveness of Wallonia. It would reinforce the bonds between technologies and the creativity. Unfortunately, until now, this recommendation has not been followed by any public decision.

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21 In July 2000, MERIT (University of Maastricht) and Ernst & Young France issued a report financed by the Minister of the Economy and the Economy Policy Division (DGEE/DPE). This report confirmed the interest of the cluster concept for a large panel of Walloon companies from different sectors of activity and examined how the Region could support the clusters. The private initiative should be the prime mover of the appearance and development of these clusters, the Region operating as a catalyst by supporting the early stages of setting-up and consolidation. This report is downloadable on this website: <http://clusters.wallonie.be>.

22 Three reports were published:
Destatte Ph. (ed.) (2002), *Foresight Mission Wallonia Wallonie 21, Wallonia tuned in to Foresight, First Report to the Ministre-President of the Government of Wallonia*, Charleroi, The Destree Institute.
Destatte Ph. and Van Doren P. (ed.) (2003), *Territorial Foresight as a tool of Governance*, Charleroi, The Destree Institute.
Destatte P. and Van Doren P. (ed.) (2004), *Foresight Mission Wallonia 21, Foresight tuned into Wallonia*, Charleroi, The Destree Institute.
These reports are available on line : <http://www.wallonie-en-ligne.net/Mission-Prospective_Wallonie-21.htm>.

Foresight for enterprises in Wallonia[23] has also been conducted by the Destree Institute in 2002-03 at the request of the Minister for Economic Affairs of the Wallonia Government, within a global dynamic called *4X4 for Entrepreneurship.* The aim was to redefine the regional support policies for companies, by taking into account the stakes and challenges on the horizon of 2020. The task went ahead mainly in conjunction with company directors, the Walloonian Union of Enterprises and experts from business circles. Through this foresight exercise, the participants strongly emphasized the need for competitiveness clusters.

3.2.2. Competitiveness Hubs

Within the framework of its "Marshall Plan", the Government of Wallonia has initiated a "Competitiveness Hubs policy", which aims at developing leading regional sectors of activity which have the capacity to reach a high level of excellence, thereby generating a new move for growth and allow to position Wallonia at the international level.

A new measure, introduced in 2006 '*Pôles de Competitivité*' fills the gap by focusing on the relationship between businesses and research institutions. Competitiveness poles policy will complement the Clusters approach developed since 2000. Whereas the clusters were financed to drive a network of enterprises and to promote innovating partnerships, whether industrial, commercial or technological, here, the Competitiveness Hubs are essentially supported by the region for the achievement of projects of investment, R&D or training in the wake of the competitive positioning strategy they have themselves defined. On the basis of a economic survey performed by Pr. Capron (ULB./DULBEA), the Government of Wallonia identified five sectors for which proposals for poles would be eligible: 1) life sciences 2) agro-industry 3) transport-logistics 4) mechanical engineering 5) aeronautics/space.

On 8 December 2005, the Government issued a call for proposals for the constitution of hubs in 5 those fields considered as crucial for the regional economic development. Proposals had to provide the following information: the strategy and the objectives of the hub should be defined the general strategy for the development of the hub, its work priorities (markets / technological fields) and fields of excellence, its objectives and expected results/impacts and the dedicated means; the scope and environment of the pole : a detailed map of the hub should be presented - which partners, their roles, their contributions, their competencies and respective degrees of involvement, as well as the networking of the hub. The external co-operation activities of the pole and its integration into international networks should also be described.. A comprehensive diagnosis of the hub and its prospects should be provided, covering its different components (industrial basis, R&D and innovation, training ...). The hub should be positioned with regard to the sector and

[23] A presentation of the foresight exercise has been made by Florence Hennart and Philippe Destatte to the Seminar on Foresight-Info organized by DATAR on 24 March 2005: http://www.institut-destree.eu/Reseaux/DIACT.htm. See also Destatte Ph. and Van Doren P . (2003), *Réflexion prospective sur les politiques d'entreprises en Wallonie, Rapport final*, Namur, Direction générale de l'Économie et de l'Emploi du Ministère de la région wallonne (Direction des Politiques économiques) - Institut Destrée, 50 p.

the market at the regional and international level. A multi-annual business plan must be provided, detailing the content of the concrete co-operation projects to be implemented by the hub (partners, objectives, dedicated means, expected results and their exploitation, timetable) and their financing means. The proposal should describe the formal and informal modalities to be installed to ensure the strategic and operational monitoring of the hub.

On the basis of opinions delivered by an international jury of experts, the Government selected the Competitiveness poles to be implemented. Four poles were selected and officially given the label 'Competitiveness Pole' on 14 July 2006, namely: aeronautics and space, agro-food, life sciences and transport and logistics. The labelling of the Mechanical engineering Hub has been obtained on 15 September 2006.

At a strategic level, a formal governance board will be set up by each pole, all of which will be topped by governing bodies. The coherence and the feedback will be provided by a member of the Task Force for Strategic Priority One who will serve as liaison between the governance of the poles and the task force. The private sector plays a major role as a driver of Competitiveness Hubs, in co-operation with the French-speaking universities represented within the Governance Council and ensures the Vice-Presidency of each hub. The poles will provide research work programmes to the regional authority every year.

The Competitiveness Hubs policy will be conducted as an experimental project up to 2009. An evaluation of the first poles is planned in 2008. The directorate general for research (DGTRE) and the directorate general for economy and employment (DGEE) of the regional administration have set up an ad-hoc administrative cell which plays a key monitoring role with specific responsibilities for the collection of data and development of tools to be used for evaluation and benchmarking purposes.

3.3. Employment policy

In the implementation of an active employment policy, one has to underline the important role exerted by the centres of competence regarding future qualifications. The Centres of competence provide qualifying training and improvement to the work applicants. Beyond the training activities strictly speaking, the Centres of competence intervene upstream (early-watching, information, sensitizing..) and downstream (validation of competences, improvement of the dies of insertion...). They are in charge of an early-watching mission on the evolution of the trades and the needs for training.

At the end of 2006, the regional agency for employment has released a report called 'Jobs and skill's requirements for the future'. This report is a transversal synthesis of the early-watching reports written by those various Centres of competence and is supported by reports concerned with the studies of 'ecosystems' carried out by the regional agency for employment called FOREM. Three important factors of change represented were highlighted for each industrial branch: economic, technological and legal factors. The importance of these factors varies from one sector to another in term of development of the jobs and skill requirements. The completely new jobs are rare. Generally, the worker is expected to hold more competences than before. He must have technical skills which evolve with the technologies used in the company, with the economic environment but also according to change within legislation and regulation concerning the sector. He must also show autonomy, have a real sense of the responsibilities and know how to communicate. Well-fit trainings to specific branch of industry is more as ever of primary importance for the workers.

4. Territorial Foresight in Wallonia

As we have seen, pure technology foresight is rather limited in Wallonia. Regional technology foresight has mainly followed informal ways rather than a structured one, except for the "40 key technologies" study. Regional technology foresight has been a quite discontinuous process. Beside technology foresight practices, Wallonia has also accumulated a huge experience in territorial foresight notably through the expertise of the Destree Institute.

Territorial (or regional foresight) could be defined as an application of foresight to territories, whatever their size and governance structure.

The Destree Institute threw itself into the territorial foresight field in the early 1980s by launching a cycle of exercises called *Wallonia to the future*, concentrating at first on issues related to civil society. Between 1985 and 2004, The Destree Institute engaged in six foresight exercises[24] of which it was both the partner and the operator.

Since November 2004, these studies on *Wallonia to the Future* have been replaced by a Regional Foresight College, consisting of thirty personalities who meet on a regular basis and concentrate their efforts on implementing a system of regional change, springing from a foresight analysis that relies on a diagnostic of the values, beliefs, perceptions and behaviour of the Wallonia stakeholders.

At the request of the minister in charge of Town and Country Planning in the Wallonia Government and the Services for Town and Country Planning,, The Destree Institute constructed an information platform called '*Wallonia territorial Intelligence Platform*' dedicated to foresight projects in Wallonia with the idea of launching the

[24] The proceedings of these initiatives were published under the following titles:
- The Destree Institute (1989), *Wallonia to the Future, Towards a new Paradigm, Charleroi.*
- The Destree Institute (1992), *Wallonia to the Future, The Challenge of Education, Charleroi.*
- The Destree Institute (1994), *Wallonia to the Future, The Challenge of Education, Consensus-Conference, Charleroi.*
- The Destree Institute (1996), *Wallonia to the Future, Which strategies for Employment?, Charleroi.*
- The Destree Institute (1999), *Wallonia to the Future, Leaving the 20th Century: Evaluation, Innovation, Foresight, Charleroi.*
- The Destree Institute (2005), *Wallonia 2020, A Citizen Foresight Thinking about the Future of Wallonia, Charleroi.*

Most of these publications are now out of print but may be consulted on line:
http://www.wallonie-en-ligne.net/wallonie-publications/Wallonie-Futur_Index-Congres.htm.

project for Regional Environmental Planning, in order to provide informations on regional foresight initiatives conducted in the field of local and supralocal cooperation. This platform has been up and running since 2005 and the products of its quarterly seminars can be ound on the website http://www.intelliterwal.net/.

Several exercises, - to some of which The Destree Institute gave methodological support - are described there, and include *Luxembourg 2010, Herve au futur, Charleroi 2020, Prospect 15, Liège 2020.*

5. Main conclusions from TF experience in Wallonia

Our conclusions about the Walloon experience of TF during the last decade could be expressed in the following items:

1) A growing attention has been devoted to the evaluation of RDI policy by the regional public authorities. This increase of the culture of evaluation is also mentioned in the Trend Chart country report 2005: "the first and then second phase of the Prometheus strategy exercise have significantly improved both the process (in terms of widening the constituency of actors involved, the regularity of debate, etc.) and the understanding of the bottlenecks in the regional innovation system which limit the innovation potential in regional enterprises ».[25] The analysis of the regional system of innovation identifies the transfer of technologies and the valorization of the R&D as the weakest links of the system of innovation. As a result, there has been a strong emphasis by the regional authorities on clustering, on achieving critical mass and also, on simplifying the process of delivering assistance and subsidies to companies.

2) Evaluation of RDI policy has received more attention than technology foresight in Wallonia during the last decade. Several factors can explain this attitude. On the one hand, the penetration of foresight in the Belgian universities until now remains very weak: the students are hardly made familiar with the culture of foresight, the methods and reference frames of foresight are not systematically taught in Belgian universities as they are in Great Britain, in Germany, or in the Netherlands. There could be a second factor that could explain the weakness of the technology foresight in Belgian teaching and practice: the future of the federal state is very debated which reduces our ability to project ourselves in a long term perspective. The very existence of the Belgian federal state is indeed often questioned. Lastly, the composition of the consultative bodies as regards RDI policy, gathering the two sides of industry and the universities and high schools, does not necessarily promote the use of foresight.

3) From a methodological point of view, the use of key technologies as a foresight method has been predominant. Scenarios, Delphi, backcasting have not been used. Nevertheless, one also has to mention the use of more general approaches like expert workshops, interviews, literature review.[26]

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[25] European Trend Chart on Innovation, *Annual Innovation Policy Trends and Appraisal Report Belgium*, 2005, p.22

[26] Keenan M., Butter M., Sainz de la Fuenta G., Popper R., *Mapping foresight in Europe and other regions of the world, highlights from the Annual mapping of the EFMN in 2005-2006*,

4) In the setting-up of regional RDI priorities, the main momentum of this technology foresight process was the 'key technologies' study, conducted within the Prometheus I programme. Otherwise, technology foresight has been a quite discontinuous process. There is a strong need to maintain and to foster a technology foresight attitude within our regional innovation system and agenda, notably through sensitizing all the innovation actors and through periodic updating of the key technologies study.

5) The key technologies' study has been the foundation stone for technology clustering policy. However, the sectors were initially reluctant towards a cross-sectoral analysis and policy.

6) One should notice that technological watch is more practised than technology foresight (among collective research centres; competitiveness hubs; centres of competence). This means that the regional strategy is more short-term oriented or medium-term oriented than long-term oriented.

7) The process of technology foresight – or technology watch – is fairly decentralized: more and more, notably through the new competitiveness hubs, strategic positioning and technology detection and watching are carried out by the actors themselves, with the help of an optional external expertise. As a result of this decentralization process, the regional administration relies more and more on external expertise and one could fear a decrease of TF expertise because of a lack of human resources within the administration.

8) Technology foresight tends to become progressively a transverse concern, cross-cutting several regional administrations and agencies, as well as different sectors. Nowadays, technology foresight also reaches regional industrial and employment policies. However, the institutional context is characterized by a highly federalized research system and a extremely strong fragmentation (e.g. during the last decade, technology clusters have grown up as well as economic clusters and export clusters, due to fairly separate responses to those different stakes).

9) Whilst expertise is growing in several academic centres in the "technology and society" field, regional initiatives on technology assessment institutionalization are merely at a standstill in Wallonia.

10) "While globalization has an impact on territories, (...) foresight has become a major instrument of regional governance. (...) Each foresight exercise is unique and should find its own path taking into account specificities of the territory, the established processes, and the diversity and roles of its actors."[27] The experience of Wallonia shows how regional technology foresight can be positively completed by territorial foresight in order to take into account specificities of the territory.

August 2006, <http://www.efmn.info>.

[27] Clar C. and Destatte Ph. (October 2006), *Regional Foresight, Boosting Regional Potential*, Mutual Learning Platform Regional Foresight Report, Luxemburg, European Commission - Committee of the Regions - IRE Network, p.6. and p.32. The document is downloadable on this website: <http//:www.innovating-regions.org>.

Regions Foresight in Europa: the Case Bashkortostan

Alexander Sokolov

Abstract

Innovation development in the regions is a key factor for increasing Russia's competitiveness. The paper presents results of a pilot foresight study implemented in the Republic of Bashkortostan and targeted closing the gap between S&T community and industrial enterprises. The methodologies used included analysis of regional strengths and weaknesses, economic specialization and other relevant factors. There have been identified regional S&T and innovation priorities that allow concentrating resources on particular technology areas and provide new policy options for regional decision-makers.

Key words

Regional foresight; critical technologies; science and technology priorities; innovation development; innovation policy

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1. Background

Russia has always been one of major contributors to the world stock of scientific knowledge. During the years of economic crisis, due to sharp decrease of budget R&D funding (4.5-fold in 1991-1998) and lack of demand from industrial enterprises, national research capacities have been strongly deteriorated, number of researchers in 1992-1998 decreased from 804 to 417 thousand (and then stabilized) – see Higher School of Economics (2006). Nevertheless, Russian science still keeps competitive positions in many fields of basic research.

The Russian S&T system has inherited from the Soviet era its peculiar features – very large scale, institutional structure fitted to centrally directed management (most of R&D is still concentrated in large research institutes), predominant orientation towards government funding. R&D institutes, being separated from industrial enterprises are often not able to produce R&D and technologies that could be in demand at the markets and competitive vis-à-vis the world best level. At the same time, share of universities in total research performance is some 5-6 per cent (4-5 times less than in developed countries).

In the recent years of stable economic growth R&D funding has been increasing, but the level of innovation activities in industries remained lower than in developed countries. One of the key elements of the government policy is ensuring competitiveness of national producers and transition from the economy based on export of raw materials and fuels towards the one based on innovation, latest technologies and providing higher added value. With this purpose, the Russian Government started developing a Concept of long-term development of Russia, whereas particular strategies are developed for major sectors of economy.

To be competitive in the market environment and globalization, Russia has to increase efficiency of its National Innovation System (NIS). The major problems in this respect are overcoming barriers between industrial enterprises and R&D, selection of strategic priorities of innovation development and developing policies for their implementation. Modernization of innovation systems is of particular importance for the Russian regions, many of which started developing relevant strategies. One of the key barriers hampering innovation development is lack of coordination between federal and regional policies.

Regional distribution of R&D in Russia is very uneven, more than 50 per cent of national R&D expenditure is spent in the Central federal district (with more than third of total – in Moscow), whereas other regions (except St.-Petersburg, Novosibirsk, few other R&D centres and science cities) are much less developed in this respect. The gap between R&D and industrial enterprises in the regions is even bigger than in the centre. Local industries are less developed. The R&D-intensive production chains have been significantly changed or disintegrated. Lack of local R&D-related initiatives, weak involvement of regional R&D units and universities to the implementation of Government S&T pro-grams leading to deterioration and disintegration of the national S&T system was one of the major concerns of the government. This was mentioned in many strategic documents, but clear policies to overcome these trends had not been developed yet.

2. The Foresight initiative and actors involved

The Foresight study of regional innovation priorities was initiated by the Ministry of Education and Science of the Russian Federation in 2005 as a pilot project aimed at developing and testing methodologies for building long-term innovation strategies at the regional level. The Republic of Bashkortostan had been nominated as a pilot region.

A few years before that, the republican government took a decision to build up a regional strategy of the innovation development. Foresight was examined and chosen as a working tool with regards to its possibilities and practical experience gained in other countries. In November 2003, UNIDO together with the Government of Bashkortostan organized a Foresight workshop in Ufa where major issues related to potential areas of Foresight implementation were discussed.

Being selected as a pilot region for an innovation Foresight study, Bashkortostan received the support from the Federal Agency of Science and Innovations. This initiative was also backed with administrative resources provided by regional authorities, in particular the republican Ministry of Industry, Investment and Innovation Policy.

The Foresight exercise was implemented by the Regional Foundation for Innovation Support and the Higher School of Economic (a Moscow based university) as a project funded in the frame-work of the Federal S&T Goal-oriented Program in 2005-2006. Besides that more than 120 experts were involved that represented largest regional industrial enterprises, universities and research institutes.

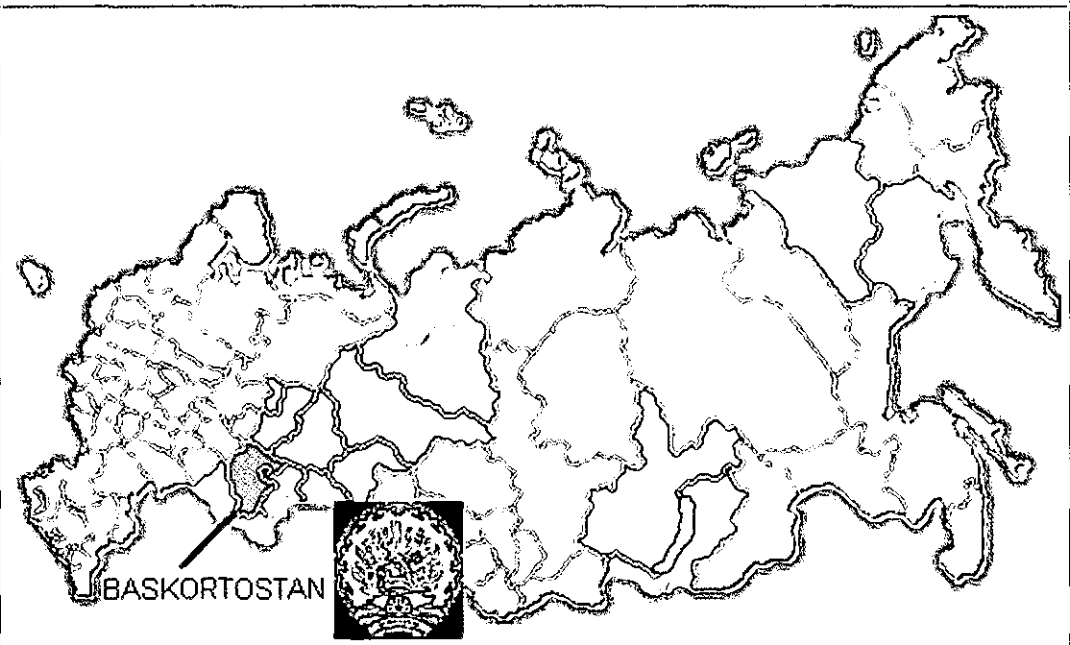
Table 1. Actors involved in the project implementation

Type	Name	Role
Federal government	Ministry of Education and Science Federal Agency of Science and Innovation	Project beneficiary Funding agency
Regional government	Ministry of Industry, Investment and Innovation Policy	Administrative support, Project beneficiary
Regional partnership organizations	Foundation for Innovation Support	Project contractor (coordination of expert panels, promotion and dissemination)
Universities	Higher School of Economics Ufa Aviation University Bashkir State University	Project subcontractor (development of methodologies, implementation and coordination) Participation in expert panels
Research units	Bashkortostan Academy of Sciences Ufa Research Centre of the Russian Academy of Sciences Applied R&D units	Participation in expert panels
Industry	Enterprises	Participation in expert panels

3. Region's characteristics

The Republic of Bashkortostan (Bashkiria) is located in the Volga region of Russia (see Figure 1). The population is over 4 mln., of which 2.6 mln. live in urban settlements (more than 1 mln. in the capital city of Ufa). By territory (143600 sq. km) the region exceeds such European countries as Austria, Bulgaria or Ireland.

Figure 1. The Republic of Bashkortostan



The republic possesses significant natural resources including oil, gas, coal, iron and copper ores, gold, salt, limestone and gypsum. The raw materials and manufacturing industries are well developed in the region. Machinery producing industry and mining (11 per cent of total sales in 2005), chemical and petrochemical industry (9 per cent) and energy (7 per cent) are the main industrial sectors. The share of the aircraft industry is also quite significant. Most of industrial enterprises are located in Ufa and several smaller towns. The energy resources fully meet the demand of regional enterprises. Company "Bash-kirenergo" is the largest regional energy supplying system in Russia. The republic is also well known in Russia and abroad for its scientific personnel. In 68 scientific organizations, there are more than 4.5 thousand of qualified researchers.

For the last few years Bashkortostan has been demonstrating a strong economic growth: in last 7 years the GRP and the volume of industrial production have grown by more than 50 per cent. The key factor of growth has been the development of the raw materials and manufacturing industries. The financial sector is also characterized by the dynamic development. Bashkortostan is one of few Russian republics with a budget surplus. Out of 88 Russian regions, it is 8th by GRP, 7th by industrial production, 2nd by agricultural production.

Despite relatively good positions of Bashkortostan, regional authorities consider that substantial economic potential of the region, its natural and human resources per se cannot secure future well-being of the region. The low level of innovation activity (just 8 per cent of all industrial enterprises in the region introduced technological innovation in 2005, which was less than for Russia total (9.5 per cent) and few times less than in developed countries), weak linkages between industries, R&D units and universities hamper regional development. Therefore one of the key goals of the Foresight study was to identify key factors to foster innovation, increase competitiveness, strengthen existing and create new networks for knowledge transfer between enterprises and academic institutions.

4. Methodologies

The general objective of the project was to develop methodologies for identification of regional innovation priorities with respect to both regional peculiarities and national interests. Among the specific objectives there were:

- Assessment of Bashkiria's S&T and innovation capacities;
- Benchmarking regional S&T potential vis-à-vis other Russian regions;
- Identification of key factors for sustainable innovation development;
- Development of the lists of regional critical technologies and the most promising areas of their practical application;
- Contribution to the regional strategy for social and economic development.

The set of methodologies was selected with respect to best available practices (UNIDO, 2005; European Commission, 2004 *et al.*). It was, on the one hand, based on a general approach and envisaged expert assessment of regional S&T and innovation capacities vis-à-vis federal S&T priorities in order to identify the breakthrough fields able to provide competitive advantages both to the regional enterprises and to Russia as a whole. On the other hand, the methods were customized for the region and included the SWOT analysis and detailed studies of innovation demand (from regional enterprises for new technologies) and supply (capacities of regional R&D units and universities to develop relevant technologies).

The whole Foresight process was designed with respect to the national priority areas for S&T and critical technologies developed by the Russian Ministry of Education and Science and approved by the President of the Russian Federation in 2006.

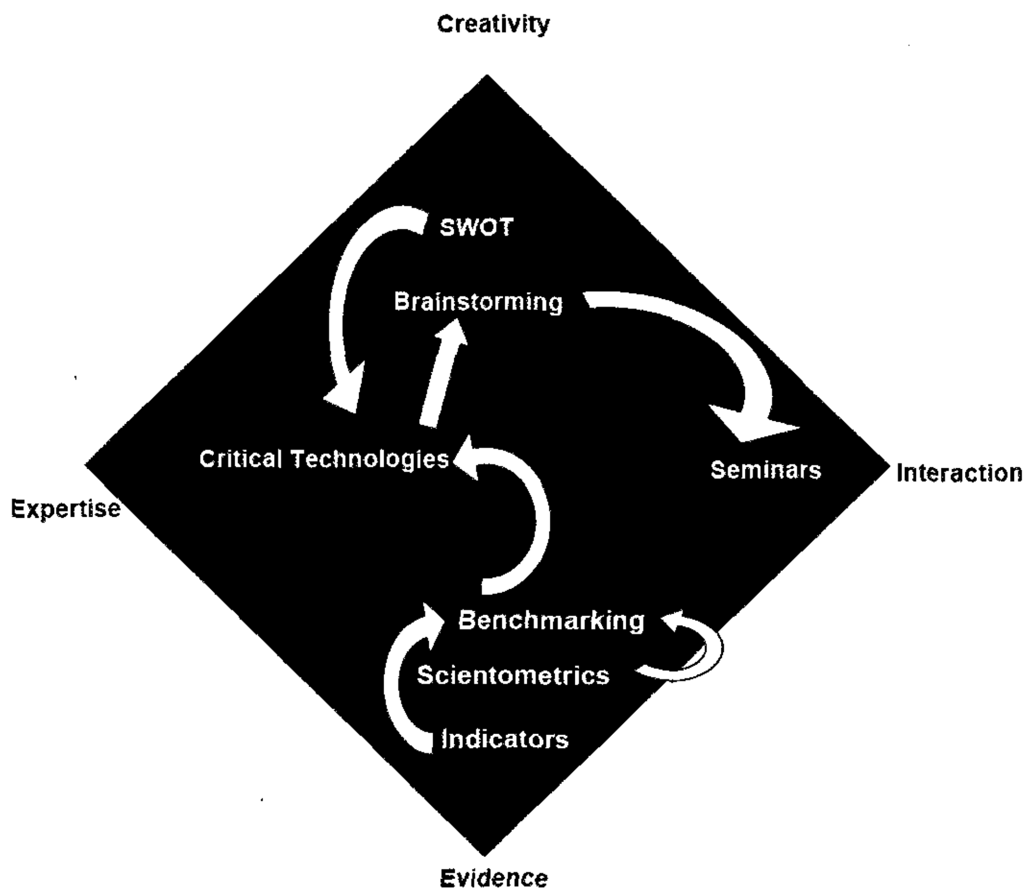
The exercise covered the following particular technology areas:

- Information and telecommunication;
- Nanosystems and materials;
- Living systems;
- Manufacturing;
- Energy;
- Rational use of nature;
- Transport and aviation.

For each area there was created an expert panel (15 to 20 leading researchers and specialists from industrial enterprises) that was engaged in the project activities during the whole period of its implementation. There have been conducted studies of statistical and bibliometric indicators in order to benchmark Bashkiria vis-à-vis other Russian regions, in particular the neighbouring ones.

A set of regional critical technologies was developed on the basis of interviews, expert surveys and brainstorming seminars conducted for each of above mentioned technology areas. The project design envisaged sequential use of particular methods with the aim to provide evidence-based analysis, maximal utilization of expert knowledge, interaction and creativity of experts' participation. The sequence of methods application is shown on the Figure 2 in the framework of the "Foresight diamond" (Popper, 2007).

Figure 2. Methodologies applied for the project



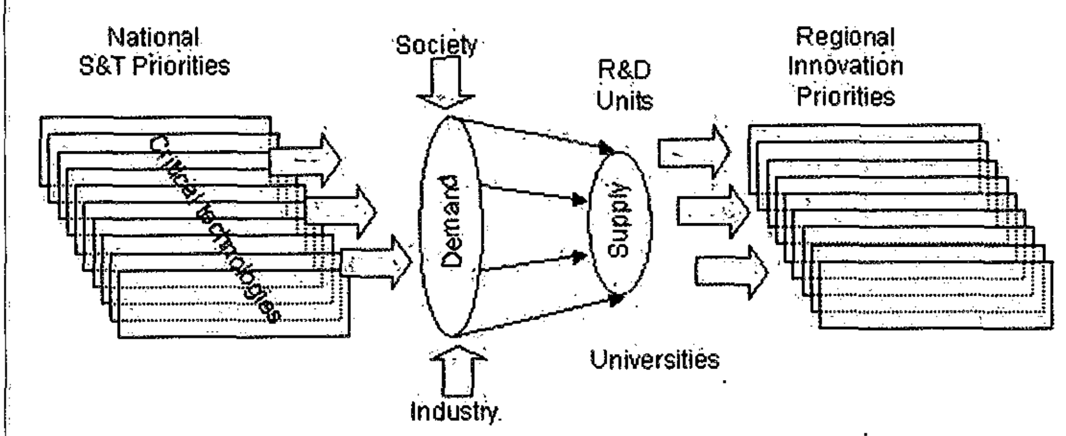
The SWOT analysis has shown that creation of the environment promoting development of knowledge transfer networks and bridging the gap between S&T community and industrial enterprises are the key issues to be addressed (Table 2).

Table 2. SWOT analysis	
Strengths	**Weaknesses**
Well developed raw materials and manufacturing industries	Underdeveloped market institutes
Energy resources	Low share of value added
Strong R&D capacities (world class research in some areas)	Dependence on the global fuels market
Human resources in R&D	Deterioration of fixed assets
Skilled workforce	High costs of production
	Low competitiveness
	Lack of innovation culture
Opportunities	**Threats**
Sustainable economic growth in Russia and increasing domestic market	Joining WTO (increased competition)
Favourable situation at the global markets	Volatility of global economic situation
High oil and gas prices	New legal regulations
Trade with neighbour regions	High barriers to enter new markets

While developing the methodology of selecting the regional innovative priorities, the consistency with the approaches earlier applied at the federal level was ensured (Sokolov, 2006).

The whole process consisted of several steps (Figure 3). The list of civil national S&T priorities consisted of 6 priority areas and 32 critical technologies. For analysis at the regional level there was added one priority area (manufacturing) and 5 relevant technology fields in order to take into account needs of regional industries. The whole set of 37 technology fields was further subdivided into more than 200 particular technologies. This list was at the first stage evaluated by regional experts with respect to supply (S&T capacity available in the Bashkortostan R&D units and universities) and demand (need from the regional industries and society). At the second stage experts were asked to formulate the most important groups of products that could be produced in the region with substantial use of locally developed technologies. For each of priority areas there were selected from 5 to 10 such product groups. Expert panels, with respect to the evaluation results, examined lists of technologies and chose (or reformulated) the most important of them. Technologies that could contribute to the innovation development got the highest ranks and were used as a basis for selection of priori-ties. The final list included 7 priority areas, 28 critical technologies (subdivided into 75 particular technologies) and more than 170 perspective innovation products. In total the regional priorities differed from the national ones, because of their strong orientation towards regional needs and availability of relevant R&D capacities. If the top level was practically the same, there were more differences at the level of critical technologies. For example, such national priorities as nuclear or hydrogen energy were not included into the regional list, whereas some areas not covered by national list like la-ser and plasma technologies were selected for the region. At the lower level those discrepancies were even more articulated.

Figure 3. Identification of regional priorities



At the last stage experts were asked to assess existing situation related to utilization of the selected technologies with respect to the following criteria:

- Research and technology excellence in the region (world best level, Russia best level, etc);
- Practical utilization at regional enterprises;
- Major applications in the region, *et al*;

and prospects of their development:

- Estimated growth rate for sales of product based on each of selected technologies;
- Importance for increasing competitiveness;
- Potential competitive positions of the products at the regional, national and global markets;
- Potential for occupying niches at emerging markets;
- Need in cooperation with Russian or foreign research centres.

5. Results

The work of expert panels has resulted in the lists of regional critical technologies (Table 3).

Table 3. Regional critical technologies

Transport and aviation
Managing transportation systems and systems of new generation
Aviation engineering
Energy-efficient engines and motors for transportation systems
Living systems
Bioengineering and cell technologies
Enzymatic, bioartificial, biosynthetic and biosensor technologies
Biomedical and veterinarian technologies of life support and defence of a human being and an animal
Medicines
Diagnostics, medical treatment, and preventive treatment of the diseases
Nanosystems and materials
Volume nanostructure materials
Surface nanostructure materials
Composite polymers and elastomers
Composite and ceramic materials
Membranes and catalytical systems
Information and telecommunication
Intellectual management systems
Processing, storing, transmission and protection of information
Distributed computing and systems
Production of software
Manufacturing
Mechatronics modules based equipment
Forming, thermal processing, control and assembly
Laser and plasma technologies
Rational use of nature
Monitoring and forecasting state of atmosphere and hydrosphere
Resources assessment and forecasting state of lithosphere and biosphere
Processing and utilisation of technogenic wastes
Decreasing risks and damages of natural and technogenic catastrophes
Environmentally safe exploration of layers and extraction of minerals
Energy
New and renewable sources of energy
Energy production from organic raw materials
Energy saving systems for transportation, distribution and consumption of heat and energy

Among the most promising societal and economic implications the experts indicated such product groups as helicopters, engines for aviation, jet nozzles with controlled thrust vector, trolley-buses (aviation and transport); medicines, immune-modulators, biofertilisers, transgenic plants, bio-diagnostic gadgets, biochips (living systems); superstrong, superfluid and other types of composites, nanostructural metals, implants, special instruments, fixing systems *et al* (nanosystems and materials); software development tools, CAD/CAM/CAE for oil and gas well-drilling, power engineering and other applications, systems for data protection and distributed computing for GRID-technologies (ICT); equipment for processing engine components, processing high-alloy steel and metals, equipment on the basis of laser, nuclear and plasma technologies for production of materials, membranes and surfaces, gas-turbine engines for power engineering and gas-pumping (manufacturing); water preparation, supply and purification, non-invasive control systems, conservation of used oil wells, seismic profiling of oil stocks, biochemical decontamination of toxic wastes (rational use of nature); gas turbines for electricity production, cooled perforated blades with multicomponent thermo barriers, energy saving equipment (energy).

Besides that there were proposed a number of policy recommendations covering the following issues:

- concentration of R&D allocations from the regional budget on priority areas;
- shift towards competition based distribution of budget R&D funds;
- building research-industry networks via joint calls with matching funding in the priority areas;
- facilitating higher education and training to build high quality human resources;
- development of technoparks and other institutions facilitating innovation activities.

6. Regional implication and policy options

The study has discloses significant capacities for intensification of innovation activities in the regional industries. The share of innovation products and services constituted only 4 per cent of total sales and 1 per cent of exports in 2005. Intramural R&D expenditure in the republic did not exceed 0.5 per cent of GRP. Even though the limited budget funds allocated to R&D are mostly distributed on the institutional basis (with respect to size of relevant R&D units) with a very small share of funds that are subject for a competition.

The technology transfer networks are underdeveloped, and industrial enterprises prefer to purchase from abroad (sometimes obsolete) key-turn technologies despite the fact that in the region there exist world-class research teams.

The Bashkortostan government has been developing a mid-term (up to 2015) strategy for social and economic development. The Foresight project findings created a background for the strategy components related to S&T and innovation. Among the policy options considered by the regional government there are complex measures aimed at modernization of major enterprises in key industries, designing efficient mechanisms for integration of S&T, universities and industries, introduction of new competition-based S&T programs with participation of businesses. There are envisaged relevant changes in the regional legislation aimed at promotion of innovation activities, technological modernization, and diversification of regional economy (transition from predominantly fuel based economy to deeper processing of oil, gas and raw materials, increasing added value, introduction of high-tech products).

The list of regional S&T and innovation priorities will become one of the key components of the regional strategy, it will be used as a background for practical implementation of regional S&T and industrial policies. The success of the regional policies will to a large extent depend on its consistency with the overall national strategies. The approach used for the Foresight study allowed detailed expert analysis of what technologies the regional economy needs, which of them could be successfully developed in the republic, and how Bashkiria could coordinate its innovation strategies with neighbouring and other Russian regions.

A very important implication of the study was building of informal networks between major stakeholders in the region (the government officials, industrialists, S&T and education communities). The consensus on the key areas of innovation development achieved in the course of expert panels and other activities creates a platform for further concerted actions and development regional policies that are consistent not just with federal strategies but could be shared by all parties involved in their implementation. There are some examples of such actions supported by the regional Foundation for Innovation Support after the project completion. There have been announced competitions for innovators (projects aimed at innovation development at enterprises with participation of research units). Another instrument is a web-site publishing requests from regional enterprises to researchers for particular technological solutions.

References

1. Science in the Russian Federation. Statistical data book, Higher School of Economics, Moscow, 2006.

2. Technology Foresight Manual. Vol. 1, 2. Technology Foresight in Action, UNIDO, Vienna, 2005.

3. The UPGRADE Blueprint: Foresight strategy and actions to assist regions of traditional industry towards a more knowledge-based community, European Commission, 2004.

4. Popper, R. Methodology: Common Foresight Practices & Tools, in Georghiou, L. *et al.*, International Handbook on Foresight and Science Policy: Theory and Practice, Edward Elgar, UK, 2007.

5. Sokolov A. Russian Critical Technologies 2015. Foresight Brief No. 079, EFMN, 2006. http://www.efmn.info/kb/efmn-brief79.pdf

Foresight for National Science-Technology-Innovation Strategy – The Case of Romania

Adrian Curaj

Abstract

The paper presents the first National Science and Technology Foresight Exercise (RTF) conducted in Romania from November 2005 to July 2006 as part of a larger project called ROST (Romanian Science and Technology). ROST had the main goal to elaborate the National RDI Strategy and Plan for 2007-2013. The prospective consultation led to a list of 26 priorities, clustered in eight areas. Six other priorities have been introduced, five of them in the supplementary space and security area, during a *strategic counselling* phase. The scientific community analysed the basic research areas where Romania has significant results, international visibility and potential for future development. Priorities for the reconstruction of the national RDI system were identified. A long-term vision document has been elaborated. More than 800 persons, representing key stakeholders participated to the negotiation workshops, and more than 6000 persons expressed their opinions through electronic surveys.

Key words

Science and Technology Foresight, research priorities, strategy for planning change

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Biographical Notes

Adrian Curaj is a Professor at the POLITEHNICA University of Bucharest, where is the Director of the Center for Strategic Management. He is an alumni of the EMBA program of the ASEBUSS and University of Washington in Seattle-Business School. He has more than 15 years experience in Higher Education and Innovation Programs. He was deeply involved as program manager for the "Higher Education and Research Reform Project" co-funded by Romanian Government and World Bank (1997-2002). He has been working as consultant with World Bank, UNESCO and UNIDO for studies in Tertiary Education, Research and Innovation, and Foresight. Since 2000, he is the Director of the Executive Agency for Higher Education and Research Funding in Romania. He was the Project Manager for the first National Foresight Exercise in S&T (2005-2006). Adrian Curaj is a member of the External Advisory Board-PEOPLE, EU-FP7.

1. Introduction

The Romanian RDI system passed through a very difficult period after 1989, underinvestment and delayed restructuring enabling only in isolated cases the connection to the global trends in S&T, while the still fragile enterprise sector in Romania could not generate a real innovation demand. Practically isolated, the R&D system became fragmented, the various components trying to survive with minimum available resources, based mainly on public funding, within a mostly formal and autarchic framework. The number of active researchers fell drastically from 1990 to 2004, while their average age increased. Many top researchers chose to leave the country. The low attractiveness of research careers has determined qualitative losses in human resources and a precarious adherence of youth to research. Low wages for those working in RDI may be considered a key factor of low attractiveness, but the reasons are more complex, as they are connected to the delayed institutional reform, poor quality of R&D infrastructure and the absence of a performance /excellence-oriented evaluation system. The lack of transparency in professional career development may be considered as another discouraging factor. The quality of outputs and weak international cooperation are reflected by the reduced number of articles in mainstream scientific publications, the low number of citations of the scientific results published by Romanian authors, and in the lack of interest towards the protection of intellectual property. The extremely low number of patent applications with Romanian authors, submitted to the national patent office, and particularly to European, US and Japanese offices, confirms this situation. However the project-based competitive funding launched since 1995 and extended in 1999, has been contributed to increase in performance and change of attitude as regards the access to resources.

Due to the significant improvement of Romania's economic performance (a continuous economic growth since 2001, with annual growth rate of about 5 percent and above) and a strong political commitment, public funding of R&D has undergone a radical process of change starting from 2005. The GDP share of public expenditures for R&D has shown a continuous increasing trend, from 0.24 per cent in 2004 to 0.60 per cent in 2007, and targeting 1 per cent in 2010. The government shows willingness to increase substantially the amount of resources allocated to science and technology, should the system prove its capacity to reform itself and produce results.

At the end of 2004 policy makers faced the complex problem of a lack of long term vision of the Research, Development and Innovation (RDI) system, no RDI strategy in place since 1990 including the consequences on planning effective use of structural funds, and the National Plan for Research, Development and Innovation I (1999-2004) was at the end of its initially planned period of implementation.

In this context, in the last part of 2004, the National Authority for Scientific Research (ANCS) launched a priority project for defining the framework of RDI Strategy development. It represented the preliminary, preparatory stage for the elaboration of the Romanian Research Strategy correlated with the National Development Plan for

2007-2013. Results were published as a Report "Methodology and procedures for defining strategic objectives and priorities for the scientific research and national technological development for 2005-2010" (Nica, 2005). The Report integrated the knowledge base of previous studies (e.g. Organizational Performance Assessment for National Plan for Research and Development I, in 2003), but also brought new element, essentially through: (i) proposal for a new investment model for RDI system; (ii) presentation of frequently used methods and procedures for RDI strategy development and possible aggregations of these methods for the effective elaboration in different time frames (6, 12, 18 months); (iii) defining a way to organize the elaboration process of National RDI Strategy, proposal for successive operations and time estimation; (iv) proposal for an alternative science and technology foresight development exercise in Romania, starting with the presentation of the international experience.

2. Romanian Science and Technology Project

2.1. Project Objectives

In early 2005, The National Authority for Scientific Research (ANCS) launched a public call for the project entitled "The Elaboration of the National RDI Strategy for 2007-2013, based on elements of a strategic planning" (*ROST* Project).

According to the Terms of References the main goal of the project was to deliver "a programmatic document which will, eventually, anticipate a future framework programme, the National RDI Plan (PN 2) for the period of time 2007-2013".

Therefore, mandatory objectives were:

- To identify the problems of the National RDI system;
- To define the set of strategic and specific objectives for the RDI system for 2007-2013;
- To develop the National RDI Strategy, structured upon the elements of a strategic planning, for 2007-2013;
- To develop the PN 2 and to outline other programmatic instruments.

In order to make sure that the project's goal and expectations were to be met, the contractor felt that a set of supplementary objectives needs to be formulated as follows:

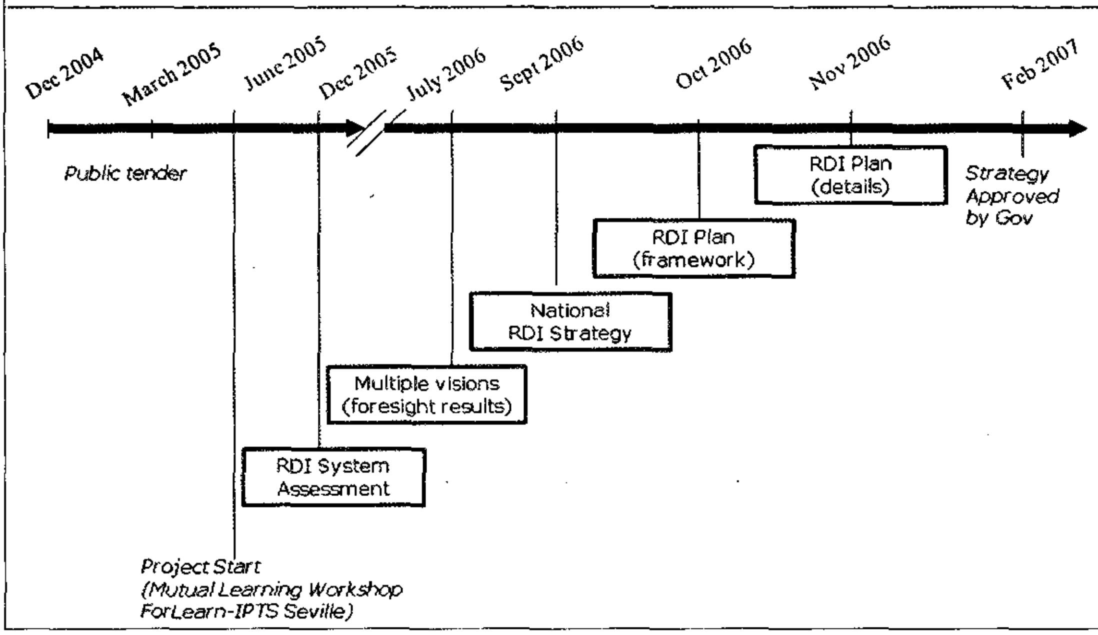
- To develop individual and institutional capabilities regarding strategic analysis, diagnosis and prognosis, and the creation of an associative model of decision orientation at the RDI system level;
- To create a knowledge base allowing the post-implementation extension and the dynamic exploitation of project results;
- To develop skills and identify opportunities for specific regional knowledge transfer (Black Sea, Balkans, etc.).

One of the main specifications of the project was the development of RTF with the following objectives: to identify challenges, key trends and long term priorities of Romanian RDI system; to develop scenarios and to ground the policy actions aiming to make RDI contribute to a better social quality, knowledge development and Romanian economy competitiveness. In this respect foresight was seen as "*a systemic means of assessing scientific and technological developments, which could have a strong impact on industrial competitiveness, wealth creation and quality of life*" (Gheorghiou, 1996).

The ROST Project was implemented by a large consortium of 26 partners (universities; national research institutes; research centres and institutes that belong to the Romanian Academy; innovative SMEs, and a think tank) coordinated by the National University Research Council (CNCSIS) and the Executive Agency for Higher Education and Research Funding (UEFISCSU). The Romanian Academy itself joined the Consortium as a full member later on, during project implementation. Disadvantages of managing such a big consortium were far less important than the value of having actively involved the key players of the RDI system in the project, and making them aware of the project results (Curaj et. all, 2005). Involving them in developing the science and technology foresight exercise became an opportunity for settling the conflict by reframing it into a different context, where barriers are overcome and reform is legitimized. It was a need because since 1989, when Romania took steps towards a democratic society, change has been the source of continuous conflicts, both interest-based and identity-based (Grosu, 2007), between the main players in Romanian S&T.

Project implementation schedule is presented in Figure 1.

Figure 1. *ROST* Project implementation schedule



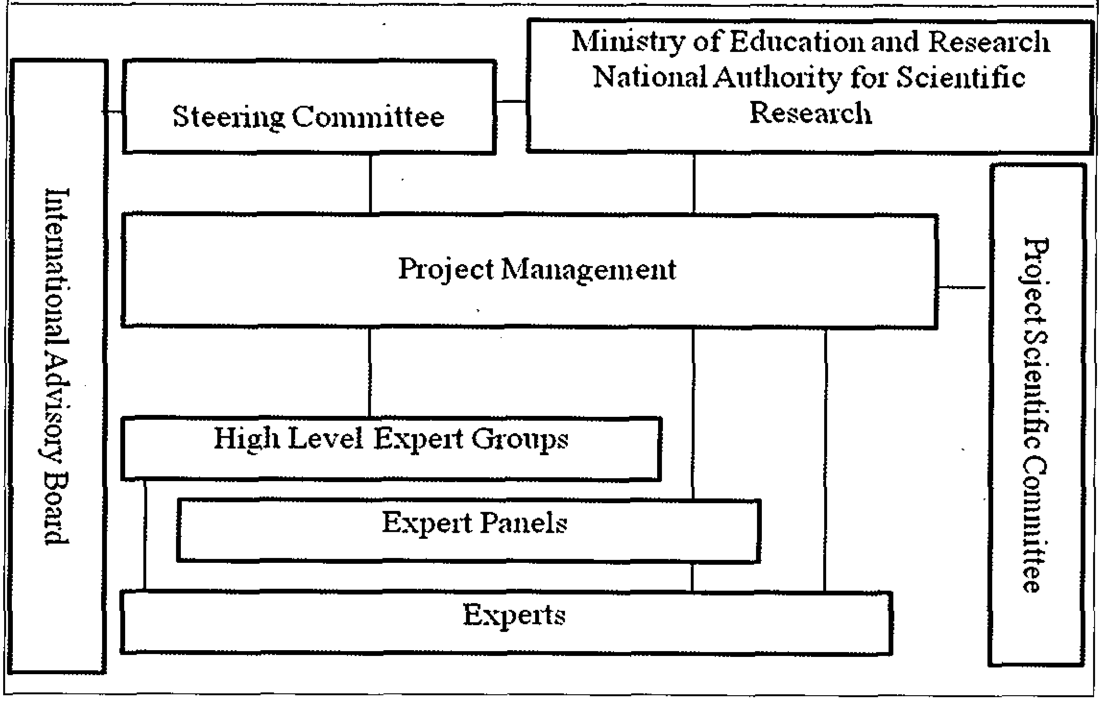
2.2. Organization and management

The coordination and the execution of the project were accomplished by the following groups:

- *Ministry of Education and Research – National Authority for Scientific Research (ANCS)* was the project promoter and sponsor. It was not direct involved in project implementation. The President of ANCS, the State Secretary for Research, was represented by a high level civil servant who participated to almost all Steering Committee meetings, High Level Expert Groups meetings as well as during the most of the intelligence gathering phase. Close to the concept of the *adaptive Foresight*, it was used a *strategic counselling phase (Weber, 2006)*, (Da Costa, 2006) when results were translated into policy strategy through an effective interaction with policymakers. It was a strong political commitment for the project, not affected by the general election at the end of 2004 and the change of Government.
- *The Steering Committee* represented the highest level decision body and assured the general project's coordination. It approved the work programme and the methodology, and monitored the quality assurance process for the project. It played a key role in raising awareness, lobbying for the project, mobilizing the experts. A proper balance in membership of Steering Committee contributed significantly to the achieving of the project objectives. Steering Committee consisted of 5 key persons: immediate past State Secretary for Research who launched the preparatory phase of the project, in 2004; the State Secretary for Research who started the first National Plan for Research, Development and Innovation (PNCDI I) implementation (1999); a Vice-president of the Romanian Academy; the

President of the Consultative Council for Science and Technology - National Authority for Scientific Research, and the President of the National University Research Council.

Figure 2. ***ROST* Project implementation structure**



- *The Scientific Council* role was to provide technical scientific support and to provide advices to ground the management decisions. Its members expressed their opinions and made recommendations on the methodology as well as on the project deliverables. Each project partner in the 31 institutions consortium was represented in the Scientific Council.
- *The Project Management Team – Project Team* led the project on a daily basis. It was composed of a Project Manager, a Deputy Project Manager, and four Rapporteurs of the High Levels Expert Groups and staff members of the Executive Agency for Higher Education and Research Funding (one of the two project's coordinators). Project Manager was in charge with the team management and took full responsibility for the project development in front of the Steering Committee. He was permanently in contact with the Scientific Board and maintained the interface between the Steering Committee and the project sponsor, Ministry of Education and Research - National Authority for Scientific Research. *The Project Management team* developed specific managerial activities in order to reach the goals and to successfully implement the project.

- *High Level Expert Groups (HLEGs)* consisted of 15 to 20 members each. Due to the project objectives and its complexity there were establish four HLEGs as following:

    - *HLEG1 – Assessment of the Romanian RDI system* – the main expected contribution was a benchmarking study of Romanian RDI System. A broad assessment of the Romanian RDI system was performed, including strengths, weaknesses, opportunities and threats, while taking into account the globalisation and the integration into the European Union. Key persons from science and technology, economy, civil society, central and local public administration, and non-governmental sector were consulted. They identified bottlenecks and subsequent corrective measures. The statistical data have been supplemented with two polls, one focused on the RDI personnel activity and professional career (more than 1000 persons: researchers, managers, etc.), and the other on the Romanian patents (more than 600 individual and institutional patent owners). The legal framework and the state aid issues were analysed. The result of the whole approach was a comprehensive benchmarking study on the Romanian RDI system, including recommendations for future actions. More than 70 experts have been directly involved in preparing the study;

    - *HLEG2 – RDI system priorities* – the tangible results consisted of justified priority proposals, and strategic vision of the RDI development: alternative scenarios specifying the key elements for the period 207-2013;

    - *HLEG3 – RDI Strategy 2007-2013* – domestic and foreign studies and reports were consulted, models of economic and social development were analysed, statistical data were compared, and RDI strategies and strategic plans were analysed. The result was a strategic study underlying this document. More than 40 experts took part in the elaboration of the study. While preparing the study, the complementarity, synergy and close connection to national economic and political documents, strategies, plans, including the National Development Plan and the National Strategic Reference Framework, were taken into account. They recommended the education strategy, particularly in its higher/tertiary education components, to be correlated with the RDI Strategy;

    - *HLEG4* – The National Plan for Research, Development and Innovation 2007-2013 – identified underlying principles for the National Plan for Research, Development and Innovation II, and proposed an investing model.

The HLEGs included experts from science, public administration, industry, science and technology management, and civil society. The first were appointed HLEGs' coordinators that were asked to propose the membership. Proposals were discussed and validated by the Steering Committee. The HLEGs worked independently, according to their specific terms of reference.

From the project start, due to its complexity and time constraints as well as the adopted projects structure, it was discussed the ways to avoid the risk to have the HLEGs work as not interrelated sub-projects running under the project umbrella. As a consequence it was decided each HLEG to be supervised by a Steering Committee Member, and to facilitate the knowledge exchange between HLEGs members. At a later stage of the project, three HLEGs (*HLEG1, HLEG3* and *HLEG 4*) merged.

- *Expert panels* consisted of 15 to 20 members each, leading national experts as well as experts from science, public administration, industry, S&T management, and civil society in a proper balance. The Steering Committee and Project Team defined the terms of conduct for the expert panels. The panel chair leader had been appointed first, and was asked to nominate experts members, to the project Steering Committee, by consulting project's partners and key stakeholders, and using her/his personal contacts. No major changes from nomination to membership.
- *Experts* were supposed to assure a high level of competence and legitimacy, therefore science, public administration, industry, science and technology management, civil society fields should be homogenously represented. These are necessary for a correct dimension of the project, a warranty for the validity of the final results. Due to the project financial constraints and time constraints it was not possible to organize an International Expert Group which to provide their opinions and views on the project methodology and results. However, the Romanian foresight exercise have had a continuous support from the ForLearn project (ForLearn, 2005), including a dedicated mutual learning workshop organized in Romania before the project start, in June 2005.
- *The International Advisory Board* consisted of key persons from different foreign/international organizations (EC/DG-R/Directorate K2 and IPTS-JRC, World Bank, UNIDO, UNESCO-CEPES, European Science Foundation, EARMA, US – NSF, Hungary Academy of Science, Spain, UK, Israel), and representatives of key institutions in Romania (Presidency – a State Counsellor; Parliament – Commission for Education and Research, and Commission for ICT; Prime Minister – a Counsellor; Romanian Academy – a Vice-president; Group Renault Romania - a Vice-president). The International Advisory Board met two times, in May and October 2006 and expressed its members' views and opinions on the methodology and project results. The recommendations formulated by the International Advisory Board were used by the project management for arguing some of the sensitive results obtained during the foresight process. It also contributed to a larger visibility of the RTF.

3. RTF – Methodology and results

3.1. Foresight Strategy

The context of Romania's National Foresight Exercise subscribes to a power-driven strategy of planning change. Therefore, the role of the authority figure becomes more important and its involvement more necessary, in order to get an optimal result (UEFISCSU, 2005).

The objective of the foresight process is change. Change as an organizational process has been studied within a framework of management of change, including three types of strategies for planning change: (i) Information-driven strategies; (ii) Value-driven strategies; (iii) Power-driven strategies (Nickols 2003). Recently, Relationship-driven strategies were added.

Information-driven strategies rely on the principle that people are rational beings and willing to change. Policymakers accordingly are willing to promote change, if it is the result of logical reasoning, is presented as a conclusion of a rationally motivated process of visioning. For the implementation of the strategy the result of foresight planning is put forward by the management group, who justifies change by pointing out the relation between the foresight rationale and the chosen methods. The level of participation needs to be underlined. Even though the whole approach is focused on data, a variety of communication strategies are used to move things forward.

Value-driven strategies are based on the assumption that change is based on people's perception on what is good and bad. All the stakeholders involved in policy dialogue deliberations have a positive and active attitude towards change motivated by their dissatisfaction with the current situation due to the clash between the political "correct" discourse and fundamental value. Thus the process of seeking scenarios for further developments becomes as important as the result itself and the involvement of as many members of the system is the underlying principle. The primary assumption is that intelligence is social rather than rational. Change extends beyond the development of common understanding at a rational level, to include personal meanings and values of the members.

Power-driven strategies emphasize that negative outcomes derive from the lack of change implementation. Both the foresight process and the resulting outcome are understood in the context of the international system. The two primary sub-strategies in this approach include the use of legitimate power to promote change and the use of economic policy instruments as a way to motivate change initiatives. Although this type of strategies appears to be based on the negative motivation approach, they are mostly combined with strategies of the first two types with effective results. But we should also notice that the power-driven approach of the foresight exercise is a rather risky one, taking into account the various external threats namely: the society might not be fully prepared to accept the foresight process, the implementing organization might not be completely able to manage such a project, comprising much more complexity than the other two previously mentioned approaches; political decision makers ordering the foresight exercise might change their priorities. Power-driven strategies include a large range of approaches, going from forcing change to understanding authority as the main catalyst of change. It is the latter approach that describes power-driven authority foresight strategy. In this case, the role of the authority figure is to generate information-driven and/or values-driven strategies, so that the dynamics of the foresight process should not be influenced by the capacity of the authority to impose change.

We must emphasize that the foresight process itself is the instrument of change and not only its final outcome. On the other hand, it is hard to imagine that change might be generated by the mere interaction of the entities of a weakly structured system, characterized by a strong resilience to change. Involving the authority figure becomes essential when motivating the experts and when taking decisions on structuring the dialogue.

3.2. Foresight Process

During the last decades Foresight has become increasingly used as a strategic policy intelligence instrument. Current Foresight theory is recognizing the complexity and reflexivity of innovation processes and conceptualizes policy making as a continuing reflexive learning process (Da Costa, 2006). The role of Foresight has been shifted from product-oriented to process-oriented policy instrument.

RTF was both product and process-oriented. It aimed to supply anticipatory intelligence such as the future challenges, risks and opportunities, SWOT analysis of the current system, and visions for change for addressing them. According to ROST's Project Terms of References, the deliverables list contains a benchmarking report, direct policy recommendations such as priority list, multiple scenarios of future developments, and recommendations for reinforcement of the institutional framework of the consultative bodies and intermediary funding agencies.

The first learning cycle of the Romanian foresight aimed at identifying thematic and systemic "directions of investigation" for Romanian RDI system as well as their specifications. It was composed out of three future-oriented activities:

- Consultations with key persons and key institutional stakeholders in science policy-making;
- An on-line issues survey - There were more than 1000 respondents out of which 80 per cent Ph.D. holders. The target group consisted of experts identified through a process of nomination and co-nomination that intended to have a balanced distribution of experts from: science, public administration, industry, science and technology management, and civil society. It was a high expectation to have a larger participation of young researchers, but it wasn't the case. The age average of respondents was 41, below but very close to the researchers' age average in Romania.
- A negotiation workshop.

The first two activities produced six directions of investigation, five of them in which one could expect ideational transformations in science and technology, while the sixth direction was dedicated to system transformational priorities in science management:

1. Information Society Technologies;
2. Competitiveness through Innovation;
3. Quality of Life;
4. Social and Cultural Dynamics;
5. Sustainable Development;
6. Institutional building/empowering.

The final activity of this first stage was the first agora developed during RTF (Grosu, 2007), a negotiation workshop. The modern agora is described as a public space translating "reliable" knowledge into socially robust knowledge, while participants are both individual and institutional (Devenport, 2005).

More than 140 persons attended the negotiation workshop. They agreed on the six directions of investigation above and concluded that there should be also an autonomous space for science governance under the *Mode 1* model of knowledge production (Gibbons, 1999), (Nowotny, 2001). The Steering Committee adopted the agora's point of view and defined a seventh direction of investigation:

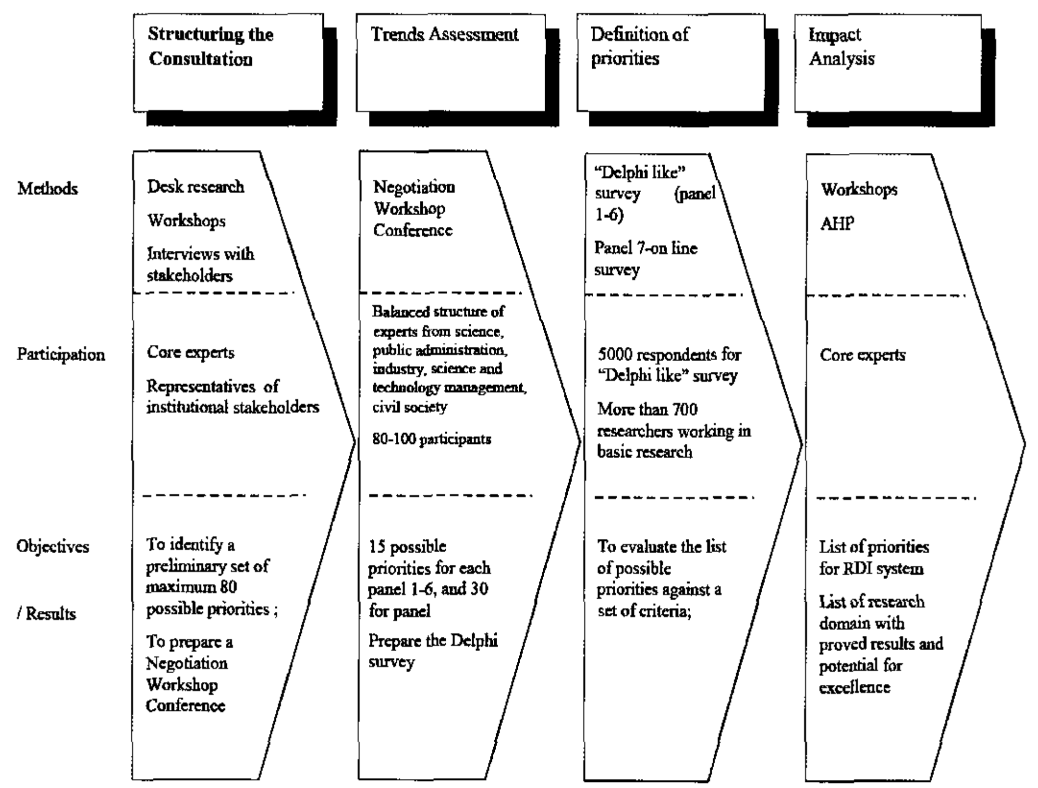
7. Science, frontier sciences and knowledge development.

The first learning cycle concluded on the name of the seven expert panels (EP 1–EP 7). Activities for defining the RDI priorities are presented in Figure 3.

The intelligence gathering phase had as key events the *Negotiation Workshop Conferences*, organized for each direction of investigation identified before. EPs coordinated preparation of those events. Their primary role was to interrogate stakeholders on possible long-term priorities for Romanian research, analyse answers, cluster them and put together an initial lists of long-term priorities, functioning thus as an early filter, close to the methodology used by German project Future. EP 7 had a supplementary role, to identify the key actors in basic research (research groups, labs, departments, institutions).

The second filter was formed by the one day *Negotiation Workshop Conferences* that have been organized using a negotiation formula that proved its efficiency in international negotiations. They were structured as series of autonomous workshops, involving key persons from the scientific community, and also from science governance, the business environment, or the civil society. Each workshop was attended by up to 100 persons. The objective for each disciplinary homogenous group was to select a short list of possible research priorities and to criticize other groups' selection. At the end, a negotiation between representatives of each group produced a package with priorities acceptable to everyone, but ideal for none. Each group was asked to accept or reject the whole package, but not to modify it.

Figure 3. The panels' activities for defining the RDI priorities



3.3. Foresight Results

The list of possible priorities was submitted afterwards to a final selection through an online voting procedure. RTF organizers felt "obligated" to use a questionnaire somewhat similar to the one used in a classical Delphi survey, since this seemed to be the sponsor's expectation, even if the time constraints gave no chance for conducting a Delphi survey.

Results were processed and prioritized using the Analytic Hierarchy Process (AHP) technique. At the end, the following short list of twenty-six research priorities of socio-economic interest was obtained, Figure 4.

The Expert Panels were asked to synthesize the debates by defining a visionary objective for each priority, the resources and science governance mechanisms required in order to evolve toward those objectives.

EP 7 conducted a survey, asking researchers to express their opinions on the existing potential of the areas of basic research to produce publications in highly ranked scientific journals and/or to converge with the identified possible priorities of socio-economic interest.

Figure 4. The list of research priorities of socio-economic interest

1	Theoretical Informatics and Computer Science
2	Advanced Information Systems for e-Services
3	Communication Technologies, Systems, and Infrastructures
4	Artificial Intelligence, Robotics and Advanced Autonomous Systems
5	Information Systems Security and Accessibility
6	Technologies for distributed systems and embedded systems
7	*Nano-electronics, Photonics, and micro and nano Integrated Systems*
8	Advanced Materials
9	Biotechnologies for Agriculture, Food Industry and Health
10	Advanced Technologies for Industrial Process Control
11	Innovative Products and Technologies for Transportation
12	Technologies for High-Precision Mechanical Products and Mechatronics
13	New Methods for Management, Marketing and Enterprise Development
14	Quality of Education
15	Quality of Health
16	*Quality of Living*
17	Quality of the Working Conditions
18	Human, Social, and Cultural Capital
19	Material/Immaterial Patrimony – Cultural Tourism. Creative Industries
20	Social Inequalities. Regional Disparities
21	Technology, Organization and Cultural Change
22	Methods and Procedures for Reducing Environmental Pollution
23	Sustainable Energy Systems and Technologies. Energetic Security
24	Territorial Planning. Infrastructure and Utilities
25	Waste Management Systems; Products Life-cycle Analysis, Eco-efficiency
26	Environmental Protection and Reconstruction of Endangered Areas; Conservation of Protected Areas

In order to complete the visioning process, the peripheral elements of the vision needed to be identified, anchoring thus the vision in its environment. The RTF initial methodology included a scenario building process and inclusive scenario workshops organized by each of the five panels, relying on the entire short list of twenty-six priorities. This did not really happen due to different reasons including the time pressure. A group of experts synthesized the data obtained from panel reports into four scenarios, answering four major challenges for the Romanian R&D system determined by the Assessment of the Romanian RDI system High Level Expert Group: (i) *Better interaction with the international scientific community*; (ii) *Better interaction with Romanian industry*; (iii) *Better interaction with Romanian non-governmental environment (SME, NGO)*; (iv) *Better interaction with Romanian Educational system*. A "strategic vision" that describes the most desirable path into the future was produced afterwards.

4. From Foresight Process to RDI Strategy and Plan

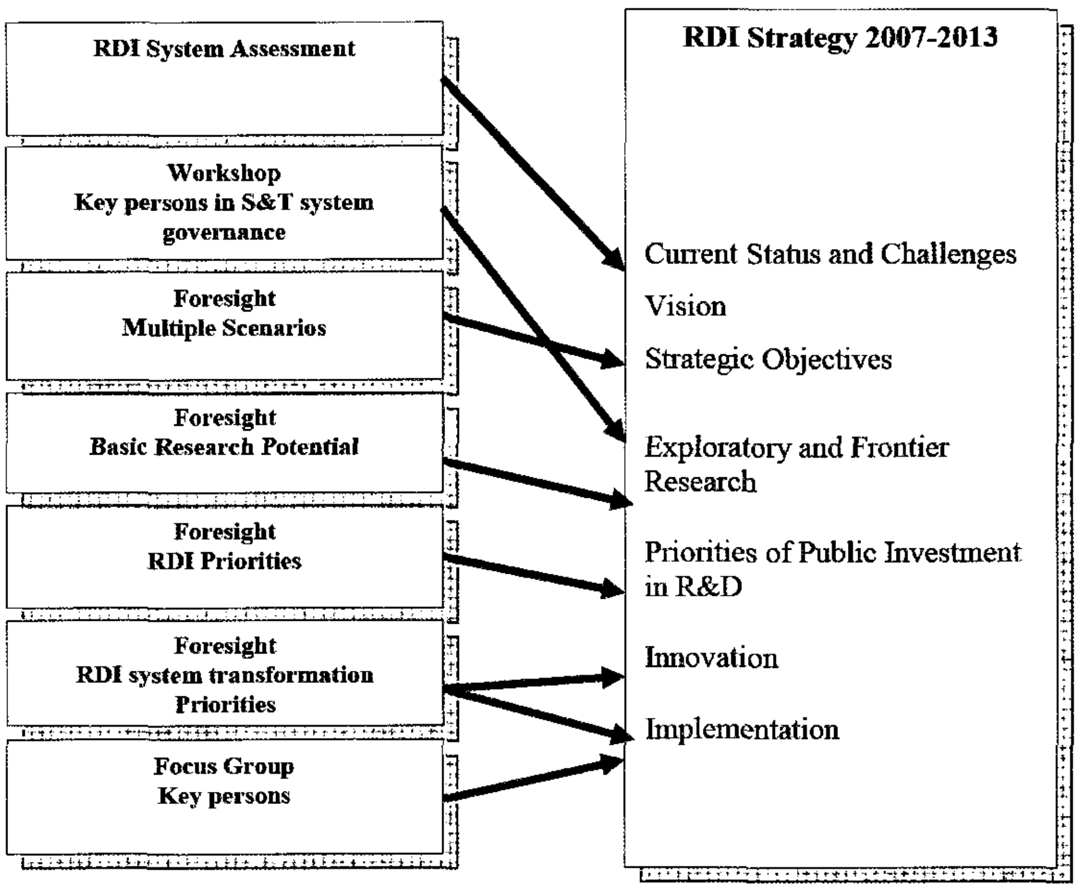
The RDI System Strategic and Specific Objectives were formulated during a number of workshops attended by key persons in S&T system governance. The discussions were focused on results of the foresight process (priorities and multiple scenarios), the links with other policies, strategies, plans as well as the role of the Romanian RDI system *"to develop science and technology, in order to increase the competitiveness of the Romanian economy, the social quality and the knowledge likely to generate added value and to expand the horizon of action"*.

To perform such role, the RDI system has three strategic objectives:

- *Knowledge creation*, i.e. getting top scientific and technological results, competitive on the global arena, contributing to the development of the global knowledge pool, thus improving the international visibility the Romanian RDI system and the application of the results into the economy and society;
- *Increase the competitiveness of the Romanian economy* through innovation with impact on the private sector, and by transfer of knowledge to economic practice. This objective concerns the achievement of top technological results, complex problem solving research of local, regional or national and international relevance, or requested by the business sector, and the development of innovative technologies, goods and services, with direct applicability;
- *Improve the social quality* through development of solutions, including technological ones, generating direct benefits for the society. This category includes solutions to local, regional and national problems related to social cohesion and dynamics, effectiveness of the policies, and issues related to health, environment, infrastructure, land management and utilization of national resources.

Figure 5 presents the way the results from the different phases of the project were used during the RDI Strategy development.

Figure 5. From Foresight Process to RDI Strategy



The specific strategic objectives are:

- Increase the overall system performance;
- Develop the system resources;
- Involve the private sector;
- Increase the institutional capacity;
- Extend the international cooperation;

Policy informing and *Policy facilitating* functions of foresight are obviously clear for RTF. Besides supplying specific information as a support to policy design, from the policy maker perspective, the main benefit from the foresight process was enhancing of the system capability to change in phase with the specific policy under consideration. It was possible a smooth implementation of policy strategies due to a better responsiveness of actors in the field, actors that took actively part to the whole foresight process.

Both RDI Strategy and Plan 2007-2013 were approved in February and respectively May 2007 by Government Decisions. The implementation phase has just started in June 2007.

We can conclude that RTF was effective in create linkages, interfaces, knowledge flows and networks between people and entities. The negotiation space created during the RTF made possible, for the first time after 1989, the RDI Strategy to be developed and supported even by people that traditionally have had opposite individual and institutional interests. Different interest groups developed a shared understanding of current situation and future challenges and agreed on a long term view. It was part of policy facilitating function of Foresight.

We may admit the RTF was able to take the momentum of implementing such a complex process valorizing a unique context.

It is expected a high impact of the RDI Strategy and Plan 2007-2013 on the S&T governing system. The institutional framework of the consultative bodies as well as intermediary bodies financing the research, development and innovation will be reinforced. Three public bodies are going to be set up/empowered: the Romanian Research Council, the Technological Development Council and the Innovation Council evolving from the existing institutional framework consisting of about 15 intermediary funding bodies.

5. Conclusions

Implementation difficulties during the Romanian foresight exercise point out on the specificity of developing Technology Foresight in a power-oriented framework for managing change. Such an approach looks like an easy solution for translating visioning into policy-making, but it could comes together with possible costly trade-offs if the process is not properly managed. The ROST project management accepted the challenge and took the momentum even if the circumstances appeared to be not exactly favourable (time constraints, lack of experience in Foresight, very high expectance on foresight results, etc.). One of the most positive outcomes could be considered that Romanian Science and technology foresight has generated the roots of a foresight culture and "made the difference" into a society with low level science-society dialogue. Peripheral elements of a shared vision can and should be continuously re-assessed; therefore, a better, more inclusive scenario building approach should be a priority in the near future for Romanian foresight practitioners. Cyber-agoras still need to be constructed, in order to produce the accumulator effect of self-fulfilling prophecies the sooner the better. RTF can be considered as a start for Romanian foresight practitioners' community development. A post implementation evaluation of the RTF is going to be launch later on in 2007 and an impact assessment will take place at the time of strategy midterm review, in 2010. Until then the very fact that a first national foresight exercise was successfully concluded in Romania should be considered an important outcome.

References

Curaj A., Grosu D., Apetroae M. (2005): "Project-based National Foresight Exercises", Proceedings of the 4th International Conference: Management of Technological Change,, Technical University of Crete, 19-20 August 2005, pp. 187-192.

Da Costa O.,Warnke P., Scapolo F., Cagnin C.(2006): "Contribution of the For-Learn Project to the Study of Foresight Impact on Policy-Making", Second International Seville Seminar on Future-Oriented Technology Analysis: Impact on Policy and Decision-Making, Seville 28-29 September 2006.

Devenport S., Leitch S. (2005): "Agoras, ancient and modern, and a framework for science-society debate", Science and Public Policy, vol.32, no.2, pages 137-153.

Gheorghiou L. (1996): "The UK Technology Foresight Programme. Futures 28, pp.359-377.

Gibbon M. (1999): "Science's New Social Contract with Society", Nature 402, C81.

Grosu D. (2007): "Technology Foresight in a Power-Oriented Strategy for Change. Conclusions after the Romanian Technology Foresight Exercis, Futura 2/2007, pages 52-66.

Nickols F. (2003): "Four Change Management Strategies", Copyright Fred Nickols.

Nica P.,Agachi S., Curaj A. *et al.* (2005): "Methodology and procedures for establishing the strategic objectives and priorities of Scientific Research and Technological Development for the period 2005-2010", Bucharest, Romania, ECONOMICA Publisher.

H, Scott p., Gibbons M. (2001): "Re-thinking Science: Knowledge Production in an Age of Uncertainty, Polity Press.

UEFISCSU-Executive Agency for Higher Education and Research Funding (2005): "Elaboration of the National RDI Strategy within the Framework of the National Foresight Exercise, Bucharest, Romania, 2005.

Weber M. (2006): "Foresight and Adaptive Planning as Complementary Elements in Anticipatory Policy-making: A Conceptual and Methodological Approach", in Voss J.-P., Bauknecht D., Kemp R. (eds.), "Reflexive Governance For Sustainable Development", Edward Elgar Publishing.

Corporate foresight – Shaping New Realities in Urban Mobility: A Case Study of Foresight-Driven Innovation in the Automotive Industry

Dr. Frank Ruff

Abstract

This case note briefly portrays the *history of a foresight-driven innovation in the auto industry* from cradle to adulthood. Starting with the question *how urban mobility could develop in the future*, alternative scenarios were developed by a research and foresight team. The scenarios built the backdrop for workshops in which a multidisciplinary innovation team developed new concept ideas for passenger cars. One of the concept ideas that fit well with the future scenarios was a two-seater vehicle concept for urban, lifestyle-oriented target groups. With an entrepreneurial decision to create a new car brand the innovative car concept was developed and introduced to the market as the today well known "smart", a brand of DaimlerChrysler. The case study demonstrates that foresight-based innovation projects are not just an intellectual exercise but that they can initiate, accompany and reframe large-scale innovation and thus play a decisive role in shaping new realities.

Keywords

Foresight, future, innovation, scenario, automotive industry, urban mobility, city, vehicle concept, market, lifestyle

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Biographical Note

Dr. Frank Ruff is Senior Manager of Social Environment and Trend Research and member of the management team of the Society and Technology Research Group of DaimlerChrysler in Berlin and Palo Alto (California). He has 17 years of practical experience in corporate foresight, applied industrial research and consulting. He was deeply involved with projects on societal change, changing lifestyles and customer needs and the implementation of research projects for product, marketing and sales strategies. Clients included automotive business units, the aircraft industry and services businesses. Previously he was working as researcher and teaching assistant at the Technical University of Berlin, faculty of planning and social sciences. He has substantial experience in developing and coordinating future-oriented research projects and making them effective by combining research with consulting.

1. Introduction

Regarded superficially, the automotive industry and water industry, the mobility sector and the water sector, belong to very different worlds. The automotive industry is of course a part of the industrial water cycle, but not a dominant one, as vehicle engineering and production do not consume much water, compared to other industries. Besides this minor link, *which is not the focus of this case study*, there are some commonalities on a more subtle level.

First, both domains are confronted with tremendous *growth of demand* and also *increasing scarcities* that typically are a consequence of strong demand. In the mobility domain, bottlenecks in infrastructures as well as environmental issues pose limits to unbounded growth. The same is true for water. Second, in both domains, *innovations usually have large-scale impacts*. Inventing new modes of mobility or introducing new vehicle concepts into the marketplace has a broad impact on societies. In the same vein inventing new technologies for supplying water also has broad impacts on society. Third, in both domains experts see necessities for *accelerated innovation*, both to serve growing demand and to promote sustainable solutions that can be implemented worldwide.

With both domains facing similar innovation challenges a case study on foresight-based innovation is justified in this context. The approach is possibly apt to stimulate thinking about foresight and innovation in the water domain. The focus of this case study is not the incremental type of small step-wise innovations that characterizes most of innovation activity in the automotive industry. Incremental innovation prevails because road vehicles today accumulate more than hundred years of engineering and usage experience. With the high level of maturity the leeway for "revolutionary" innovation is naturally limited. Despite the dominant mode of incremental innovation the focus of this case study is an innovation path that is, if not revolutionary, at least clearly more than "incremental" because it aspires not just to add another product to an established category but to shape new realities.

2. The limits of linear thought

Our research group is charged with conducting foresight projects in the *context of society, market and technology* for the business units of DaimlerChrysler. Naturally, we are frequently confronted with the questions:

- How does the future come about?
- What will the future of mobility look like?
- What type of innovations and solution will fit into the future?

Not surprisingly there are many answers to these questions. Dan Quisenberry, a famous baseball player and poet, summed things up neatly in an answer that corresponds to the common sense in modern societies: "The future is much like the present, only longer". Another – somewhat more profound – answer was given by

Joseph Beuys, German artist and art theorist: "Before we know what we're doing, we must know how we're thinking".

In other words, to understand the current and future change in society and mobility, *it is instructive to think about how we think about mobility and society.* As this is much easier to demonstrate in retrospect I will highlight a historical example here.

If we take a look at mobility back in the 1870s the roads and streets of London were still full of horse-drawn carriages and pedestrians (figure 1). What environmental problems stimulated public debate back then? Far too many tons of horse manure on the roads!

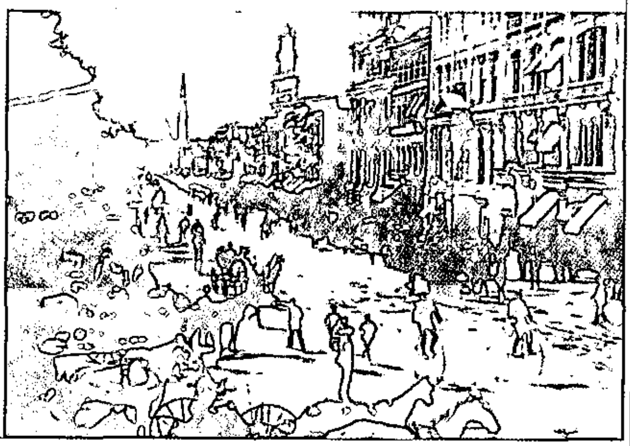
In 1873, it was actually forecasted that if the volume of horse-drawn carriage traffic continued to rise, England would be covered by a metre of horse manure by 1961. As a result of this, there were even calls from some quarters to restrict horse-drawn traffic carriage in the city.

Figure 1

How does the future come about?
The limits of linear thought

"Given the constant growth of transport with horse-drawn carriages, the territory of England will be covered by 1 metre of manure by the year 1961."

(forecast from 1873)



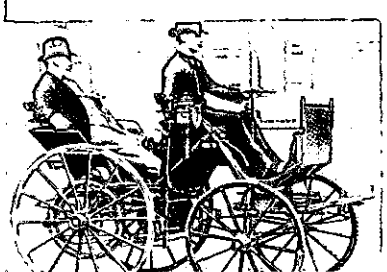
In retrospect, we can easily identify into what *mind trap* these forecasts fell, like so many others. These forecasts assumed a linear development of the technical means of mobility then available. We know today that the challenges of that time were not resolved or overcome by banning horse-drawn carriages or restricting individual mobility, but by inventing and introducing new forms of transport in the city – light rail systems and underground railways as well as two-wheeled and four-wheeled engine-powered vehicles.

Around 13 years after this forecast, our company was first-to-market with the original motor carriage by Gottlieb Daimler, which later evolved into the car. Motorized mobility gave rise to an amazing explosion of options.

The outpouring of innovation that triggered the Industrial Age between the late 19th and early 20th centuries in the area of mobility was intense and full of imagination. It is not by chance that turns of centuries are phases when radical new changes loom large. Around 1900, there was a series of pictures on French chocolate boxes that depicted the world in the year 2000 (figure 2). The enthusiasm around mobility at that time culminated in the vision that we could use all degrees of freedom in the city. We know today that for physical, economic and safety reasons, the flying car has not yet appeared. However, inventors will continue to eagerly pursue this utopian idea and we will see what will be possible in future.

Figure 2

How does the future come about?
Innovations inspire new ideas



Invention of the motor carriage, 1886

L'Avenue de l'Opéra. Chocolate wrapper, around 1900

3. Thinking "from the outside in"

About 20 years ago, i.e. 100 years after the age of horse-drawn carriages, our European societies again saw a surge of forecasts on the growth in contemporary modes of mobility and fundamental debates on the future of mobility arised again.

- How will transport continue to develop?
- Are there limits to growth?
- What impacts does mobility have on the environment?

At this time too, there was another rash of traffic forecasts that predicted the imminent end of mobility. One thing that all these forecasts had in common with the forecasts a century earlier was that they operated on the basis of more or less linear extrapolation of figures.

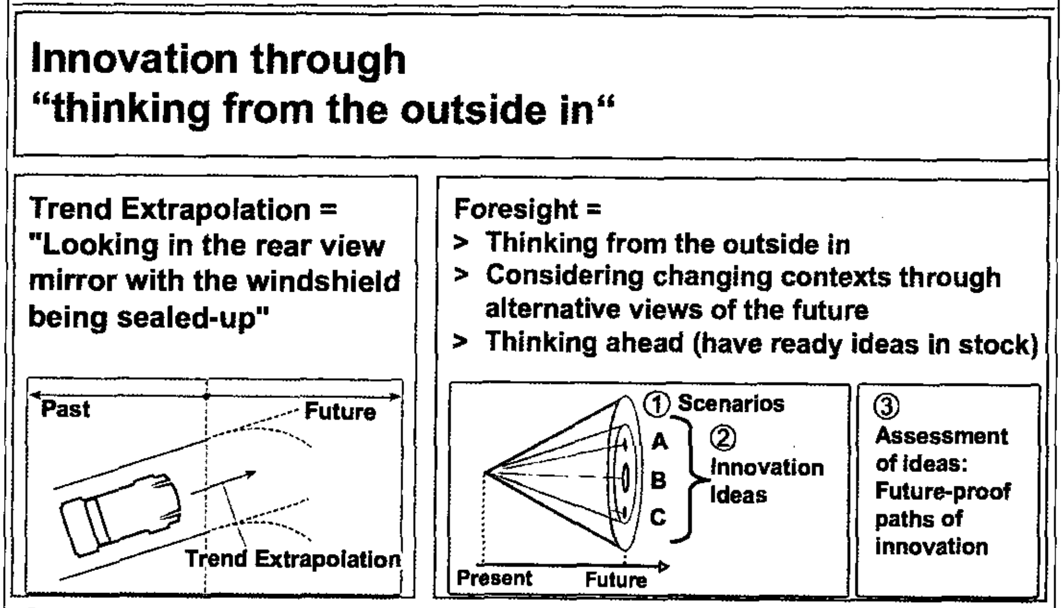
This pattern of thought basically corresponds to the perspective that we would adopt if we sat in a car with a sealed-up windscreen. We would be inclined to assume that we could see the road ahead by looking through the rear-view mirror (figure 3).

In the late 1980s and early 1990s, the critical confrontation with this kind of linear view of the future led us – colleagues in research, development and marketing – to change the perspective and the questions we asked. The perspective became *forward-looking*. Instead of forecasting developments by looking into the rear view mirror, we turned to foresight with images of the future and scenarios. Instead of the question "which future will we see with a continuation of the developments of the past?, it was now about the question "how could the contexts for mobility change?"

The practical consequence of this shift of perspective was a joint project with vehicle developers, designers and market experts, in which we established a working process that departed from the usual routines. Before dealing with vehicle concepts or technologies, we started open-mindedly with the question of how the environment of urban mobility could look in the first decade of the 21st century.

The entire project followed an unconventional but simple philosophy and a *structured innovation process* in 3 steps. The philosophy corresponded to the described change in outlook: "Thinking from the outside-in": We linked the question about the future of the car not to the car itself, but to the future change of the living space in the city.

Figure 3



The innovation process consisted of three steps. In the first step, we devised *scenarios*, in other words different images of the future relating to urban mobility. Inspired by the scenarios, *innovation ideas* were developed in the second step. In the third and final step, the innovation ideas were assessed in the context of the images of the future, and *"future-fit" ideas* were identified.

Key questions when devising our images of the future included:

- How are urban living spaces developing – living, working, leisure and culture?

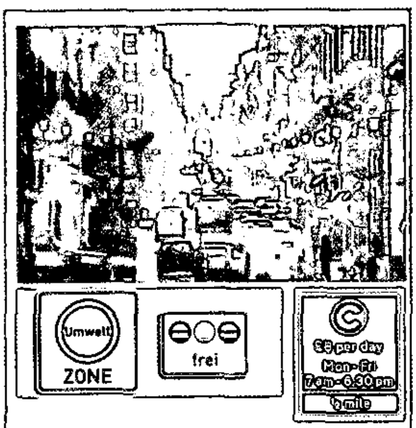
- What shortages are to be expected in cities in future – in terms of space, access entitlements or environmental aspects?
- What aspects of quality of life are important for city dwellers in future, in particular for trendsetters in matters of mobility?

The overall view of the various images of the future gave rise to the insight that despite all uncertainty of individual developments in the long term, some driving factors can be regarded as premises. These premises include (figure 4):

- Increasing shortages in urban habitats (e.g. roads, parking spaces)
- Usage, cost and image advantages for intelligent, resource-efficient solutions
- Individual lifestyles and changes in the world of work are leading to new models of mobility: the classic model of the commuter who drives to work in the morning and back home in the evening is being supplemented by journeys between various workplaces, culture and leisure activities
- Growth of mobile services in the city, triggered by the growing importance of the service economy, such as delivery services, health and care services

Figure 4

Innovation through "thinking from the outside in"



Urban Mobility - Driving Factors:

- **Increasing shortages in urban living space (circulation area, parking places)**
- **Usage, cost and image advantages for intelligent, resource - efficient solutions**
- **More flexible patterns of individual mobility**
- **Growth of mobile services in the city**
- **...**

The discussion in the third step, which we deliberately put back a long way in the course of the project, was especially vigorous. This step was focused on the question: what vehicle concepts, what innovations could fit in particularly well with these future city environments? But because we started with the future context of mobility and because we understood that there are interactions between innovations and the context, we added another level of aspiration: With what concepts could we promote a paradigm shift to shape a new image of individual mobility in cities?

In the innovation workshops, there was a growing certainty that a totally new, highly compact yet safe and spacious vehicle concept could provide a special opportunity to give individual mobility a new face in the urban context and be first-to-market with this idea.

Fortunately, the engineers could also draw upon earlier work. The research division of Mercedes-Benz had already developed an initial two-seater research vehicle in the 1980s. The "thinking ahead" in this project was followed by the corporate decision in 1994 to establish the brand "smart " with the smart fortwo as the core product. Today we can see the consequences of this step, which added new dimensions to urban mobility since the smart was launched in 1998. When we stroll through European cities, we now see that the smart has added new usage patterns and images to the mosaic of urban mobility.

4. Co-designing turning points

With the smart, the aspect of efficient use of resources and environmental acceptability was prominent from the beginning of the project. Even so, we had extremely frank discussions as to whether and when the ecology debate could give further impetus to the project. From our market analyses, we knew that ecology was a low-priority issue in the minds of our customers, particularly if this involved considerably higher costs or sacrifice of safety, comfort and individuality. Thus, one of the key questions was:

When could there be a *tipping point in society* to take environmental topics from their niche status to the centre of society?

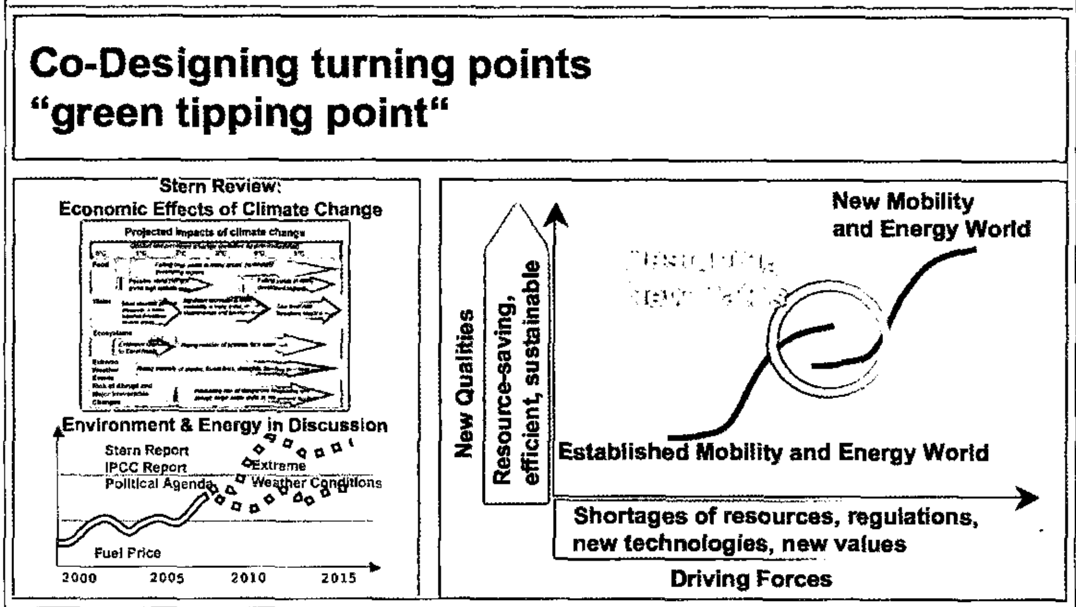
This takes us to the present day: there is much evidence that the years 2006/2007 will go down in history as a "tipping point", as a "green tipping point" (figure 5).

Three milestones that have to be mentioned here are the Stern Report on the Economics of Climate Change, which appeals to *economic reason*, the IPCC report on climate change, which appeals to the notion that climate change is *real and global*, and the film "An inconvenient truth" by Al Gore, which appeals to the *emotions* regarding the environmental challenge.

We expect one significant consequence of this "green tipping point" to be a rise in the number of consumers who want to lead an energy-conscious lifestyle but without sacrificing individuality, mobility, comfort and safety. "Driving with fun and painlessly green" is the central theme here. The "thinking ahead" that led to the smart has proved its worth. We are in the middle of a phase of shaping new paths into new mobility and energy worlds.

If we hadn't already invented the smart, we would have had to invent it today.

Figure 5



Our little journey into the past has now taken us back to the present, and it is now time to ask how individual mobility in cities could evolve in future. "Will the future simply be longer than the past?" (Dan Quisenberry) or do we need to follow Beuys and "know how we're thinking before we know what we're doing"?

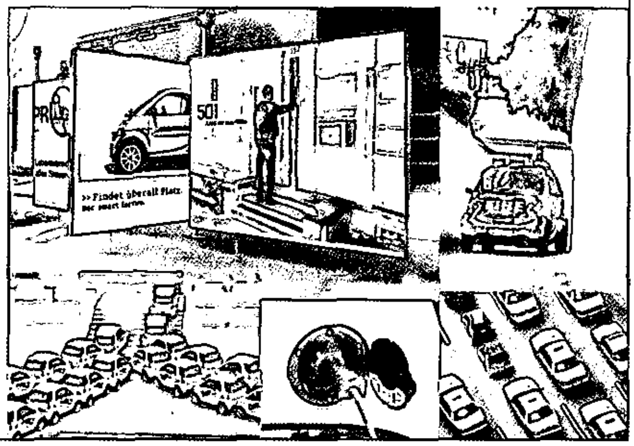
Is that actually a contrast? Here too, we find a groundbreaking perspective from an artist and art theorist of the 20th century, namely Kandinsky. In 1927, in an international journal, he wrote an article on contemporary history entitled: "And – Some Remarks on Synthetic Art" (figure 6). The "and" had a special meaning to Kandinsky. He contrasted it with the "either-or" that he saw as the model in the course of the 19th century. He believed that the 20^{th} century would be characterized in social terms by syntheses. From today's perspective, of course, we must emphasize that he somewhat overestimated the speed of the transition to postmodernism in society in the 20th century, emphasizing the idea of "synthesis" the idea of "AND" which means combining features that were seen as contradictory before. If you look at the smart you can recognize this principle of "AND", the integration of features that were seen as "either – or" alternatives before.

Figure 6

Co-Designing turning points the principle of "AND"

"This order of things departs from the basic rule of 'either – or' and slowly reaches a new – 'and' "

Wassily Kandinsky, 1927



And in this concept of synthesis, our current deliberations on the mobility of tomorrow meet the perception of society of modern artists.

Finally, let's take a short journey into the future. In the year 2022, your personal digital assistant alerts you and refers you to two agency reports:

United Nations: The Attraction of Cities continues to hold

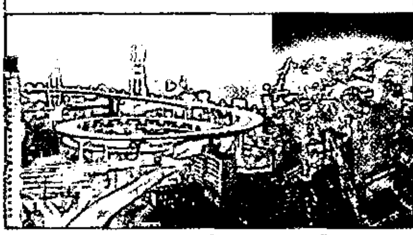
In 2008, the world reached an invisible but significant milestone. For the first time in history, more than half of humankind, namely 3.3 billion people, lived in urban areas. Today, in 2022, almost 60 per cent of the world's population live in cities, with the figure rising to four out of five inhabitants in the industrialized nations (figure 7).

At the UN conferences back in 2010, attention was mainly focused on the mega-cities. As the smaller cities have accounted for most of the growth since then, a new initiative of city partnerships called "Alliance for Sustainable Meso-Cities" was set up in 2015.

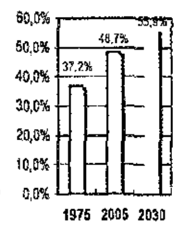
Figure 7

Journey in time to the year 2022

>> The attraction of cities continues to hold



- **> In the year 2008 for the first time in history more than half of humanity lived in cities**
- **> Today, in the year 2022, nearly 5 billion people reside in the cities**
- **> In the industrial nations four out of five inhabitants live in cities**



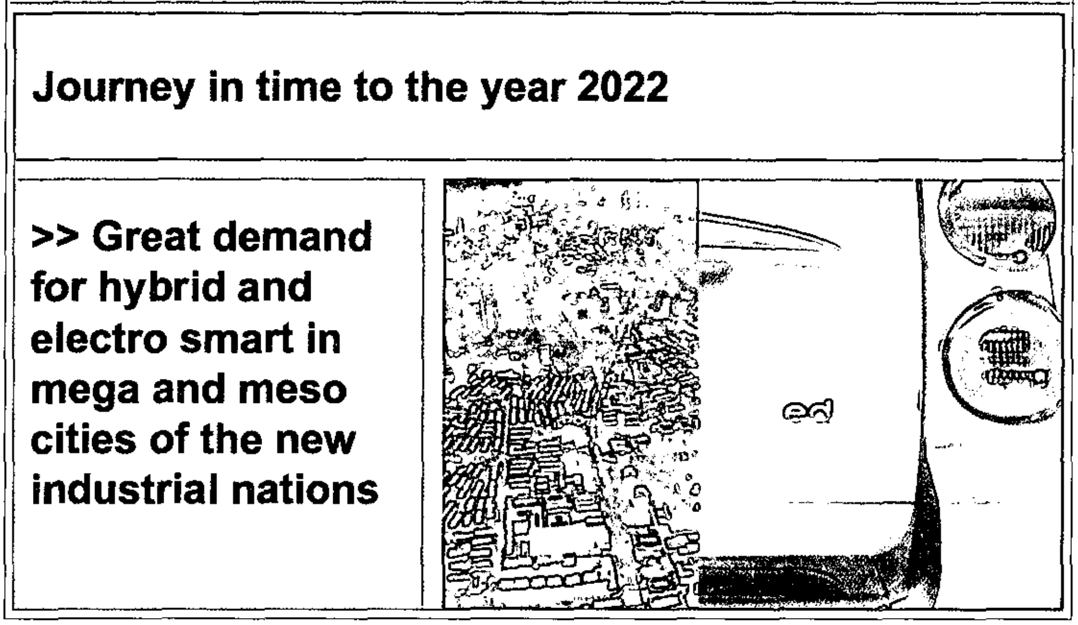
Percentage of city population worldwide

Using voice input, you give your intelligent digital assistant the command: "look for other related reports!". After a few seconds, your assistant alerts you:

Great Demand for Urban Hybrid and Electro smart in Mega- and Mesocities

At an international conference on urban policy and mobility in 2022, the Chairman of the "International Alliance for Sustainable Cities" explained that the member states of the alliance had decided to pursue urban development concepts based on European models. In his closing speech, the Chairman stated: " At the beginning of this century, European cities like London, Paris and Berlin achieved significant results in maintaining the high quality of life of the European cities as well as diversity of individual mobility through innovative technical and organizational solutions. At the same time, considerable increases in efficiency were attained. Urban vehicles like the smart were key element in these solutions invented in Europe, which shaped a new image of individual mobility in cities" (figure 8).

Figure 8



These futures are closer than it may appear!

6. Conclusion: Lessons to be learned from this case

This case note briefly portrayed the *history of a foresight-driven innovation in the auto industry* from cradle to adulthood. The story of the innovative car concept "Smart" shows that for market success it is not sufficient to have a creative, innovative idea that is embraced by certain target groups in the market. It shows that innovations, that by necessity require high investments are risky, even if the innovation basically fits into the emerging future business environment. The case also shows that changes in the business environment, in this case the further rise of environment and efficiency issues, can profoundly reframe innovations that companies were close to abandon.

In fundamental terms the case shows that foresight-based innovation projects are not just an intellectual exercise but that they can initiate, accompany and reframe large-scale innovation and thus play a decisive role in *shaping new realities*.

Priority Setting for Future Critical and Key Industrial Technologies as Driving Forces for Economic Development and Competitiveness

Professor Ron Johnston

Abstract

While the professional foresight literature has moved on to 'third generation' foresight which regards technology as just one of the drivers, there remains a strong interest in being able to map the emergence and future directions of technology, *notably through technology roadmapping. Major exercises to identify future key* technologies continue as industry and government face the challenge of making their investments and plans for an uncertain and rapidly changing future. Key issues which emerge in all these exercises are the criteria to identify key technologies, the level of aggregation of the technologies and achieving policy relevance.

A number of case studies are provided to illustrate the direct way in which foresight studies can shape planning and decision-making, particularly when they are characterized by a clear and shared focus, engagement of relevant stakeholders, embedding of the foresight in the existing planning and decision-making structures, and explicit outcomes.

The paper concludes by pointing to the special role of foresight in innovation systems, and that that rather than attempting to abolish uncertainty, foresight provides a potentially robust social process for acknowledging and addressing that uncertainty. For companies, as for governments, advantage arises not from knowing the future with certainty, but having developed robust and adaptive processes and systems that allow some sense to be made of how the future might unfold, that provide the capacity to monitor and identify at an early stage new contingencies, and that have a deep organizational capacity to respond to and take advantage of these changes.

Keywords

Foresight, innovation, critical technologies, strategy, planning, priority-setting

Address

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Biographical Notes

Professor Ron Johnston, Executive Director of the Australian Centre for Innovation (ACIIC) has worked for more than twenty five years in pioneering better understanding and application of the ways that science and technology contribute to economic and social development, of the possibilities for managing research and technology more effectively, and of insights into the processes and culture of innovation. He is one of Australia's leading thinkers about the future. He led the major Australian national foresight study. Over the past eight years, he has led more than one hundred futures and foresight projects for private and public sector organizations in Australia, Asia, Europe and the Pacific. He was a Visiting Scientist at IPTS in 2006.

1. Foresight and Future Key Technologies

The development of foresight over the past decade has been characterized by a number of authors as moving through successive phases or generations. For example, Cuhls (2003) has provided a detailed account of the achievements and failures of technology forecasting over four decades.

Georghiou (2001) proposed that the evolution of foresight could be characterized in terms of three successive generations. He identified first generation foresight as being concerned with forecasting of technological developments carried out by technical experts. Second generation foresight involved industry and the market as the main actors. Third generation foresight added to the elements of the second generation a social dimension and a user-oriented (ie customer) perspective. A fourth generation was also proposed in which foresight moved away from a national approach to a more distributed role in the science and innovation system.

Johnston (2002) proposed five stages in the chronology of foresight, with technology forecasting and futurism leading to technology foresight, from which emerged foresight, with its wider understanding of the economic and social processes that shape technology. He notes the strong progression within foresight studies towards being embedded within and directed towards planning and decision-making processes at a level appropriate (frequently local or sectoral) to the responsible organization

The focus of professional foresight practitioners, and foresight studies, not to mention academic publications, has moved strongly towards the more recent of these generations. However, as with generations of species, this does not mean that the more recent (ie younger) generations have completely displaced the earlier or older traditions. They continue to co-exist.

Indeed, the first generation model of foresight, with its emphasis on technology forecasting, has continued, and even strengthened, in the process forming in part a largely distinct community of interest in understanding and predicting future technology developments. This is seen most strongly in the emergence of technology roadmapping as a separate sub-species of foresight.

Technology roadmapping (TRM) has been defined as "a needs-driven technology planning process to help identify, select and develop technology alternatives to satisfy identified needs." (DISR 2001) The essentials of the process are:

- It is a normative foresight tool, requiring agreement be reached about the future that should be achieved;
- It is industry and/or market-driven;
- It commonly has a time horizon of 5-15 years; and
- It requires the assembly of a team of technical and industry experts to develop it.

TRM can be applied at the company or industry level to help plan and coordinate technology developments. It provides:

- A means to develop a consensus about a set of needs and the technologies required to satisfy those needs;
- A mechanism to help experts forecast technology developments in targeted areas.

As a result of technology roadmapping, a company or industry can make better investment decisions because it has a better information base from which to:

- Identify critical product needs that will drive technology selection and development decisions;
- Determine the technology alternatives that can satisfy critical product needs;
- Select appropriate technology alternatives; and
- Generate and implement a plan to develop and deploy appropriate technology alternatives. (Garcia and Bray, 1997)

An example of the perceived value of first generation technology roadmapping is provided by the Canadian Government's investment in TRM. Over the past decade, more than twenty technology roadmaps have been developed, covering industries/technologies as diverse as welding, fuel cells, aluminium casting and languages. (Industry Canada, 2006)

How can this persistence in using first generation foresight methods be explained, in the face of the many analyses which demonstrate the difficulty, if not impossibility of predicting accurately the future development of technology?

As Wagner and Popper (2003) state in their excellent review of the 'critical technology' movement in the US, and its apparent lack of impact:

"When discussing the future course of technology, whether from the perspective of public or private concerns, we are touching upon matters of profound uncertainty. Our lack of understanding of future technology courses is not owing to a failure of due diligence; it is inherent in the processes we are seeking to harness. This deep uncertainty is the bane of our usual practices in strategizing and planning. What is ideally required in such circumstances is to employ methodologies that will allow us to frame plans that are both adaptive in their design and robust against a range of alternatives."

However, in simple terms, it would appear that the benefits which emerge for companies from engaging in a process which reduces the uncertainty about the basis of future competitive advantage are sufficiently large to outweigh philosophical limitations of the approach. For national governments, it provides some basis, no matter how limited, for establishing priorities for their large investment in research and development (R&D). As Keenan (2003) has noted: "A main reason for the popularity of national technology foresight exercises over the last decade has been their promise of allowing emerging generic technology areas to be identified and prioritized for resource-allocation purposes."

2. Some Recent Examples of Future Key Technology Identification

One relatively recent example is provided by the work of the United States' (US) National Intelligence Council (2005) in its report *Mapping the Global Future.* The National Intelligence Council (NIC) is a centre of strategic thinking and over-the-horizon analysis for the US Government. This is the third unclassified report prepared by the NIC in the past ten years that takes a long-term view of the future.

The project extended over one year, and the processes used included extensive consultation with experts around the world, a series of regional conferences to develop and test ideas, and an interactive Website which contained several tools including a 'hands-on' computer simulation that allowed novice and expert alike to develop their own scenarios.

The sixteen top-ranked technology applications to 2020 were:

1. Cheap solar energy: Solar energy systems inexpensive enough to be widely available to developing and undeveloped countries as well as to economically disadvantaged populations that are not on existing power grids;

2. Rural wireless communications: Widely available telephone and Internet connectivity without a wired network infrastructure;

3. Communication devices for ubiquitous information access: Communication and storage devices - both wired and wireless - that provide agile access to information sources anywhere, anytime. Operating seamlessly across communication and data storage protocols, these devices will have growing capabilities to store not only text but also meta-text with layered contextual information, images, voice, music, video, and movies;

4. Genetically modified crops: Genetically engineered foods with improved nutritional value - e.g., through added vitamins and micronutrients, increased production - e.g., by tailoring crops to local conditions, and reduced pesticide use - e.g., by increasing resistance to pests;

5. Rapid bioassays: Simple, multiple tests that can be performed quickly and simultaneously to verify the presence or absence of specific biological substances.

6. Filters and catalysts: Techniques and devices to effectively and reliably filter, purify, and decontaminate water locally using unskilled labour;

7. Targeted drug delivery: Drug therapies that preferentially attack specific tumours or pathogens without harming healthy tissues and cells;

8. Cheap autonomous housing: Self-sufficient and affordable housing that provides shelter adaptable to local conditions as well as energy for heating, cooling, and cooking;

9. Green manufacturing: Redesigned manufacturing processes that either eliminate or greatly reduce waste streams and the need to use toxic materials;

10. Ubiquitous radio frequency identification (RFID) tagging of commercial products and individuals: Widespread use of RFID tags to track retail products from manufacture through sale and beyond, as well as track individuals and their movements;
11. Hybrid vehicles: Automobiles available to the mass market with power systems that combine internal combustion and other power sources;
12. Pervasive sensors: Presence of sensors in most public areas and networks of sensor data to accomplish widespread real-time surveillance;
13. Tissue engineering: The design and engineering of living tissue for implantation and replacement;
14. Improved diagnostic and surgical methods: Technologies that improve the precision of diagnoses and greatly increase the accuracy and efficacy of surgical procedures while reducing invasiveness and recovery time;
15. Wearable computers: Computational devices embedded in clothing or other wearable items such as handbags, purses, or jewellery;
16. Quantum cryptography: Quantum mechanical methods that encode information for secure transfer. (Silberglitt *et al*, 2006)

Almost all of these technologies are currently available in some form, or are quite visibly in development. This does not detract from the value, or 'accuracy' of such a list. Rather, it reflects the development time of major technologies, and the extent to which their realization requires the substantial transformation of production, consumption, financial and regulatory regimes. They can quite rightly be characterized as driving forces for economic development and competitiveness.

Another national technology forecast exercise which has been conducted on a four-five year cycle for many years is the Japanese *Science and Technology Foresight Survey*, conducted by NISTEP (2006).

The core of the NISTEP technology forecasting is a major Delphi exercise. In the most recent Eighth Report 130 areas and 858 topics were selected through repeated discussions among more than 170 experts in the subcommittees on the 13 fields. The fields are a mix of broad technology sectors and areas of application:

- Information/communication
- Electronics
- Life science
- Health/medical care/welfare
- Agriculture/forestry/fisheries/foods
- Frontier technologies
- Energy/resources
- Environment
- Nanotechnology/materials
- Manufacturing
- Industrial infrastructure

- Social infrastructure
- Social technologies.

A questionnaire with the participation of 2,300 Japanese researchers, engineers, and other experts surveyed scientific and technological, economic, and social impacts in each area, as well as the importance to, and level of research and development in Japan. For each topic, the forecast times of technological realization and social application were polled, as well as the need for government support and policies.

The technology advances that were identified as most important to Japan were strongly related to the Japanese vulnerability to natural disaster, through earthquake, volcanic eruption and storm. Seven of the top ten topics were of this kind (eg the most important technology identified was "a risk management system that utilizes disaster observation satellites, communications satellites, GPS, unmanned aircraft, and so on to observe disasters, understand situations after disasters occur, and respond swiftly (send the necessary information where it is needed)." Of the other three, two were concerned with the management of greenhouse gases and the third with the demolition of nuclear power stations.

The top ten technology areas in terms of increase in impact, assessed against the three criteria of increased intellectual assets, economic impacts, and social impacts, were:

A. Increased intellectual assets

1 New principles for information and telecommunications
2 Environmental and ecological biology
3 Optimization of industrial infrastructure through regional dispersion and concentration
4 Ultra-transparent communications and human interfaces
5 Software technology for large-scale networks
6 Ubiquitous networking
7 Nanobiology [Life Science field]
8 Brain generation and growth
9 Nanoscience for a safe and secure society
10 Nanomaterials modelling simulation

B. Economic impacts

1 New principles for information and telecommunications
2 Environmental and ecological biology
3 Ultra-transparent communications; human interface
4 Ubiquitous networking
5 Nanoscience for a safe and secure society
6 Integrated systems
7 Molecular and organic electronics
8 Nanobiology [Life Science field]
9 Information biology
10 Brain generation and growth

C. Social impacts Current Medium-term

1 Nanoscience for a safe and secure society
2 Ultra-transparent communications; human interface
3 Environmental and ecological biology
4 Integrated systems
5 Ubiquitous networking
6 New principles for information and telecommunications
7 Nanobiology [Nanotechnology/materials field]
8 Brain generation and growth
9 Bioelectronics
10 Molecular and organic electronics

As for the previously described study, these highlighted areas of technology development are likely to act as driving forces for economic development and competitiveness over the next twenty years. Evaluations of previous reports, in hindsight, have found that about ⅓ of predictions were fully realized within the expected time, ⅓ were partially realized, and ⅓ were not realized at all.

It should be recognized that the NISTEP Delphi exercise is only one component of their continual effort to identify key technologies. Some of their other projects have examined, for example, identification of 'hot' research areas by bibliometric analysis, benchmarking technology development and supporting policies in different countries, and documenting levels of technology imports and exports.

A third notable project, with a somewhat different approach was that of the German 'Futur' project. (Giesecke, 2006) This project, known also as the German Research Dialogue, is designed to assess the future needs and demands for science and technology and to consider their broader implications for the socio-economic and cultural development of the country. The intention is to include a large number and broad variety of participants in the exercise representing not only science and technology but also the various stakeholders of German society. In all about 1250 experts have been involved.

The main objective of Futur is to identify new priorities for future R&D funding activities that would respond to relevant societal needs and demands, bring together different fields in an interdisciplinary approach, support the competitiveness of the German economy and be innovative.

Four 'lead visions' have been formulated which link socio-economic and technological trends. These are:

Socio-Economic Challenges

1. *'Creating Open Access to Tomorrow's World of Learning'* envisages a society where each member is guaranteed access to his/her individual worlds of learning, adaptable to personal needs, comprising institutional as well as human resources.

2. *'Healthy and Vital throughout Life by Prevention'* reflects the aging society in Germany. The goal is to stay healthy by preventative rather than repair approaches to health by means of health-conscious behaviour by each individual.

3. *'Quality of Life through Healthy Nutrition'* addresses the question how a balanced diet can improve human health. It raises issues such as sustainable supply chain of nutrition, transfer from nutrition science into every-day practice, and the role of the food sector in the innovation system.

4. *'Water as resource – visions for a guaranteed supply and access for all in the 21st Century'* – dealing with new technologies for the processing, distribution, use, regeneration and substitution of water coupled with new concepts of water management.

Technological Trends

1. *'Understanding thought processes'* – exploration of how the brain manages information processing, cognition and creativity. One anticipated area of application is the development of medical neuro-prostheses that could give physically challenged people a new perspective.

2. *'Living in a Networked World: Individual and Secure'* – aiming to create a more personal access to the ongoing and accelerating networking of information technologies. Networks and technologies should be individualized, but the social context of the individual has to be taken into consideration to prevent social isolation.

3. *'Bionics: Ideas from Nature for intelligent housing'* is based on the assumption that by analysing and copying construction principles as they are applied by nature housing can be adjusted and designed according to the changing demands and needs of inhabitants.

4. *'Biological engineering'* is a possible future lead vision aiming to use biological systems, biological engineering and engineering sciences. The expectation is that this combination would open up new possibilities for the systemic technical use of biological systems.

There are two other aspects to briefly mention. Firstly, there is a great deal of technology analysis and forecasting devoted to particular prospective technologies, but of a form that is less precise than usually associated with a roadmap. As an example, the author has identified more than twenty independent projects examining the prospects for nanotechnology being conducted in 2006-7.

Secondly, it is not only national governments that have an interest in technology forecasting. Consulting firms have recognized this as a knowledge-based service with great market potential. To cite just one example, Batelle (2006) has identified the 'top ten 'technologies in a number of fields, including in strategic technologies to 2020. These are:

- Genetic-based Medical and Health Care
- High-power energy packages
- Green Integrated Technology
- Omnipresent Computing
- Nanomachines
- Personalized Public Transportation
- Designer Foods and Crops
- Intelligent Goods and Appliances
- Worldwide Inexpensive and Safe Water
- Super Senses.

A different approach has been adopted by the Microsoft Research Institute in their report 'Towards 2020 Science' (2006). This study sought to identify the requirements necessary to accelerate scientific advances - particularly those driven by computational sciences and the 'new kinds' of science the synthesis of computing and the sciences is creating. Already this synthesis has led to new fields and advances spanning genomics and proteomics, earth sciences and climatology, nanomaterials, chemistry and physics.

The authors noted: "this report is *not* about attempting to predict or 'forecast' it. Instead, our starting point was simply to consider what we believe are some of the greatest challenges and opportunities for the world in the 21st century that urgently require advances in science to address. From there, we considered how computing and computer science needs to, and can, play a vital role in realizing such advances, starting from how even current applications of computing and computer science are already having an important impact on science and consequently on society. Finally, we considered what needs to happen in computing and computer science - as well as in science policy and in education - to accelerate advances in the sciences that can then help address key global challenges towards 2020."

3. General Approaches to Future Key Technology Identification

While these examples show there are a variety of approaches to the identification of key technologies, a number of generalizations can be drawn, in particular about the criteria of importance, the level of aggregation, and the policy relevance.

With regard to the criteria that are used to identify key technologies, there is considerable variation. Remarkably, the process for the US critical technology exercises were determined by legislation: the Defense Authorization Act which was an amendment to the National Science and Technology Policy, Organization, and Priorities Act 1976. The legislation mandated the preparation and submission to the President and the Congress of a biennial report on the nation's critical technologies through the year 2000, and that a panel of 13 experts, seven from government and six from industry or academia.

Wagner and Popper (2003) note: "Unlike the practices in other countries undertaking a review of nationally important technologies, the critical technologies panels and the staff supporting them did not use formal forecasting or survey methods to arrive at the list of technologies... The first two panels took their charge as one of determining among themselves, based on their expertise, the list of critical technologies. The third report drew from a larger group of experts, but, similarly, did not use any specific method to determine what should be on the list. The fourth report used a face-to-face interview method based on 14 questions to elicit from experts both nominations for important technologies as well as broader views on where within the system these technologies should be developed and how government creates the infrastructure for innovation."

The criteria applied in producing four reports on critical technologies in the period 1989-99 were a mix of significance for the trade balance and for defence security, together with the potential of emerging technologies to develop into commercial products. The first report identified six broad categories of critical technologies: materials, manufacturing, information and communications, biotechnology and life sciences, aeronautics and surface transportation, and energy and environment. The second report expanded on the list by exploring national capabilities in nine 'economically important technology-intensive industrial sectors'. The third report contains a large list of over 100 technologies broken down into more specific sub-categories. The fourth report lists eight technology fields that are critical because they either have "cross sector ubiquity" or they appear at the interstices of various important sectors.

In summary, the criteria used in the US to identify critical technologies are largely regarded as self-evident, easily recognizable by appropriate experts. The more recent US National Intelligence Council report on *Mapping the Global Future,* described above, appears to follow the same approach, though introducing a more global focus, and using the powers of the Internet to engage more people in consultation.

Similarly, there does not appear to be explicit criteria used in the Japanese Delphi studies. The process of formulation of the many topics is based on expert opinion and detailed review, but ultimately appears to be the product of collective informed judgement.

In contrast, in the UK, Keenan (2003) notes the considerable attention to formalizing criteria to identify key technologies. Thus, "the term 'generic' could have at least three distinct meanings: (1) a class of closely related technologies; (2) a technology the development of which will have implications across a range of other technologies; or (3) a technology the exploitation of which will yield benefits for a wide range of sectors of the economy and/or society.

According to Martin (1993), 'Of the three possible definitions put forward above, one could argue that definition (1) represents the strict or traditional definition of "generic". [However], as far as the UK Government is concerned, what is of most interest is category (3). One reason for assuming this is that these will tend to be more disaggregated or specific than category (1) technologies and therefore more useful for policy purposes. In addition, it is precisely for technologies likely to yield benefits across a range of sectors that the "market failure" rationale can be used to justify some government support in the early stages of their development.'

On the use of the term 'emerging', the following definition from the US Department of Commerce was quoted in Martin (1993): 'An emerging technology is one in which the research has progressed far enough to indicate a high probability of technical success for new products and applications that might have substantial markets within approximately 10 years.'

Reflecting these arguments, six criteria were applied in the first UK foresight study - economic or social demands/opportunities, the ability of the UK to exploit those opportunities ahead of other countries, scientific opportunities, scientific strengths and weaknesses of the UK that will affect its ability to take advantage of the scientific opportunities compared with other countries, cost and timeliness.

This approach clearly has the value of the criteria for selection being explicit. However, as Keenan (2003) shows, the translation of these criteria into practical judgements still raised many problems.

Hence, it must be concluded that attempts to identify critical technologies at anything more than the most generic level reflecting an agreed likelihood to have great promise and potential for exploitation (as in the current worldwide focus on nanotechnology) have had limited success. The widespread hunt in the market place to identify the "killer application" of a technology reflects the difficulty in doing just this, and the intensive interaction in the marketplace necessary for such a technology application to emerge.

Another issue is the level of aggregation which is to be applied. Statements that nanotechnology, or renewable energy technologies are likely to have a significant impact on addressing future issues and will lay the foundation of new industries provides only the most limited intelligence, and no direction at all ascot what to do about it.

Again, Keenan (2003) notes: "Attempts at identifying critical technology lists in other countries have highlighted the problem of defining discrete technology areas to prioritize, i.e. what should be the degree of disaggregation or 'granularity' of technology to be considered? This is a question of compromise, requiring consideration of two opposing tendencies: (1) a desire to generate a list of technologies detailed enough to yield specific policy implications; and (2) a need to avoid generating an inordinately long and complex list that would require excessive amounts of effort to appraise.

I believe it can be concluded that identification of critical technologies at the generic level serves the useful, but limited role of a signpost, raising awareness of the potential associated with an emerging area of science or technology. At the more detailed level, specific applications emerge as a result of the effort and insights of individuals and companies. In between these two, there is a place for technology roadmapping where companies can cooperate to identify a variety of technology trails to the achievement of identified capabilities.

A third issue is policy relevance. Keenan's (2003) detailed analysis of the UK Foresight exercise noted that "Foresight has undergone a shift in emphasis, away from identifying and ranking priorities towards an exercise focused upon the development of networks between disparate communities." The generic priorities identified by the Steering Group were not readily translatable into policy action. Rather, "the more focused priorities of the sector panels were better suited to perceptible follow-up action, including network-building." Indeed, it was the business managers on these panels that formed a ready-made implementation vehicle whenever they identified potential advantage for their companies.

4. Assessing the Impact of Foresight on Decision-Making

Georghiou and Keenan (2006) have noted the difficulty of assessing the impact of foresight exercises, among other reasons because of the different rationales for different projects, and for different actors in the same project. Thus, "some common stated goals for foresight are:

- *Exploring future opportunities so as to set priorities for investment in science and innovation activities...*
- *Reorienting the Science and Innovation System...*
- *Demonstrating the vitality of the Science and Innovation System*
- *Bringing new actors into the strategic debate...*
- *Building new networks and linkages across fields, sectors and markets or around problems."*

In order to assess the impact of a particular foresight exercise it is crucial to identify what is the goal, or combination of goals, that is being pursued through the application of foresight.

This difficulty is particularly apparent when addressing national foresight projects. A special issue of the Journal of Forecasting published in 2003 contains a number of papers which attempt to assess the impact of various national foresight studies.

Thus, Keenan (2003), in his detailed analysis of reasons for the limited impact of the UK foresight exercise, reached the conclusion. Among others, that: "There is an inherent tension here between (a) a desire to identify topic areas sufficiently focused as to yield specific policy implications and (b) a need to avoid generating an inordinately long list of topic areas requiring excessive amounts of effort to appraise. This tension is particularly acute at the national level, simply because of the breadth and possible number of potential topic areas. From our account of the UK Technology Foresight Programme, it is apparent that this tension was never satisfactorily resolved. This resulted in the SG being criticized for identifying generic topic areas that were too broad to yield specific policy implications."

Durand (2003), in his report of the French 'key technology 2005' foresight exercise, noted the aim was: "to (a) identify technologies potentially important for the future of Europe, (b) evaluate how critical these may be, and (c) for each of the most critical technologies, position the relative strengths of France and Europe versus world competition." While 120 key technologies were selected, they were "not stand-alone items. They combine and recombine in unexpected ways. Key Technologies were thus qualified as 'meeting points' or 'roundabouts', connecting items from many different origins."

As I have noted previously (Johnston, 2002): "it must be acknowledged that for a great many foresight projects, particularly those at the foundational stage with an emphasis on learning, creating a stronger future orientation, and building networking, it is extremely difficult to identify any direct policy impact.

In some cases this may be because the studies have little intrinsic value to the policy process. In others, the key policymakers have not been involved - a problem of communication. In still others, the nature of the product and the process can be best considered as infrastructure in support of policy, rather than a direct contributor, in the same way that the collection of reliable statistics may contribute to improved decision-making.

Hence, it is apparent that in order to assess the contribution of foresight to policy and planning, we need more than a simple empirical measurement. Indeed, the notion that a simple empirical assessment can be conducted has proven illusory. The systems are too complex, the number of intervening variables too many. Rather, we need to establish a framework that will assist in understanding the structures and dynamics of each of the arenas – foresight and policy and planning, and their inter-relationship."

The conclusion that can be drawn from these and other findings is that it is likely to be far easier to identify and demonstrate the impact of a foresight study if it has quite specific and limited objectives. As a consequence national foresight studies probably represent 'the most difficult case' in terms of clear demonstration of impact. For these reasons, the case studies reported in the next Section are all modest in scale, focus on a particular sector, and had precise objectives. They also are foresight projects the author was closely involved in, and hence is in a position to apply insider knowledge.

5. Case Studies of the Impact of Foresight on Decision-Making

5.1. Advanced Medical Devices

There is a substantial medical devices industry in Australia. In 2002-03, it comprised almost 2000 establishments, generated revenues of $832 million, imported goods worth $1.9 billion and employed more than 5,500 people. It is characterized by high levels of expenditure on research and development, a highly specialized and skilled workforce, predominantly small to medium-sized enterprises, a significant degree of fragmentation, or limited coherence, and a small number of globally recognized products/companies.

In order to strengthen this industry, the Minister for Industry, Tourism and Resources called on the industry in 2004 to develop a coherent 'Action Agenda' which would provide the medical devices industry sector with an opportunity to position itself for future growth and sustainability (DITR, 2005).

Action Agendas are a central element of the Government's industry strategy. Their primary purpose is to foster industry leadership in developing strategies for growth, agreeing on priorities and making commitments to change. The focus in Action Agendas is on the actions industry itself can take to achieve its objectives. Whole of government access is provided in addressing major issues including: innovation, investment, market access and development, regional development, education and training, environmentally sustainable development, workplace relations and regulatory reform.

Scenario planning was used to address the agreed objectives of:

- considering the major forces likely to shape the future of the Australian medical devices industry over the next twenty years (to 2025);
- identifying major threats and opportunities;
- developing viable scenarios of the future of the Australian medical devices industry; and
- developing strategies addressing these possible futures to guide decision-making and provide a sound basis for the Action Agenda.

The outcomes of this foresight project include the commitment of all major companies in the industry sector to a shared vision of the future of the industry based on developing world-class capability, increasing speed to market; and expanding market opportunities. The Government has committed funding through a number of programs to assist the industry to address the major challenges it has identified for the future growth of the sector.

In summary, foresight provided a means of identifying and developing the extent of shared interests between companies in this sector, the basis for constructing a consensual vision of the future, the opportunity for an industry cluster to begin to emerge, particularly through joint development projects, and for the attraction of government support. Tangible results in terms of increased exports are expected to be visible in the financial year 2007-08.

5.2. Future Housing

The origin of this foresight project began with the realization by the representatives of the Copper Industry in Australia that, with the emergence of new technologies, it was important to look ahead to the changes that were likely to occur over the next 20 years in one of its largest market sectors – the Building Construction Industry, which uses up to 60 per cent of the world's total copper output each year. The results of such a futures study would enable technology suppliers, both within and outside the copper industry, to focus better on future opportunities and to develop their products to meet the emerging market.

In 2004, the Copper Development Centre of Australia (2005) signed an agreement with the Australian Department of Industry, Tourism and Resources to collaborate on this industry-led, government-supported undertaking. Its objective was to explore new and emerging technologies as they will affect the infrastructure and building construction industries in 20 years' time, with particular reference to home building.

The foresight process used relied on input from a variety of different groups of experts within a structure defined by four alternative scenarios of the future. The first stage involved 40 futurists and strategic planners from industry, academia, government instrumentalities and professional societies in examining the likely major trends and key characteristics of dwellings during the next 20 years under the four different scenarios.

The second stage involved industry experts in exploring the future 'last kilometre' of infrastructure services to and within the property, including electricity, gas, water and cabling for the delivery of information, communication and entertainment, again under the four different scenarios. Ten key characteristics of future housing were identified, including flexibility of form, efficient water and energy management, and high grade telecommunications capabilities supporting security, health, shopping, education, work and entertainment, smart services and self-diagnosis and maintenance.

The third stage required technology experts to examine the enabling technologies that would address these ten key characteristics. In the final stage the trends and enabling technologies underlying the ten characteristics were ranked to facilitate identification of market opportunities and the challenges in achieving them.

A specific outcome of this foresight project is the formation of a number of cross-industry working groups to pursue the opportunities presented. In at least two cases, the development has reached the stage of intellectual property negotiations prior to moving on to design and manufacture.

5.3. Future of Irrigated Agriculture

The objectives of the project were to:

- Enable key stakeholders to develop a shared vision for the future of irrigation in a major catchment area over the next 30 years and to identify major constraints and opportunities and regional response options;

- Understand the social, economic and environmental consequences of various scenarios through impact assessment;
- Build a consensus on preferred regional options for future irrigation, and recommend regional follow-up actions; and
- Develop a methodology that can be applied elsewhere in Australia for sustainable irrigation planning at a catchment scale.

Key features of the project were:

- The structured combination of hindsight, insight and foresight - the process prepared for consideration of possible futures by an examination of the past, and engaged the participants in identifying community aspirations prior to considering possible futures
- A 'slow' foresight process, with intensive stakeholder engagement over two years
- Deep embedding in existing decision-making structures
- Relying largely on local/regional expertise
- A regional economic development focus with local and regional planning authorities as the major clients
- A developmental approach based on adaptive management
- Avoidance of pre-determined scenario logics to define the key characteristics of the scenarios to be developed
- Generation of a manageable number of scenarios by a separate process based on the interaction of a Narrative team and an Analytical team
- Modelling of the quantitative consequences of each scenario
- A wide range of outputs tailored for different sectors of the stakeholder community
- Explicit consideration of the implications of the scenarios for regional stakeholder organizations in their planning

Specific outcomes of this project include:

- The organization responsible for water supply and management is planning for a major reconfiguration of the irrigation distribution system to dramatically increase flexibility based on scenario implications;
- The catchment management authority is reshaping its five-year plan for catchment management to meet the major contingencies that emerged through the scenario planning process
- Local Councils examining the implications of the scenario conditions for their land-use planning, and economic and demographic projections

These case studies illustrate the practical implications of appropriate foresight exercises on planning and decision-making. They are characterized by a clear and shared focus, engagement of relevant stakeholders, embedding of the foresight in the existing planning and decision-making structures, and explicit outcomes.

6. Application of Foresight to Industry

The use of foresight in industry has been widespread, though typically less reported than for the public sector (Kuhls and Johnston, 2006). Thus, the UNIDO Technology Foresight Manual (2005) reports: "In the last two decades several large enterprises in such diverse sectors as energy, automotive, telecommunications and information technology have established foresight groups and strategic planning processes, which analyse the long-term prospects of new technologies and their impact on markets and corporate strategies. DaimlerChrysler's Society and Technology Research Group (STRG) is one of the first future research groups to be established within a company. Since 1979 it has investigated, in close cooperation with its customers, the factors shaping tomorrow's markets, technologies and products."

A survey of 18 major European firms with substantial R&D budgets in highly competitive sectors (Becker, 2002) revealed that all were engaged in foresight, with a focus on technology trends, or market trends, or both. There were two principal reasons given: either they are a consequence of a companies' business operation which inherently demand such a long-term orientation (as in industries with long product cycles), or they are undertaken as a proactive step to better cope with uncertainties in the business environment in general.

Five major objectives of corporate FTA have been identified (Becker, 2002, p. 9):

- Anticipatory intelligence, i.e. providing background information and an early warning of recent developments
- Direction setting, i.e. establishing broad guidelines for the corporate strategy
- Priority setting: i.e. identifying the most desirable lines of R&D as a direct input into specific (funding) decisions
- Strategy formulation, i.e. participating in the formulation and implementation of strategic decisions and
- innovation catalysing, i.e. stimulating and supporting innovation processes between the different partners

In a review of their foresight activities, Daimler-Chrysler concluded:

- Foresight and future-oriented projects (beyond conventional strategic planning) have developed from a "nice to have" status to a "we commit to";
- Small and medium-sized companies might benefit strongly from foresight programs, trainings, initiatives etc. supported by national, regional and trans-regional programs;
- Education, training and consulting is necessary to enable newcomers to conduct foresight-related projects;

- Instead of setting up intricate evaluation and controlling schemes for foresight projects "client satisfaction" and "demand for more" should be lead principles in evaluation. (Ruff, 2007)

There remain many opportunities for the more extended application of FTA in the business sector. In the traditional area of strategic planning, FTA approaches have much to offer in the development of visions and goals, in the analysis of the environment external to the organization and the opportunities and threats it may pose in the future, and in the development of strategic intelligence. In risk management, there are enormous opportunities for the better identification of potential future risks, and of the stakeholders who may be affected.

7. Conclusions

The growing application of foresight in the public and private sectors has been demonstrated, and evidence of specific contributions to strategizing, planning and decision-making identified. But while technology is a key driver of future competitive advantage, it is not the only one. More importantly, the ways in which technology generate new capabilities are profoundly shaped by the socio-economic context and the capacities of innovation systems – the supportive environment within which technologies are shaped, identified and refined.

In an earlier paper, the role of foresight in "wiring up the innovation system" was emphasized (Martin and Johnston, 1999). Our understanding of innovation has moved profoundly away from linear models where the emerging technology determines its future application and impact. Developing this idea, Georghiou and Keenan (2006) emphasize that the rationale of foresight needs to be understood in terms of addressing system failure. Thus:

> "This move away from the linear model of innovation in itself reinforces the current understanding that foresight needs to be an activity closely engaged with wider socioeconomic trends. Typical questions addressed of foresight as an instrument of innovation policy under this rationale would be:

- Whether the support helps to overcome a lock-in failure by introducing a firm to a new or extended technology or market area? In this case the firm, without the benefit of public intervention through foresight, receives signals only from its own market and existing technological networks and misses the major threats and opportunities coming from beyond these horizons;
- Whether the support is building new networks or coordinating systemic innovations such as those requiring establishment of standards, either between firms or between firms and the science base? Again historical factors may have created certain configurations and relationships which could be deficient in supporting the emergence of a new idea or area. Foresight can be used to build the new social structures, especially in the context of the more distributed and open innovation systems referred to in the definition above."

A second element that needs to be understood is that foresight does not attempt to abolish uncertainty. Rather, it provides a potentially robust social process for acknowledging and addressing uncertainty:

> "When discussing the future course of technology, whether from the perspective of public or private concerns, we are touching upon matters of profound uncertainty. Our lack of understanding of future technology courses is not owing to a failure of due diligence; it is inherent in the processes we are seeking to harness. This deep uncertainty is the bane of our usual practices in strategizing and planning. What is ideally required in such circumstances is to employ methodologies that will allow us to frame plans that are both adaptive in their design and robust against a range of alternatives... once we make explicit acknowledgement of the presence of uncertainty, it becomes clear that the issue is not how to reduce that uncertainty but how to conduct ourselves in its presence. Clearly, foresight then may be seen for what it is-or ought to be in practice. Not an attempt to predict, forecast, or otherwise put a name on the future and therefore reduce the anxiety we experience in its presence, but as a means for reasoning about robust, adaptive strategies." (Wagner and Popper, 2003)

There is no question that emerging technologies are driving forces for economic development and competitiveness. There is equally no question that the form and path of development these technologies will take is a result of multiple interactions between the many players, institutions, regulations and practices that form part of the dense and complex innovation system.

For companies, as for governments, advantage arises not from knowing the future with certainty, but having developed robust and adaptive processes and systems that allow some sense to be made of how the future might unfold, that provide the capacity to monitor and identify at an early stage new contingencies, and that have a deep organizational capacity to respond to and take advantage of these changes.

References

Batelle Technology Forecasts, *Strategic Technologies for 2020,* 2006, http://www.battelle.org/forecasts/technology2020.stm, accessed 5 July 2007.

Becker, P. (2002), *Corporate Foresight in Europe: A First Overview*, Working Paper, European Commission, available at ftp://ftp.cordis.lu/pub/foresight/doc/st_corporate_foresight_0401 09.pdf.

Copper Development Centre of Australia, *Building Construction Technology Roadmap*, 2005, http://www.copper.com.au/cdc/technology_roadmap/roadmap/index.html, accessed 9 July 2007.

Cuhls, K., and Johnston, R., 'Corporate FTA', Anchor Paper, Proceedings of the Second FTA Seville Seminar, *Future-Oriented Technology Analysis: Impacts on Policy and Decision Making*, IPTS, 2006.

Department of Industry, Science and Resources, *Technology Planning for Business Competitiveness: A Guide to Developing Technology Roadmaps*, Emerging Industries Occasional Paper 13, Canberra, 2001.

Department of Industry, Tourism and Resources, *Medical Devices Industry Action Agenda: Discussion Paper*, Canberra, May 2005, http://www.industry.gov.au/content/itrinternet/cmscontent.cfm?objectID=846E5372-65BF-4956-BA4E09561F266D13, accessed 9 July 2007.

Durand, T., 'Twelve lessons from 'Key Technologies 2005': The French technology foresight exercise', *Journal of Forecasting*, Mar/Apr 2003. Vol.22, Issue. 2/3; pp.161-178.

Garcia, M.L. and Bray, O. H., *Fundamentals of Technology Roadmapping*, Sandia National Laboratories, Albuquerque, 1997.

Georghiou, L., 'Third Generation Foresight: Integrating the Socio-economic Dimension', *Proceedings of the International Conference on Technology Foresight – The Approach to and Potential for New Technology Foresight*, NISTEP Research Report, Tokyo, Vol. 77, 2001.

Georghiou, L., and Keenan, M., 'Evaluation of National Foresight Activities: Assessing Rationale, Process and Impact', *Technological Forecasting and Social Change*, Vol. 73, 2006, pp. 761-777.

Giesecke, S, *Futur – the German Research Dialogue*, EFMN Foresight Brief No. 001, 2006, http://www.foresight-network.eu/index.php?option=com_docman&task=cat_view&gid=15&dir=DESC&order=number&limit=5&limitstart=90, accessed 6 July 2007.

Industry Canada, http://www.strategis.ic.gc.ca/epic/site/trm-crt.nsf/en/h_rm00051e.html, accessed 6 July 2007.

Johnston, R., 'The State and Contribution of International Foresight: New Challenges', The Role of Foresight in the Selection of Research Policy Priorities, IPTS Seminar, Seville, 13-14 May 2002.

Keenan, M., 'Identifying emerging generic technologies at the national level: The UK experience', *Journal of Forecasting*, Vol.22, Issue. 2/3; pp.129-160. 2003.

Martin B., *Research Foresight and the Exploitation of the Science Base*, HMSO: London, 2003.

Martin B.R., and Johnston R., 'Technology Foresight for Wiring Up the National Innovation System - A Review of Recent Government Exercises', *Technological Forecasting and Social Change*, Volume 60, Number 1, pp. 37-54, 1999.

Microsoft Research, *Towards 2020 Science*, available at research.microsoft.com/towards2020science/

National Intelligence Council, *Mapping the Global Future*, Washington, DC, 2005, http://www.dni.gov/nic/NIC_2020_project.html, accessed 6 July 2007.

NISTEP (National Institute for Science and Technology Policy), http://www.nistep.go.jp/index-e.html, accessed 5 July 2007.

Ruff, F., 'Current and Future Applications of Foresight in Industrial Enterprises', UNIDO 2007 Expert Group Meeting, Vienna, 29 May 2007, http://www.unido.org/file-storage/download/?file_id=67569.

Silberglitt, R., Anton, P., Howell, D., and Wong, A., *Global Technology Revolution 2020*, EFMN Foresight Brief No. 090, 2006, http://www.efmn.info/kb/efmn-brief90.pdf, accessed 5 July 2007.

UNIDO (2005), *Technology Foresight Manual*, Vienna, available at http://www.unido.org/data/forms.cfm?formcode=TFMANUALREG.

Wagner, C.S. and. Popper, S.W., 'Identifying Critical Technologies in the United States: a Review of the Federal Effort', *Journal of Forecasting*, Vol. 22, Issue 2/3, pp.113–128, 2003.

Key technologies for Czech National Research Programme

Karel Klusacek

Abstract

This contribution brings an overview of an ongoing foresight project in the Czech Republic. The main objective of this foresight-based initiative is identification and formulation of key technologies (research themes) for the National Research Programme III (2009 - 2014). Methodology used for this exercise combines analytical desk research, work of multidisciplinary panel of experts, exploratory and normative scenario building and it considers also a prioritization procedure based on multicriterial assessment of technologies suggested by experts. Results of this foresight initiative will help to identify priority thematic areas for financing research in new research capacities built in the Czech Republic within the time period 2007 – 2013 using investment resources based mainly on the EU Structural Funds.

Key words

Key technologies, research priorities, foresight, scenarios, expert panels, EU Structural Funds

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Karel Klusacek is Director of the Technology Centre AS CR. His main professional interests include studies of various aspects of research and innovation, foresight, identification of research priorities and formulation of regional innovation strategies. He is President of the Czech Society for Promotion of Technology Transfer, Czech delegate of the Scientific and Technical Research Committee (CREST) of the European Commission and member of the Czech Engineering Academy. He has recently coordinated several international and national projects in the area of technology transfer, foresight, business incubation, knowledge-based competitiveness and regional innovation strategy. Mr. Klusacek manages national project "Strategic Studies for Research and Development" focused on providing strategic information to policymakers. In 2001 – 2006 he was the coordinator of two cycles of the Czech National Foresight Exercise.

1. Introduction

About 25 per cent of public expenditure on research and development in the Czech Republic are allocated through the National Research Programme (NRP). The main objective of the NRP is to support key research directions (research in key technology areas) having a strong potential to contribute to a favourable economic development and to the satisfaction of societal needs. The first National Research Programme (NRP I) was launched in January 2004. It was based on a national foresight exercise [1] conducted in 2001-2002. Due to (temporary) restrictions of public spending on R&D in the Czech Republic in 2004 an additional work was performed to focus NRP more on practical research results - wide consultations with application sector were carried out. The updated NRP has been formally renamed to National Research Programme II.

With a renewed rise of public spending on R&D and with opening of a part of Structural Funds EU (2007-2013) for investments in research and innovation infrastructure, the Czech Government formulated a request to prepare a new National Research Programme III (NPR III). The NRP III will be launched for the time period 2009–2014, i.e. application horizon for research results is to be considered in the time frame 2015-2020. The NRP III is also to be a financial source for funding research to be carried out in research capacities built under the co-financing from the EU Structural Funds in the programming period 2007-2013.

The Ministry of Education of the Czech Republic (responsible for R&D in the Czech Republic) entrusted the Technology Centre AS CR with coordinating a foresight-based project leading to identification and formulation of key (priority) research themes (technologies) for the NRP III. Thematic part of the project (completed in June 2007) is to be followed by work at the Ministry of Education focused on preparing a system for organization, management and supervision of the NRP III. The proposal of the NRP III will be submitted to the Czech Government for approval in March 2008.

2. Methodology

The Foresight methodology used in this work can be characterized as a problem-oriented multi-disciplinary approach consisting of several methodical steps:

- Analytical desk research;
- Work of multidisciplinary panel of experts - about 70 people from a wide spectrum of scientific disciplines (ranging from socio-economic fields to technical areas);
- Exploratory and normative scenario building;
- Prioritization procedure based on multicriterial assessment of themes suggested by experts;[28]

[28] Prioritization procedure is considered for reduction of the set of initial research themes

- Combination of a back-cast look (analyses) and forward looking (scenarios generated by experts);
- Formulation of thematic priorities of the NRP III.

With regard to the objective of the project the thematic sectors corresponding to the NRP III priorities should take the following main aspects into account:

- Above-average and excellent fields of both theoretical and applied research;
- Fields dominant in international cooperation in research;
- Fields having demand for research infrastructure development (EU Structural Funds);
- Distribution of R&D funding and its dynamics;
- Development of economic structure of the Czech Republic since 1990.

2.1. Analytical desk research

Analytical stage preceded work of the expert group. The main purpose consisted in creating a background map, specifying the needed expertise and R&D segments corresponding to the priorities for the NRP III:

- R&D analysis:
    - R&D output - scientific publications, patents;
    - allocation of R&D funds;
    - innovation potential of Czech regions;
    - topics of projects proposed as preliminary intentions for drawing financing from the EU Structural Funds through the Operational Programme R&D for Innovation (2007-2013);
    - international cooperation of the Czech Republic in R&D, especially in the EU Framework Programmes;
    - analysis of the NRP I and NRP II course of development and their results.
- Structural analysis of the Czech economy
- Analysis of human resources for R&D
- Review of strategic R&D documents

2.2. Panel of experts

About 70 experts were invited to participate in the panel of experts constituted for this foresight exercise. Thematic specialization of invited experts followed from results of the preceding analytical stage of the project. The main objective of experts' work consisted in identifying key opportunities and challenges for the Czech Republic in the time horizon 2015-2020,[29] to the solution of which research

(technologies) formulated by experts.

[29] It is assumed that the application interval of the NRP III will last about 5 - 6 years after its termination in 2014.

supported from the NRP III may contribute, and identifying key thematic research directions.

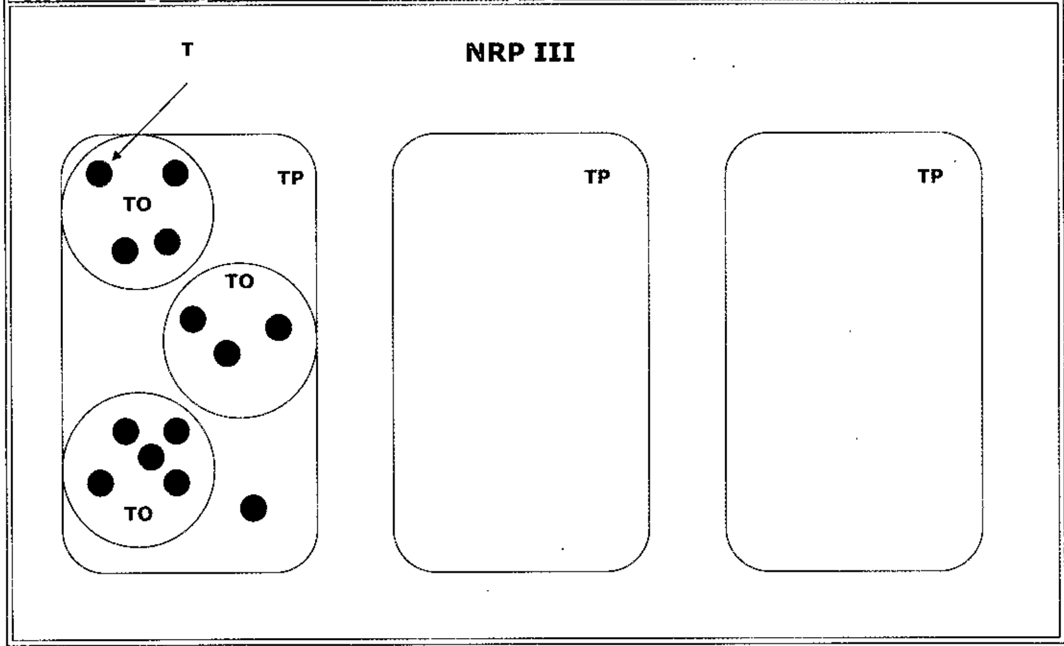
First, the experts were asked to suggest key themes from their research field and outline a likely scenario for each theme, resulting in a probable future state regarding the theme suggested. Probable future state indicated opportunities and threats (problems) for the Czech Republic in the time horizon considered. To allow for a final summary and evaluation of scenarios prepared by experts from different thematic fields the experts followed a general template structure provided by the coordinator (team of the Technology Centre) of the project:

- Theme proposed;
- Probable future development: locally and abroad, a likely situation in the Czech Republic in 2015-2020, consequence(s) of such a development;
- Objectives achieved and benefits for the Czech Republic should either the opportunity be exploited or the threat avoided;
- Research to be supported related to the theme.

A project-dedicated website was developed to support communication among experts. Each expert published his/her theme on this website and all other experts had an on-line access to it with an opportunity to make remarks and recommendations. Their input was edited by the coordinator in cooperation with the author of the original theme. Some themes and scenarios were prepared jointly by experts from different fields (e.g. molecular biology, IT and social sciences). On-line discussion among experts regarding individually prepared scenarios and their joint work on some scenarios created conditions for a multidisciplinary approach needed for complex research tasks specified by experts.

Once the themes were collected they were sorted/grouped in cooperation with the panel into thematic areas which would represent the main level for opening calls for project proposals for the National Research Programme III. Some issues were discarded after discussion with experts to reduce thematic width of the NRP III. The structure of the NRP III is illustrated by the following Figure 1.

Figure 1. Schematic depiction of the hierarchy of the National Research Programme III: Themes (T) are grouped in Thematic Areas (TO), which are further grouped in Thematic Priorities (TP).



At this stage, the experts were asked to outline normative scenarios related to the areas of grouped issues in terms of suggesting what to do so that the future opportunity is exploited for a maximum benefit or the expected threat is minimized or even avoided. Normative scenarios were concealed in the structure of the template:

- Situation in the Czech Republic and abroad;
- Description of the desired state (regarding the issue) in 2015-2020;
- Objectives to be achieved, and their justification;
- Expected benefits;
- Research to be supported so that the objectives are met;
- Measures needed so that the objectives and the desired state in the future are achieved (exploitation of opportunities – suppression of threats).

2.3. Multicriterial assessment of themes

From methodological point of view there is always a possibility in exercises looking for priorities that experts suggest an excessive number of initial topics/issues to be included in the final priority list. A rational and transparent selection procedure is a difficult task. In this project reduction of initial set of themes suggested by experts has been achieved through a comprehensive discussion of themes in the group of experts. Nevertheless, due to budget restraints for the NRP III the Ministry of Education may still require further reduction of themes suggested in the final stage of the project. For such a case a multicriterial assessment of themes is considered. A similar assessment was used for selection of priority research themes in the first

Czech foresight exercise in 2001 which led to formulation of the National Research Programme I. The procedure is based on an assessment of each particular theme against a set of criteria. Criteria are usually arranged into groups which are aggregated into a low number (usually 2) of final parameters, e.g. "importance" and "feasibility". The prioritization procedure is looking for maximum values of both final parameters. The multicriterial analysis outlined briefly here is described in detail in literature [2].

2.4. Results

Using the methodology outlined in the above section thirty-one thematic areas were defined and these were grouped into four thematic priorities for the purpose of administering the NRP III. Description of the full structure of the NRP III (including thematic areas and individual themes) is beyond the scope of this concise contribution. Summary of the final project report including the detailed structure of the NRP III is to be published on the website www.foresight.cz after the project completion by the end of 2007. Brief information on the structure of NRP III (cf. Fig. 1) is summarized in the following Table 1.

Table 1. National Research Programme III – thematic priorities and thematic areas

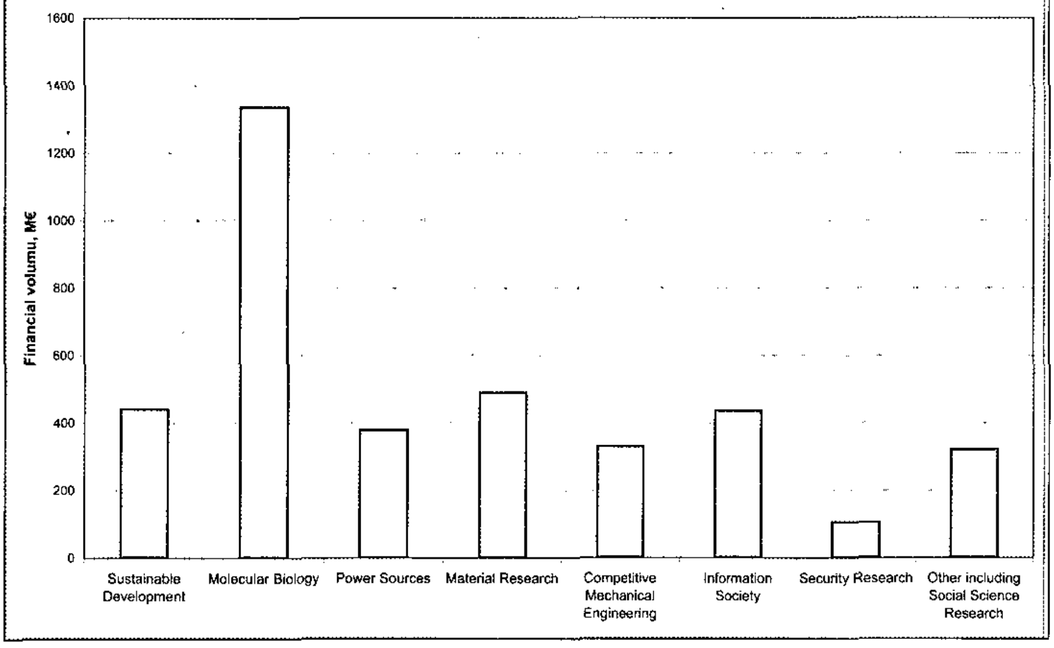
1. Research and Development for a Competitive Industry	2. Molecular Biology for Health and Prosperity	3. Information Society	4. Society and Environment
1. A. Alternative Energy Sources 1. B. Nuclear Energy 1. C. Increasing Effectiveness of Power Systems and Networks 1. D. Integrated Mechanical Engineering 1. E. New Production Technologies, Machines and Devices 1. F. Competitive Transport *Mechanical Engineering* 1. G. Nanomaterials, Nanostructures and Nanotechnologies 1. H. Microstructures and Components 1. I. New Materials for Increasing Competitiveness	2. A. New Analytic and Diagnostic Methods 2. B. New Treatment Methods and Drugs 2. C. Advanced Biotechnologies 2. D. Genome and Proteome in Health and Illness	3. A. Intelligent Environment 3. B. Advanced Robotics 3. C. Computer Modelling and Simulation 3. D. Monitoring and Diagnostic Systems 3. E. Processing and Presentation of Knowledge 3. F. Biomedical Informatics and e-Health 3. G. Intelligent Transport Systems 3. H. Network and Communication Infrastructure 3. I. New Computing and Software Architectures	4. A. Development of Life Quality and Sustainability 4. B. Optimal Land Use 4. C. Food for Healthy Nutrition 4. D. Safe Society 4. E. Protection of Population, Environment and Critical Infrastructure 4. F. Population Trends in the Czech *Republic and Their Political, Economic* and Social Implications 4. G. Governance, Public Administration in the Czech Republic and EU 4. H. Competitiveness of the Czech Republic, Labour Market, Education 4. I. Social Cohesion and Marginalization
LPRD: Power Sources, Competitive Mechanical Engineering, Material Research Input from LPRDs: Molecular Biology, Information Society	**LPRD: Molecular Biology**	**LPRD: Information Society** Input from LPRDs: Molecular Biology, Competitive Mechanical Engineering, Social Science Research, Sustainable Development	**LPRD: Sustainable Development, Security Research, Social Science Research** Input from LPRDs: Information Society

LPRD = Long-Term Principal Research Direction (8 LPRDs were adopted by the Government of the Czech Republic and included in the National R&D Policy in June 2005)

A significant growth of research and innovation infrastructure is foreseen in the next few years (2007-2013) in the Czech Republic. Development of this infrastructure includes in particular building new research capacities. Financing will be provided mainly by using the EU Structural Funds. Total financial volume available for that type of investment in the Czech Republic will reach more than € 5 billion (provided jointly by the Ministry of Education and Ministry of Industry and Trade).

National Research Programme III is supposed to be one of the main financial sources for research carried out in new research capacities created using investments from Structural Funds. General thematic orientation of investments is given by the Long Term Principal Research Direction (LPRD) adopted by the Government of the Czech Republic in June 2005. Recent screening performed by the Czech Council for Research and Development has revealed that there is a large number of potential projects on new research capacities. Their distribution according to LPRD is illustrated by Figure 2.

Figure 2. Thematic distribution of investments into projects aimed at building of new research capacities using Structural Funds in the Czech Republic in 2007-2013



Comparison of Figure 2 with information on structure of the NRP III in the Table I shows thematic links between both financial instruments through LPRD. Investments into new research infrastructure will become operational in the next 3 – 5 years which is matching the assumed launching of the NRP III.

Literature

1. Klusacek K.: *Technology Foresight in the Czech Republic*, International Journal of Foresight and Innovation Policy, Vol. 1, No. 1-2, pp. 89-105, 2004.

2. *UNIDO Technology Foresight Manual, Organization and Methods*, Vol.1, pp. 194-208, United Nations Industrial Development Organization, Vienna, 2005. Available for downloading at http://www.unido.org/doc/5216.

Scenarios and Road mapping for Key Technologies: UK Case Note – Scenario Analysis in Flood and Coastal Defence

Ian Miles

Abstract

The Flood and Coastal Defence (FCD) project of the United Kingdom Foresight Programme was involved a scenario exercise that has been very influential on UK policy. The scenario approach had an extensive prehistory, and its use in a water management context predates FCD. It continues to evolve and influence decision-making in many fields. This study presents an overview of the approach and how it has come to be so influential.

Keywords

Scenarios, flooding, Foresight

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Reference

I Miles, 2007, "Scenarios and Road mapping for Key Technologies: UK Case Note – Scenario Analysis in Flood and Coastal Defence" prepared for UNIDO 2nd Technology Foresight Summit, Budapest, 27-29 September 2007.

1. Introduction: The Case

The Flood and Coastal Defence (FCD) project of the United Kingdom Foresight Programme, a project that ran from 2002-2004, involved an influential scenario exercise. This had an extensive prehistory (including involvement with water management issues), and which continues to evolve within a context where much scenario work is underway.

The current (third) round of the United Kingdom Foresight Programme[1] was launched in 2002. The Programme operates through having a number of projects underway at any one time. Of the five completed projects reviewed in the evaluation, the Flood and Coastal Defence project was both the most expensive (it cost c£1 million) and the one regarded as having the greatest impact. It began in 2002 as a two-year project (the norm for UK Foresight), and its results were launched in 2004. Work conducted for an independent evaluation of the Programme (PREST, 2006) enables us to trace its impacts.

UK Foresight projects tend to be either technology-specific (an approach that often lends itself to roadmapping) or problem-driven. FCD is an example of the latter. "Problems" inherently raise issues that transcend disciplinary and professional boundaries; a great deal of network-building is required in order to secure collaboration and exchange knowledge. Such interdisciplinarity is also seen as essential in the more technology-focused exercises.[2]

FCD was a one-country, nation-wide, study - though generating much data at more regional and local levels. Subsequent work has often involved developing further analyses at local levels – e.g. regional authorities, cities. Much work had already been carried out on flooding by the likes of Defra (the Department of the Environment, Food and Rural Affairs)[3] and the Environment Agency (EA).[4] FCD was conducted by the Foresight Programme, but sponsored by Defra, and distinguished by its integrated analysis of drivers and impacts of flood risk in the UK over a time-scale of 30 to 100 years.

2. The FCD Project

2.1. The Issue

The project aimed to produce a long-term vision for the future of FCD in the UK, addressing (1) how the risk of flooding and coastal erosion might change over the next 100 years, and (2) the best options for government and the private sector for responding to the future challenges. The work was conducted with a time horizon 30 to 100 years into the future. The objectives specified for the project were to:

- Identify and assess the relative importance of drivers which will affect future flood risk;
- Construct a set of risk-based scenarios 30 to 100 years out;
- Provide an overview of responses and when best to use those responses;

- Inform policy and its delivery;
- Consider implications for the future skills base;
- Identify possibilities for knowledge transfer from other areas of science and technology;
- Inform public understanding; and
- Promote effective and enduring dialogue between the science base and stakeholders.

2.2. Societal and economic implications

Flooding and flood management currently cost the UK over £2 billion each year. Around £800 million is spent on flood and coastal defences. Damage caused by flooding creates repair costs of around £1400 million. Climate change is seen as likely to exacerbate risks. The rising values of buildings and their contents imply increasing economic and financial costs, and social costs are incurred by those affected. The flooding issue is situated, too, within ongoing debates as to how and how far society should intervene in natural processes that create wetlands and coastal erosion, and the ecological impacts of either course of action.

2.3. Actors involved

A guiding principle of the current round of UK Foresight is to conduct work where science and technology-related issues require cooperation across government departments. (Earlier rounds of Foresight had underplayed this, focusing more on government-industry dialogue.) FCD thus reported both to a technical expert advisory group and to a high-level ministerial stakeholder group. Strong support was given by the Environment Minister, Elliot Morley. Close links with Defra meant that the Foresight team could rely on that department's commitment to the project.

From the outset, a leading professor devoted himself for one year to the project as a lead expert, clearing his diary of teaching. This is considered to be one of the crucial success factors for the project. Significant human resources were devoted from Defra – about half a person per year in total, spread among 6-7 persons. (This had the added benefit of inculcating "ownership" of the project's process and results).

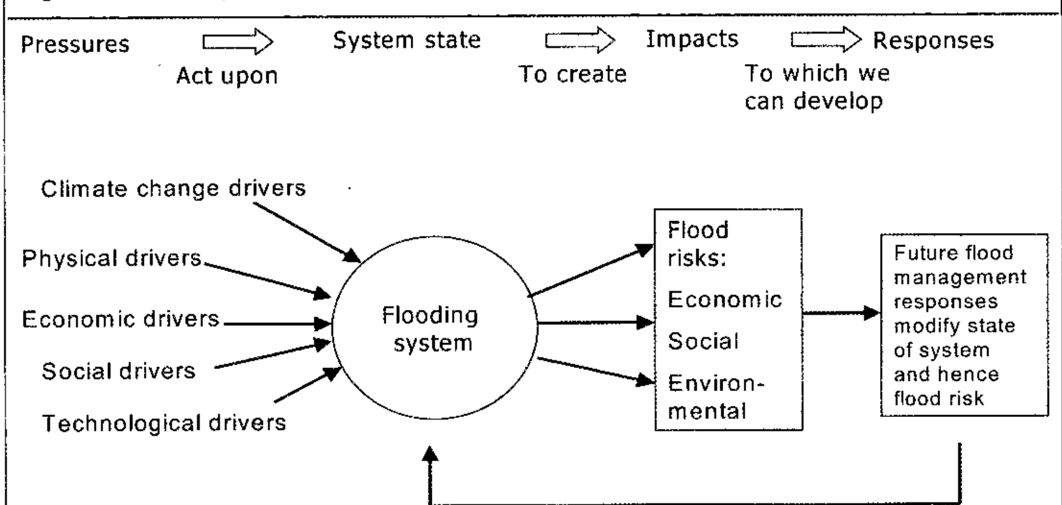
Following earlier experience in UK Foresight, the importance of wider participation was centrally recognized. The project was designed so as to involve a wide range of stakeholders, with the goals of bringing their expertise and knowledge to bear, and securing their commitment to involvement in implementing the action plan. Some stakeholders provided further funding (e.g. a report specific to Scotland was funded by the Scottish Executive) and some provided access to intellectual property (e.g. datasets to underpin the FloodRanger software were made available free of charge).

2.4. The Approach

The methodology was elaborated as the project proceeded, combining various methods - some expert-driven, others more views-based. Whilst the project team needed to prepare detailed plans, they also had to be careful not to stifle creativity – an element of flexibility was essential. A three phase project structure (see Figure 1 below), facilitated flexibility and adaptation to changes in priorities. The three phases were:

- Phase 1 – *scoping the problems* of flooding and coastal erosion; developing methodology for the analysis in subsequent phases.
- Phase 2 – *analysis of drivers and potential impacts* of future flood risk under baseline assumption - existing flood management policies continue unchanged - enabling existing policies to be assessed against future risks, and identification of useful changes. Better understanding of the drivers, their impacts and relationships by adding additional qualitative and quantitative analysis to that carried out in Phase 1. Figure 2 presents some results here.
- Phase 3 – *analysis of responses*: potential changes to flood management and related policies that would improve the management of future flood risk. Different flood management responses will be explored, in order to provide policymakers with indicators as to possible future policy directions. The testing of responses involved assessing the impacts on flood risk of varying these flood management responses, against a background of different futures scenarios, and of uncertain climate change.

Figure 1. FCD Project Structure



Source: OST (2003)

Figure 2. Key Drivers – Degree of Control

DRIVERS — **No control** ⟶ **RESPONSES** — **High control**

GENERAL

• Earth's orbit	• Global values • Global prosperity • Global greenhouse gas emissions	• CAP • EU regulation • National prosperity Public perceptions • Insurance industry	• Urban and rural land use • Building practices	• Flood • defences • Flood forecasting and warning

COASTAL

• Relative sea level rise • Surges • Waves • Coastal morphology and sediment supply	• Land use planning • Increasing storage and infiltration in urban areas • Recovery strategies • Reduced health and wider social impacts	• Forecasting and warning • Flood proofing of buildings and changed construction practice • **Engineering and other large scale interventions**

↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑

Engineering and other large scale interventions
• Physical barriers - raising linear defences
• Energy modulation / harassing
• Morphological protection - maintenance of foreshore levels
• Realignment of flood defence infrastructure
• Abandonment

Source: Compiled from: OST (2003) and Sayers (2004)

A scenarios-based approach was deemed appropriate to the long-term nature of this project, involving integration of the use of two different types of scenario:

- Climate change (CC) or emissions scenarios. FCD used the scenarios developed as the UK Climate Impacts Programme's UKCIP02 climate scenarios.[5] These involve four emissions scenarios: Low, Medium-low, Medium-high and High (Figure 3). Main predictions from the UKCIP02 scenarios relevant to flooding included -
  - o average annual temperatures across the UK may rise by between 2º and 3.5ºC by the 2080s. In general there will be greater warming in the south east of the UK;
  - o annual average precipitation across the UK may decrease slightly, by between 0 and 15 per cent by the 2080s depending on scenario;

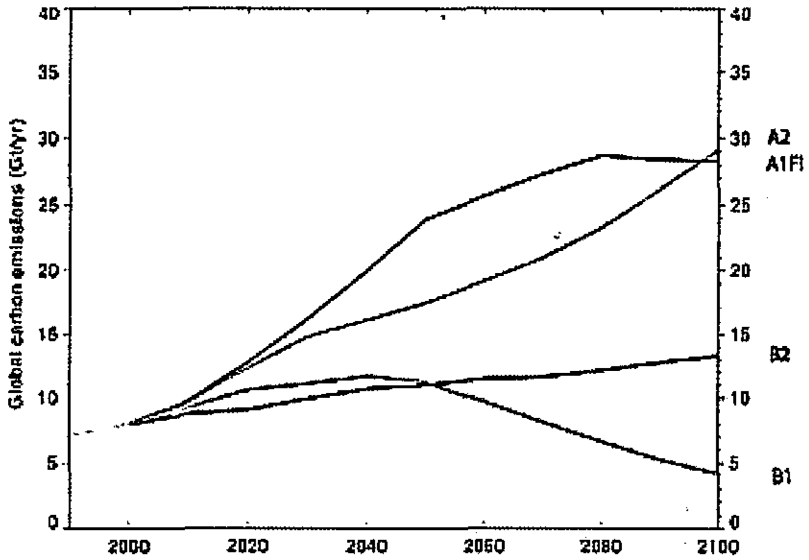
- o the seasonal distribution of precipitation will change, with winters becoming wetter and summers becoming drier, the biggest relative changes being in the South and East. Under the High Emissions scenario winter precipitation in the South East may increase by up to 30 per cent by the 2080s;
- o by the 2080s the daily precipitation intensities that are experienced once every two years on average may become up to 20 per cent heavier. No guidance is given on the effects of climate change on more extreme precipitation events;
- o by the 2080s and depending on scenario relative sea level may be between 2cm below and 58cm above the current level in western Scotland and between 26 and 86cm above the current level in South East England; and
- o for some coastal locations a water level that at present has a 2 per cent annual probability of occurrence may have an annual occurrence probability of 33 per cent by the 2080s for Medium-High emissions.[6]

- Socio-economic (SE) scenarios. The four "Foresight Futures" developed in the first cycle of UK Foresight were employed.[7] They were developed on the basis of literature reviews and stakeholder consultations, with detailed assessments of implications for specific sectors (e.g. of water management issues for the Environment Agency) being developed in workshop settings. Figure 4 outlines these, with the vertical dimension concerning the system of governance (whether power remains at the national level or moving upwards or downwards e.g. to the EU or regional governments), and social values (more or less individualistic or community-oriented values). Table 1 summarizes the key parameters.

The CC and SE scenarios were developed in different way, for different purposes. The emissions scenarios used in UKCIP02 are *global* emissions scenarios. The Foresight Futures make implicit and explicit assumptions about the global situation, but their main parameters are specifically focused on the UK. FCD developed an approximate mapping between the two sets of scenarios (Table 2).

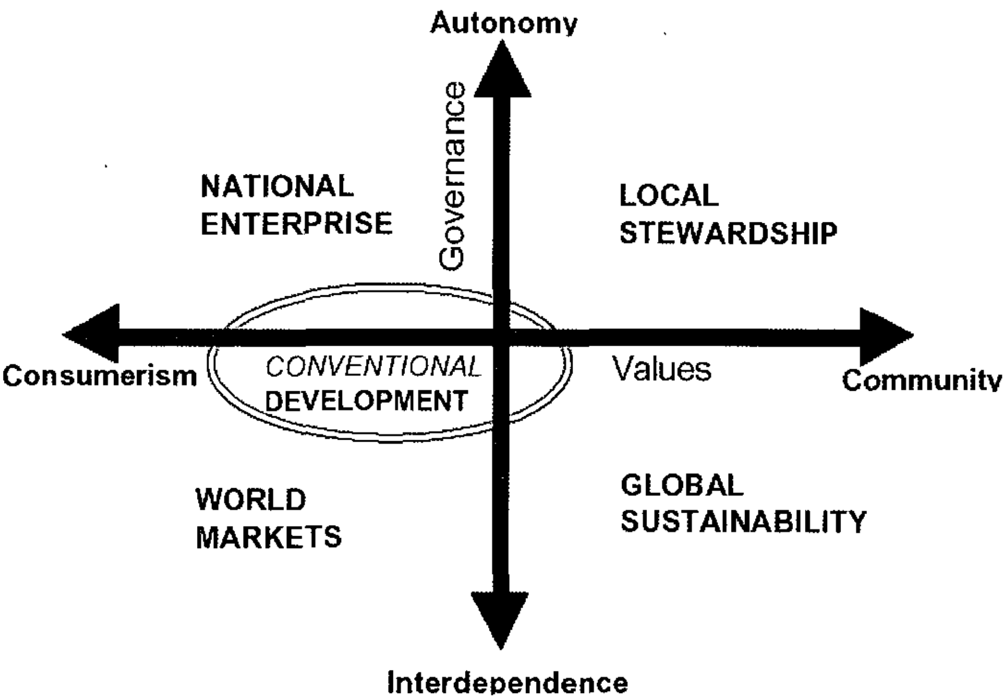
FCD found that CC and SE scenarios both tend to be presented at highly aggregated scales; and SE scenarios in particular often involve vague qualitative formulations. For the FCD risk analysis it was necessary to represent the scenarios in terms of quantified (or at least ordinal) values. Some data derived from models – dealing with hydrological and marine drivers of flood risk, for instance – could be used. But much of the task of interpreting scenarios and expressing them at the scale and in the format required for risk analysis was based on expert judgement.

Figure 3. Global carbon emissions in the four UKCIP02 emissions scenarios.



Source: UKCIP02 (Scenarios produced by Tyndall and Hadley Centres for UKCIP)

Figure 4. Foresight Futures scenario framework.



Source: Berkhout and Hertin (2002)

Table 1. The Foresight Futures

Features	World Markets	National Enterprise	Global Responsibility	Local Stewardship
Governance structures	Internationalist, libertarian	Nationalist, individualist	Internationalist, communitarian	Localist, co-operative
Role of policy	Weak, dispersed, consultative	Weak, national, closed	Strong, coordinated, consultative	Strong, local, participative
Economic development	Minimal, enabling markets	State-centred, market regulation to protect key sectors	Corporatist, political, social and environmental goals	Interventionist, social and environmental
Structural change	High growth, high innovation, capital productivity	Medium-low growth, Low innovation, Maintenance economy	Medium-high growth, high innovation, resource productivity	Low growth, low innovation, modular and sustainable
Fast-growing sectors	Rapid, towards services	More stable economic structure	Fast, towards services	Moderate, towards regional systems
***Declining* sectors**	*Health & leisure,* media & information, financial services, biotechnology, nanotechnology	*Private health* and education, Domestic and personal services, Tourism, Retailing, Defence	Education and training, Large systems engineering, New and renewable energy, Information services	*Small-scale* manufacturing, Food and organic farming, Local services
Unemployment	Manufacturing, agriculture	Public services, civil engineering	Fossil fuel energy, Traditional manufacturing	Retailing, tourism, financial services
Income	Medium-low	Medium-high	Low	Medium-low (large voluntary sector)
Equity	High	Medium-low	Medium-high	Low
GDP growth p.a. (now 2.5%)	3.5%	2%	2.75%	1.25%
Total investment (19 % of GDP)	22%	18%	20%	16%
Agricultural activity (2% of total activity)	1%	2%	1.5%	3%
Newly developed land (now 6500 hectares per year)	6000	4500	3000	1000
Primary energy consumption (230m tons of oil equivalent)	280 million av. change pa 1.7%	270 million av. change pa 1.5%	230 million av. change pa 0.1%	230 million av. change pa 0.1%

Source: OST (2003)

Table 2. UNCIP and Foresight Scenarios

SRES	UKCIP02	Foresight Futures	Commentary
B1	Low emissions	Global responsibility	Medium-high growth, but low primary energy consumption. High emphasis on international action for environmental goals (e.g. greenhouse gas emissions control). Innovation of new and renewable energy sources.
B2	Medium-low emissions	Local stewardship	Low growth. Low consumption. However, less effective international action. Low innovation.
A2	Medium-high emissions	National enterprise	Medium-low growth, but with no action to limit emissions. Increasing and unregulated emissions from newly industrialized countries.
A1F1	High emissions	World markets	Highest national and global growth. No action to limit emissions. Price of fossil fuels may drive development of alternatives in the long term.

Source: OST (2003)

The scenarios were used as the basis for risk assessments. The second and third phases of FCD, quantified and costed risks, and established detailed visions of each scenario.

3. Project outputs

3.1. Reports

In the project introduction, the Chief Scientist, Sir David King described the FCD project as "the most wide-ranging analysis of the problem of increasing flood risk that has ever been made in the UK and possibly internationally" - the interviewees for the evaluation study broadly agreed with this assessment.

FCD's reports were targeted at policymakers, in central and regional Government, and at the private sector (e.g. construction and insurance firms). They were also disseminated to a wide range of professionals whose work is affected by flooding and coastal erosion (including planners, environmentalists, those in business, social scientists, researchers and flood managers). The imagery used for the project outputs, especially the maps indicating flood risks, conveyed key messages to non-experts. The main project reports achieved substantial media coverage, with many reproductions of maps illustrating impacts on different regions of the country (examples in Figure 5).

Figure 5. Some Graphic FCD Results.

Figure 2.1 **The distribution of average annual damage from flooding across England and Wales in the 2080s. The maps represent changes in risk by the 2080s for the four future scenarios. Darker shades of red signify progressively greater increases in damage. Green signifies a reduction.**

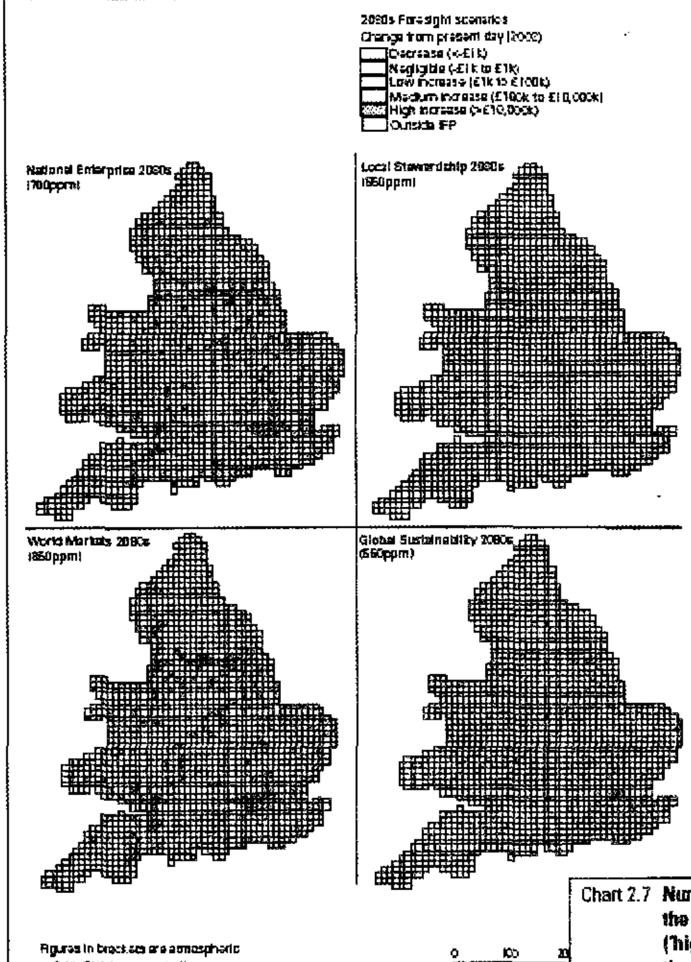
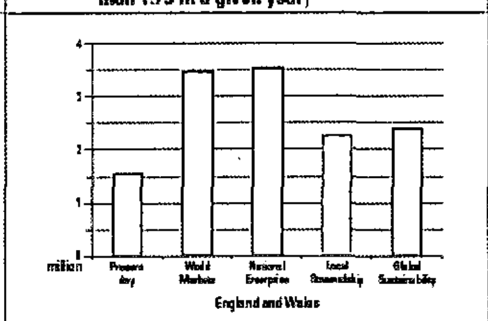


Chart 2.7 **Number of people at high risk now and in the 2080s – river and coastal flooding ('high' means a chance of flooding of greater than 1:75 in a given year)**



Source: OST (2004)

FCD's main published outputs[8] were:

- *Executive Summary*
- *Key messages for stakeholders*: a series of information sheets for researchers, skills providers, local and regional government, and the insurance and financial services.
- An overview of the science used in two *Scientific Summaries* (Volume I – Future risks and their drivers; Volume II – Managing future risks)
- *Scotland.* A detailed technical report analysing the extent and nature of future risks specifically for Scotland.
- A series of *technical papers* detailing the underlying work of the project. (Much interim analysis and documentation was also available on the project website)
- *FloodRanger* A computer-based flooding simulator, mainly for educational purposes. This tool enables users to explore the interaction of many issues– including climate change, planning, infrastructure provision and flood defences - for (an imaginary part of) the UK.[9]

3.2. Problems addressed by the results from the exercise

Two key messages from the project were (1) if the UK continues with existing policies the risks grow very substantially, in virtually every scenario considered; (2) the risks need to be tackled across a broad front. Reductions in global emissions would reduce the risks greatly – but these are unlikely to be sufficient. Hard choices are required: the UK must invest more in sustainable approaches to flood and coastal management - or learn to live with increased flooding.

3.3. Policy options to policy makers that result from the exercise

The *Executive Summary* (OST, 2004) set out key choices for policymakers, listing such main points of discussion as:

- Aims for future flood management: should policy accept increasing levels of risk of flooding? Seek to maintain risks at current levels? Seek to reduce the risks?
- Importance of managing climate change to the risks from flooding: reduction of climate change - through controlling emissions or, in the future, by macro-engineering the climate - could make the task substantially easier.
- Additional challenges for towns and cities: given high uncertainty in the case of intra-urban flooding, how (much) to invest in better modelling and prediction of flooding in urban areas to enable more effective forward planning?
- Factors that should inform long-term approach to flood management: the balance between state and market forces in decisions on *land use*; whether to implement societal responses with a longer lead time, or increasingly rely on larger structural *flood defences* with potential economic, social and environmental costs; How much emphasis to place on measures that are reversible and those that are highly

adaptive?. Key issues to consider were: where to concentrate future urban and economic development? when to invest in flood-risk reduction? and how to manage flood risk in those areas?

- Governance: needs to support the concept of a portfolio of responses to increasing flood risk, in order to allow its integrated implementation. *Adaptability* will be important in the portfolio of responses, and its governance arrangements. It is important that the responses can respond to changing societal and climatic drivers. *Investment* will be needed for future flood and coastal management, to promote long-term solutions, appropriate standards and equitable outcomes. *Market mechanisms and incentives* should be fully used to manage future risks – while recognizing the central role of all levels of government. Science and technology can play a key role in the development of long-term policies in flood-risk management. *Periodic reassessment of the long-term strategy* for managing flood risk should be made – to take account of new scientific data, and to enable it to be adapted to an evolving future. The points discussed are: Who pays? Public perception of risk and acceptance of solutions for the social good; Possible obstacles and opportunities.
- Implications for science and technology: Investing more, to ensure better informed decisions on long-term flood management, and doing more to join up different areas of science. The three broad areas with the greatest bearing on future risks, but where there is most uncertainty are: 1) Reducing uncertainty in risks and responses: e.g. intra-urban precipitation; land-use planning and management; 2) Strategic assessment of responses: e.g. strategic risk assessment for intra-urban flooding; evaluation of non-monetary flood damages; 3) Sustainability and Governance: e.g. whole-system costs and benefits; human and ecological consequences of managed realignment and abandonment of defences.
- Implications for skills: in particular, continuing need for civil engineers to contribute to flood risk management – in particular for the design of flood defence works and urban drainage systems. Engineers and other professionals involved in flood-risk management will require a wider range of skills to address issues holistically.

3.4. Impact and results of the exercise

As with other Foresight projects, the sponsoring ministry, Defra, was expected to take responsibility for follow-up action. An Action Plan was assembled by OST, in consultation with Defra and stakeholders, covering: (a) implications for policy; (b) applying and deepening the work in specific parts of the country; (c) informing research priorities; and (d) informing the climate change agenda.

Impacts are most obvious in the sponsoring ministry, Defra, where FCD was used heavily to inform Defra's long-term strategy on flooding, "Making Space for Water". For instance, in the Autumn 2004 public consultation document, Foresight is cited 58 times.[10] Defra does not consider FCD to have provided "the answers" to these great challenges but to have provided a "route map" for policy development and decision making (including these consultations). This is influential on huge amounts of public investment, infrastructural decisions, and research strategy.[11]

Defra personnel saw FCD's main success as having brought together the key players (industry, government, the insurance sector, etc.) to dialogue and reach a shared understanding of complex issues. One interviewee described FCD as a "wake-up call" for Defra itself – as reflected in the extensive use being made of the results in Defra's strategy development. The project is considered to have improved knowledge in a few areas. But it is the bringing together of a holistic picture within a sound logical framework, that is seen as more important.

But the project has also given a wider group of stakeholders a better understanding of the potential scale of future flood risks and has helped to inform strategic planning and investment in managing them. For example, the Environment Agency (EA) has used the work to inform its Science Strategy and the work of the joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme. The EA also reports that the Flood Ranger simulator has become a respected and valuable part of its Flood Risk Management toolbox. The Agency has found it particularly useful in communicating key messages on the political impacts of climate change to stakeholders.[12]

4. Wider Context

Flooding shot up the political agenda in 2007 following major floods in the summer. Policy development and implementation continues. Defra anticipates that FCD will feed into its review of policy for some years to come. Foresight's policy impacts cannot be instantaneous., especially for such a large and rapidly evolving topic. Policy makers can return to the route map set out in the reports - a "reservoir" of knowledge to be drawn on. Since it is more visionary than detailed, Defra and other users, such as the EA, are developing the knowledge base further, in order to continue to incorporate messages from FCD and its successors into policy and strategy. One example is the EA's extension of the earlier scenario work to deal with the issues facing specific regions, for developing regional water management strategies.[13] Substantial research effort is being directed at the flooding issue, too, with some elaboration of new scenario approaches (e.g. probabilistic scenarios").[14]

References

Berkhout, F and J Hertin, (2002), "Foresight Futures Scenarios: Developing and Applying a Participative Strategic Planning Tool", Greener Management International Issue 37 pp37-52, available online at http://www.greenleaf-publishing.com/pdfs/gmi37ber.pdf.

Defra (2004) Making Space for Water London: Defra.

Defra (2006) Making Space for Water: Environment Agency strategic overview – strengthening our strategic approach to sea flooding and coastal erosion risk management available at http://www.defra.gov.uk/corporate/consult/msw-eaoverview/consultation.pdf.

Defra (2007) Making Space for Water: Summary of responses to the Consultation on the Environment Agency Strategic Overview for Sea Flooding and Coastal Erosion Risk Management March 2007 available at: http://www.defra.gov.uk/corporate/consult/msw-eaoverview/responses.pdf.

OST (2003) FCD project, Phase 1 Main Report London, OST.

OST (2004) Future Flooding: Executive Summary available at: http://www.foresight.gov.uk/Previous_Projects/Flood_and_Coastal_Defence/Reports_and_Publications/Executive_Summary/Executive_Summary.html.

PREST (2006) Evaluation of the United Kingdom Foresight Programme: Final Report mimeo, Manchester Business School, University of Manchester; available at http://www.foresight.gov.uk/Publications/Current%20round%20General%20Publications/Foresight_Evaluation_2006/Foresight_Evaluation_Final_Report_June_2006.pdf.

Sayers, P (2004) "Present and Future Flood risk" presentation at ICE conference Land-sea margins 18 March 2004, http://cozone.org.uk/overtop/04-PS.pdf.

Notes

1 The Programme is run by the Office of Science and Innovation (OSI – previously the OST, Office of Science and Technology), based in the Department of Trade and Industry (DTI). See http://www.foresight.gov.uk.

2 More technology-driven exercises are: Cognitive Systems; Exploiting the Electromagnetic Spectrum; Intelligent Infrastructure Systems; Sustainable Energy Management and the Built Environment. More problem-driven exercises are: Cyber Trust and Crime Prevention; Brain Science, Addiction and Drugs; Detection and Identification of Infectious Diseases; Mental Capital and Wellbeing, Tackling Obesities.

3 For Defra's Horizon Scanning and Futures Programme, see http://horizonscanning.defra.gov.uk/default.aspx?menu=menu&module=About&NavID=9. For the RASP project on the performance of defences, see http://www.rasp-project.net/.

4 For the EA's work on environmental futures, see http://www.environment-agency.gov.uk/science/922254/922694/922696/?version=1&lang=_e while its scenario approach is at http://www.environment-agency.gov.uk/aboutus/512398/1504325/1504417/831980/832317/?lang=_e.

5 See the UK Climate Impacts Programme Scenarios Gateway at http://www.ukcip.org.uk/scenarios/.

6 FCD Phase 1 report at http://www.foresight.gov.uk/Previous_Projects/Flood_and_Coastal_Defence/Reports_and_Publications/Phase_1_Reports/Drivers_Scenarios_and_

Workplan.html.

7 These scenarios are available as "Foresight Futures 2020: Revised Scenarios and Guidance" at: http://www.foresight.gov.uk/publications/ current_round_general_publications/foresight_futures_2020_revised_scenarios_and_guidance/ind ex.htm. The approach is discussed in Berkhout & Hertin (2002). For an earlier discussion of use of scenarios in Foresight, and a set of four profiles, see David Stout's essay at: http://www.foresight.gov.uk/Previous_Rounds/Foresight_1994__1999/General_Publications/The%20Use%20Of%20Scenarios%20In%20Foresight/index.htm.

8 Outputs listed and available at: http://www.foresight.gov.uk/Previous_ Projects/Flood_and_Coastal_Defence/Reports_and_Publications/Project_Outputs/Outputs.htm.

9 This is retailed commercially at http://www.discoverysoftware.co.uk/ FloodRanger.htm where it is described as being aimed at flood defence practitioners, local authorities, insurers, universities and schools. The description is that "The objective of the game is to defend urban areas and sites of special scientific interest while maintaining levels of housing and employment for an expanding population. The game uses a virtual terrain loosely based on the east coast of England. The user can select between two world future scenarios in combination with four climate change scenarios taken from the UK Hadley Centre for Climate Change." The game received considerable media comment; a current project draws on the experience in developing a similar tool for shoreline management – see http://www.defra.gov.uk/environ/fcd/ policy/strategy/sd7/sld2313.htm.

10 The original consultation document Defra (2004) no longer seems to be available, but for more details and much background documentation see: http://www.defra.gov.uk/environ/fcd/policy/strategy/ consultation.htm. A subsequent consultation has also been held. Defra (2006, 2007) – for more on this process see http://www.defra.gov.uk/ corporate/consult/msw-eaoverview/index.htm and http://www.defra.gov.uk/environ/fcd/policy/strategy.htm.

11 Important impacts are also reported in Scottish and Welsh agencies.

12 On impacts, see the Evaluation study, and also the details at http://www.foresight.gov.uk/Previous_Projects/Flood_and_Coastal_Defence/One_Year_Review/R eview.html#7.

13 See for example the work for the Midlands, explicitly reworking the scenarios, at: http://www.environment-agency.gov.uk/regions/ midlands/567079/567098/112954/?version=1&lang=_e#.

14 Thus a workshop on The Use of Probabilistic Climate Scenarios in Impacts Assessment and Adaptation Studies was held in November 2006, for climate scientists, scenario end users and stakeholders concerned with the impacts of climate change on the built environment, infrastructure and utilities, to examine how probabilistic climate scenarios can be used in practice for planning, design and management, to help prepare the end-user community for the arrival of probabilistic scenarios, and to disseminate new climate and socio-economic scenarios work from the a set of BKCC projects. See http://www.k4cc.org/events/workshops/probablistic-scenarios-workshop-review for full details. BKCC (Building Knowledge for a Changing Climate – see http://www.k4cc.org/bkcc) is a partnership (between EPSRC and UKCIP) supporting several research projects designed to improve understanding of the multidisciplinary challenges required for the adaptation of UK buildings and infrastructure to climate change. These projects include ASCCUE (Adaptation Strategies for Climate Change in the Urban Environment); AUDACIOUS (Adaptable Urban Drainage - Addressing Change in Intensity, Occurrence and Uncertainty of Stormwater); BESEECH (Economic and Social Information for Examining the Effects of Climate Change); BETWIXT (Construction of climate scenarios for the built environment, transport and utilities); BIONICS (Biological and Engineering Impacts of Climate Change on Slopes); CRANIUM (Climate change Risk Assessment: New Impact and Uncertainty Methods); Engineering Historic Futures (EHF): Adaptation of Historic Environments to Moisture-Related Climate Change; GENESIS (Climate Change Impacts assessment on the Electricity Supply Industry and Utilities); and finally Impact of Climate Change on UK Air Transport. A wider initiative is Sustaining Knowledge for a Changing Climate (SKCC) – see http://www.k4cc.org/.

Also of considerable interest here are the research activities especially focused on flooding – see the Flood Risk Management Research Consortium at http://www.floodrisk.org.uk/, which also involves projects taking up scenario analysis for risk management. A wide range of approaches is being pursued – reuse of the FCD scenarios, creation of new scenarios on workshops, modelling, etc. But the need for scenario analyses and Foresight more generally is well-embedded in research and policy communities, and business like insurers and construction firms are increasingly attentive to such work.

Water Productivity in the Industry of the Future

The Future of Water Use in Industry

Dr. Ania Grobicki

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Biographical Note

Dr. Ania Grobicki is a chemical engineer and an economist by training, and a policy analyst on water and the environment. She received a PhD in biotechnology from Imperial College, London in 1989. Subsequently, she worked as a consultant for both the public and the private sectors in South Africa and the UK, prior to moving to Geneva in 2003 in order to work with United Nations organizations. Her scientific contribution in the field of industrial water treatment and water reclamation was recognized by the award of a gold medal by the Water Institute of Southern Africa in the year 2000. She has experience of advising at ministerial level both nationally (in South Africa) and internationally. On behalf of UNIDO, Dr. Grobicki was the principal author of the chapter on "Water and Industry" in the latest edition of the World Water Development Report, published by UNESCO. She has consulted to the United Nations Environment Programme and the World Meteorological Organization as well as UNIDO, and is currently employed by the World Health Organization.

Introduction

There is tremendous competition between the water needs of agriculture, industry, and the growing number of people in our world, and there are severe and increasing freshwater shortages in many areas. Indices and maps of water scarcity have been drawn up, there is talk of "the water crisis", and predictions of wars to come over water. Yet our planet is a water planet, with an abundance of water. So why is there so much concern about our future water security?

This question is not so surprising if we consider that of the total amount of water in the world, only 2.5 per cent exists as freshwater, while 97.5 per cent is seawater. It takes a great deal of energy to desalinate seawater, and of course energy is also increasingly constrained. Hence in most places, large-scale desalination is hardly a viable option with current technologies. Of the relatively small proportion of water, which is fresh, about 90 per cent is inaccessible for our use. Two-thirds is locked up in glaciers and ice caps, while most groundwater cannot be sustainably extracted. Fossil aquifers are being tapped in many places - water which is many thousands of years old and not readily renewable. There are many large aquifers, most notably the Ogolalla aquifer in Texas, and the aquifer which underlies the Indo-Gangetic plain, which are seeing dropping water levels, accompanied by rising costs of pumping in order to extract the deeper water. Where groundwater was being pumped from 30 metres depth, it is now necessary to pump from 100 metres or much more, with accompanying increases in energy costs.

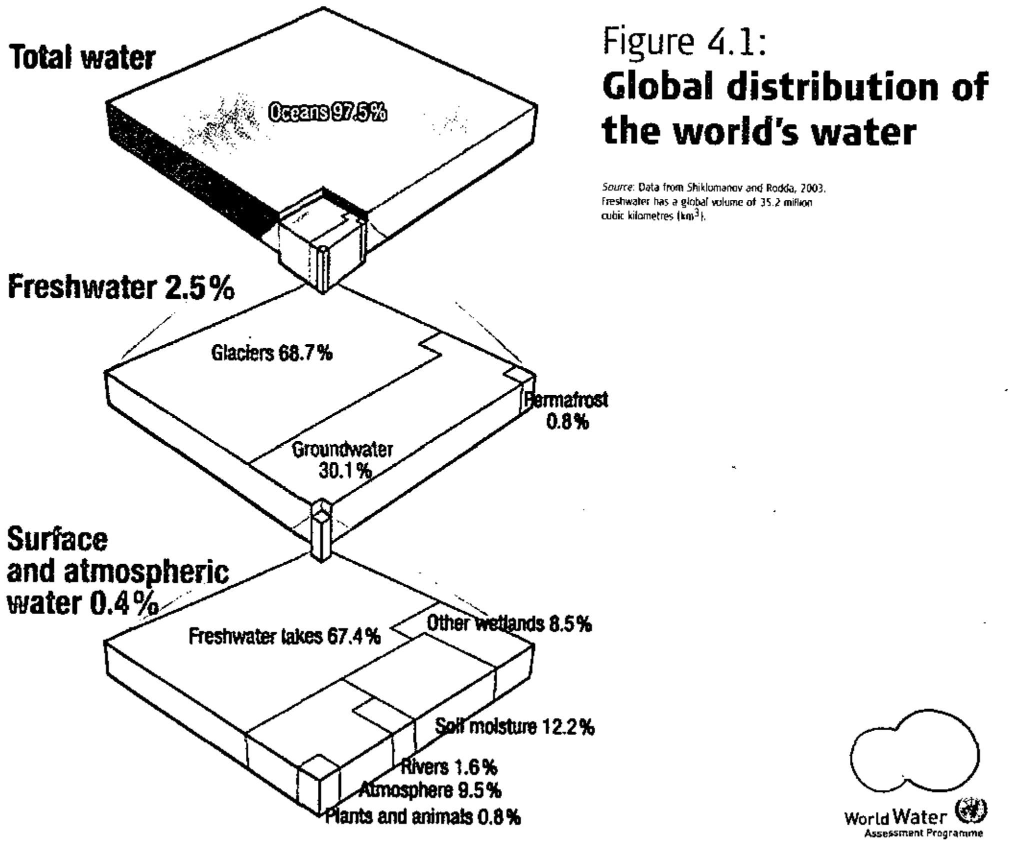
Rivers, lakes and wetlands account for less than 0.4 per cent of the world's water (see Figure 1 below). Many of these are remote and not easily accessible. We are now starting to see startling declines in the size of many of the world's lakes and inland seas, notably the Aral Sea, the Dead Sea, and Lake Chad - a freshwater lake shared by 4 African countries which has declined to 10 per cent of the size it was in 1963. The volume of water in the Aral Basin has been reduced by 75 per cent since 1960. The Yellow River, which is one of the largest and longest rivers in the world (over 4000 km long) has ceased to reach the sea for long periods since 2002, due to massive over-extraction for industry, for agriculture, and for the 120 million people who now live in the catchment area of the river basin.

On the other hand, the rainfall, which replenishes our freshwater resources is highly variable in many parts of the world, and much of this freshwater arrives in floods which cannot be usefully harnessed. The frequency of hurricanes, floods and droughts is increasing hand-in-hand with climate change. Much of the surface water and soil moisture is lost to evaporation and evapotranspiration, both of which are also being increased by global warming and higher temperatures. All of these factors affect the outlook for sound and sustainable water management, together with the increasing competition between the needs of various water users and the natural environment. We need to consider the challenges that these changes pose for industry, as well as the opportunities that exist to improve our future water security. In this paper I will be talking about two key opportunities which are available to us today.

1. The challenge for sound water management

By the year 2050, the world population will reach 10 billion, 90 per cent of whom will live in developing regions. We are already well over 6 billion people on earth, and in this year 2007, for the first time in history, over half of humanity is living in cities. It has been well put by Bill McKibben, in his book entitled *The End of Nature*: "We are no longer able to think of ourselves as a species tossed about by larger forces - now we are those larger forces."

Figure 1. Global distribution of the world's water in 2003 (Source: World Water Development Report)

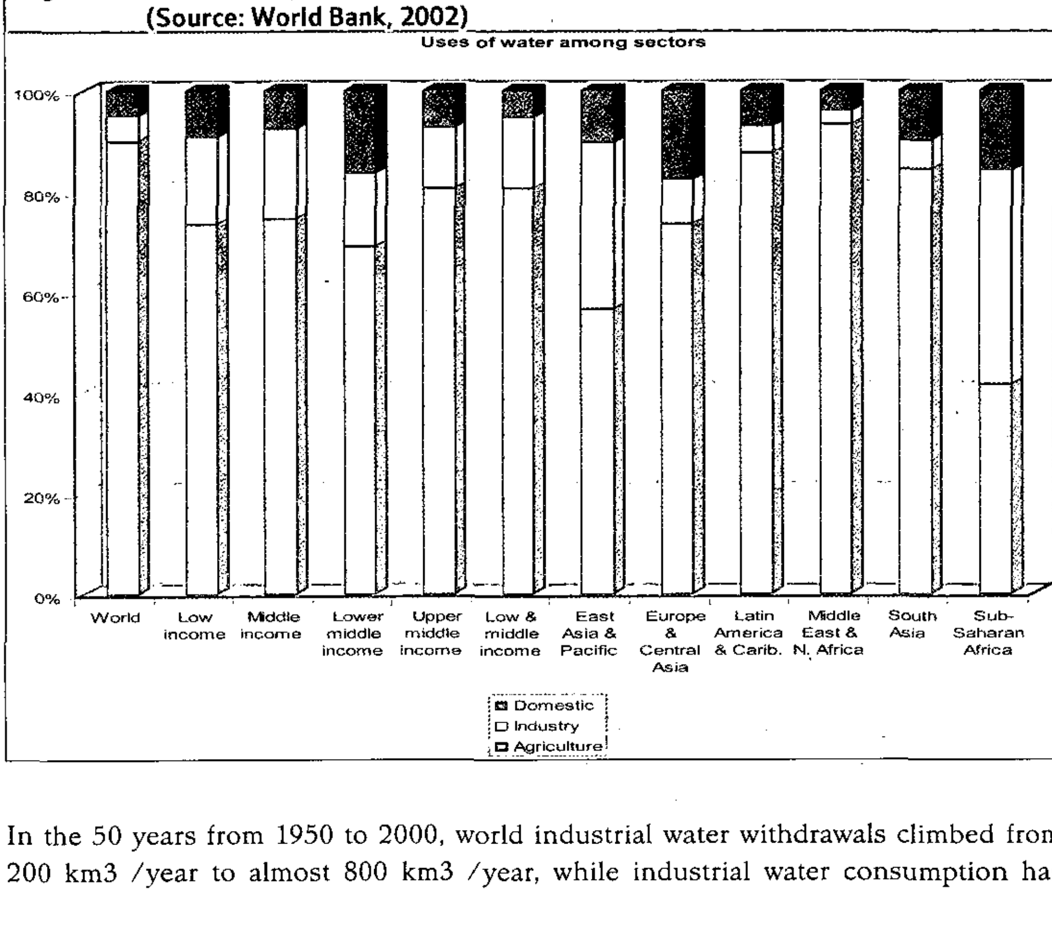


Cities and industry are both demanding ever greater volumes of water, while at the same time producing wastes and effluent which in many places taint and damage the quality of this precious resource on which all life depends. In agriculture, unsound irrigation practices are creating salinisation problems for both soil and water, and agricultural runoff carries pesticides and fertilizer. While the *quantity* of freshwater available represents one side of the coin of the water crisis, the *quality* issue represents the other. However, in the end, they are both sides of the same coin. Water that is too polluted to be used for a particular purpose, whether for drinking water, for industry, for irrigation, or for sustaining ecosystems, is in effect water that is not available for use. Hence if we are looking to preserve and maximize the *quantity* of this resource, it is essential to ensure at the same time that its *quality* is fit for the use for which it is intended. Technology foresight is the key tool to use to identify the innovations which will enable us to meet this challenge, and to put in place the strategies and the policies which will lead to improved water security and sustainability.

2. Trends in the use of water in industry

Agriculture at present uses the lion's share of water world-wide, with between 70 per cent and 90 per cent of all water in most regions. Interestingly, the East Asia/Pacific region and sub-Saharan Africa are the two exceptions to this, with industrial water use taking a large proportion of water, but for opposite reasons : in East Asia/Pacific, industry has grown extremely rapidly and often unsustainably in recent years. Industry now provides 48 per cent of the total GDP in the region, and this proportion is still increasing. On the other hand, in sub-Saharan Africa, industry takes a large share of total water use not because the industrial sector is especially strong, but because most agriculture is rain-fed and there is relatively little water storage available on the continent.

Figure 2. Water use by industry, in various regions of the world (Source: World Bank, 2002)



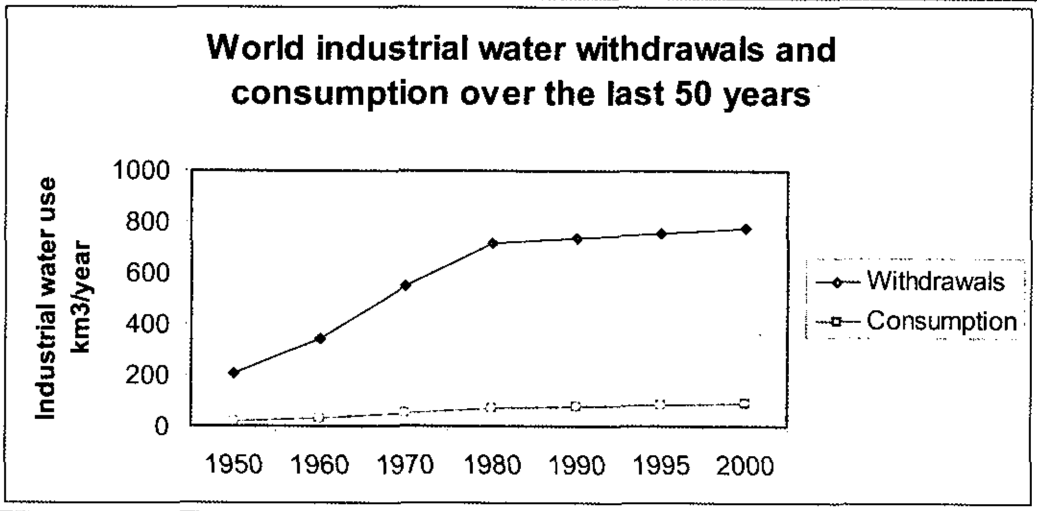
In the 50 years from 1950 to 2000, world industrial water withdrawals climbed from 200 km3 /year to almost 800 km3 /year, while industrial water consumption has increased from 20 to about 100 km3 /year. The relationship between industrial water withdrawal and industrial growth is not linear, as technological advances lead to water savings as well as water reuse in industry. Hence industrial water withdrawals in many developed countries have flattened off, while industrial water consumption (which is only a fraction of the total water withdrawal) continues to grow. This can be clearly seen in Figure 3 below, which shows total world industrial water withdrawals and water consumption from 1950 to 2000. However, industrial water use is usually measured in terms of withdrawals. What is the difference?

Water is used by industry in a myriad of ways: for cleaning, heating, or cooling; for generating steam; for carrying dissolved substances or particulates, for instance when pumping slurry; as a raw material; as a solvent; and as a constituent part of the product itself (for example, in the beverage industry). Some of the water evaporates in the process. The water, which is consumed by industry is therefore the water which evaporates, as well as the water which remains in the product, the byproducts or the solid waste generated. The balance of the water is discharged after use as wastewater or effluent. This is why the total withdrawal of water by industry from surface and groundwater is often much more than the water which is actually consumed.

$$Wi = Ci + Ei$$

where:
Wi = the water withdrawal by industry
Ci = the water consumption by industry
Ei = the industrial effluent discharge

Figure 3. World industrial water use from 1950 to 2000 (Based upon data from Shiklomanov, 2002)



The gradual increase in water consumption therefore reflects the continuous increase in industrial production. However, as noted above, water withdrawals do not have to increase in proportion, indeed, by cutting back on the volumes of effluent generated, by reusing and recycling water, these two factors can be delinked. What is obvious is that despite the continued expansion in industrial production since 1980, water withdrawals for use by industry world-wide are no longer growing as quickly as pre-1980. This can be seen even more clearly if we disaggregate the water use data by region.

Figure 4. Comparison between industrial water use in Europe (4a) and in Asia (4b) from 1950 to 2000 (Based upon data from Shiklomanov, 2002)

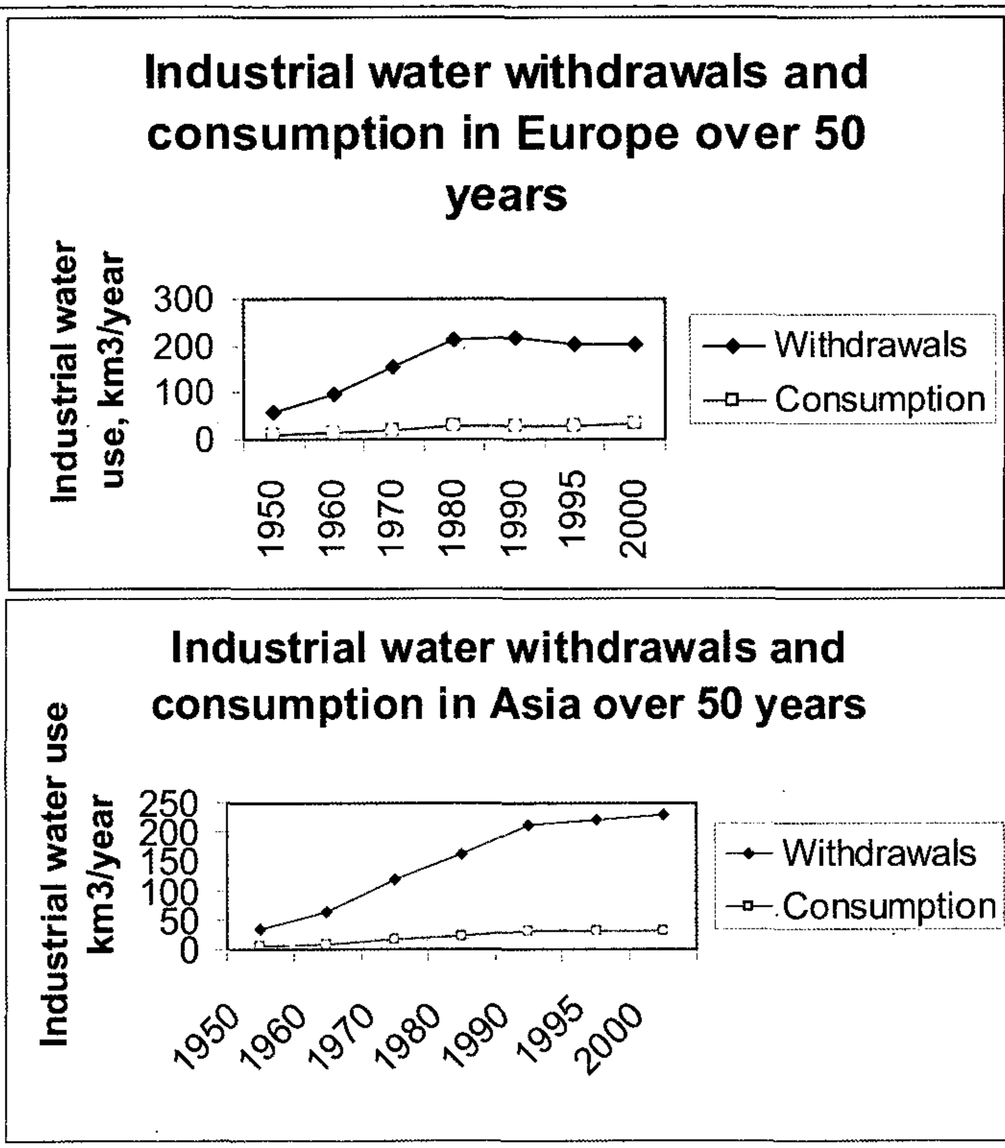


Figure 4a shows that industrial water withdrawals in Europe have actually been dropping since 1980, although industrial output continues to grow. With its strong emphasis on environmental protection, this is evidence that in Europe water re-use and recycling measures are taking effect, allowing industry to grow without putting further strain on water resources. However, as you can see there is still a very large gap between withdrawals and consumption (approximately 160 km^3/year), representing the quantity of effluent that is discharged by industry. Hence there is plenty of scope for improvement and growth. The limit would be reached when the two curves touch - the point at which there would be zero discharge.

In Asia, the growth in industrial water withdrawals was rapid up to the early 1990s, and has since been growing more slowly, as Figure 4b shows, despite the region's continued high growth in manufacturing output. Hence the intensity of water use in industry is increasing both in Europe and in Asia/Pacific - but not as rapidly in the latter. Progress is being made most quickly in those countries where water scarcity is being experienced, and action is being taken both at policy level, at regulatory level and at the level of individual enterprises. As an example, in one Australian brewery, the water used (calculation based upon water withdrawals) dropped from 15 litres per litre of beer produced in 1996, to just 6 litres of water per litre of beer in 2003. This represents an efficiency improvement of 60 per cent in 6 years!

Another way of looking at this improvement at national level is to take the industry value added (in US$ for purposes of comparison) and divide by the industrial water use (measured by withdrawals); this gives the industrial water productivity, measured in US$ per m^3. The figures in Table 1 show that this indicator can different greatly among the largest world economies. If we compare Japan, where water recycling and reuse is a way of life, with the United States, we can see that the industrial water productivity is an order of magnitude higher in Japan. We find that Denmark has the highest industrial water productivity world-wide. One reason may be that most water withdrawals in Denmark are from groundwater, because there is relatively little surface water due to its topography, and hence water has always been viewed as a resource to be conserved. In Canada, on the other hand, which has the highest water availability of any country, we find that despite their sound environmental record their industrial water productivity is relatively low: lower than in the United States.

Table 1. Industrial water productivity by country, 2000/2001

Country	Industry, value added (IVA)(billions constant 1995 US$)	Industrial water use (km3/year)	Population (million)	Industrial water productivity
	Year: 2001 (some 2000) Source: World Bank 2001	Year: 2000 Source:AQUASTAT 2003	Year: 2000 Source: AQUASTAT 2003	($ IVA/m3)
Armenia	1.19	0.13	3.79	9.18
Austria	82.15	1.35	8.08	60.85
Azerbaijan	1.02	4.77	8.04	0.21
Belarus	5.76	1.30	10.19	4.44
Bulgaria	3.48	8.21	7.95	0.42
Canada	**205.98**	**31.57**	30.76	**6.52**
Czech Republic	20.97	1.47	10.27	14.31
Denmark	**44.90**	**0.32**	5.32	**138.59**
Estonia	1.72	0.06	1.39	26.80
Finland	53.22	2.07	5.17	25.66
France	430.02	29.76	59.24	14.45
Germany	748.18	31.93	82.02	23.43
Greece	28.18	0.25	10.61	114.44
Hungary	17.26	4.48	9.97	3.85
Italy	332.94	16.29	57.53	20.44
Japan	**1889.94**	**15.80**	127.10	**119.62**
Kazakhstan	8.39	5.78	16.17	1.45
Kyrgyz Republic	0.36	0.31	4.92	1.17
Latvia	1.88	0.10	2.42	19.60
Lithuania	2.48	0.04	3.70	60.34
Moldova	0.78	1.33	4.30	0.59
Netherlands	119.90	4.76	15.86	25.17
Norway	49.05	1.46	4.47	33.56
Poland	50.65	12.75	38.61	3.97
Portugal	36.71	1.37	10.02	26.87
Romania	12.32	7.97	22.44	1.55
Russian Federation	139.79	48.66	145.49	2.87
Spain	208.17	6.60	39.91	31.54
Sweden	81.68	1.61	8.84	50.67
Tajikistan	0.70	0.56	6.09	1.25
Turkmenistan	3.46	0.19	4.74	18.34
Ukraine	21.62	13.28	49.57	1.63
United Kingdom	340.03	7.19	59.63	47.28
United States	**2147.80**	**220.69**	283.23	**9.73**
Uzbekistan	2.79	1.20	24.88	2.33

Source : World Water Development Report 2, UNESCO, 2006.

3. Opportunities for the future

In this paper I wish to present two opportunities, which exist to look at water use in industry in a different way: strategies for more socially and environmentally responsible use of water; strategies which I believe will take us a long way down the line to addressing the problems and threats to both the quantity and the quality of water available for use. Because security of water supply is essential for stable industrial development, these opportunities must be worth taking.

The first opportunity relates to increasing industrial water productivity, which as shown in the last section can be assessed and monitored over time. This can prove to be an incentive for improvement. The second opportunity is a longer-term, more visionary effort - achieving zero discharge. There are a number of intermediate strategies, which can take us closer to this end point. While it may take time to achieve everywhere, and is without a doubt easier to achieve on an individual enterprise level or on a small district level, zero discharge is a worthwhile goal.

3.1. Opportunity #1: increasing industrial water productivity

The higher the water productivity, the greater is the value, which is intrinsically being placed upon water. In water-scarce regions, where there is competition for water among various users, water is likely to be allocated to the more highly productive uses. Various strategies are available to improve industrial water productivity, such as:

- Water auditing
- Matching water quality to use requirements
- Water recycling and reuse on site
- Using reclaimed water
- The concept of the virtual water trade in manufactured products
- Policy instruments and economic incentives

Water auditing

Carrying out a water audit over an industrial plant or manufacturing facility shows clearly where the water, which is supplied to the plant is used, how much is used in each process, and where it ultimately ends up. Rainwater, which falls on the site, as well as the natural evaporation which occurs, should also be included in the audit. Hence the topography of the site can also be important. Once a water audit has been done, it is possible to draw a flow chart and show the water balance over the plant, or over individual units of the process. This is the first step in finding innovative ways to save water on an industrial site.

Water can be saved either by cutting down on water input, where it is being unnecessarily wasted, or by identifying water recycling and reuse opportunities, which are discussed in more detail below. Rainwater harvesting on site may also be considered, since this is preferable to allowing rainwater (which be contaminated) simply to run off into the stormwater system. There are some generic lessons that can be learned for a given production sector, but in the end each factory site needs to be audited and analysed individually.

Matching water quality to use requirements

In many instances, the water used in industry is of an unnecessarily high quality for the use to which it is put. The analogy in domestic water use is, for instance, using water of drinking quality in order to flush toilets, or to water the garden. Similarly, in industrial processes there are many applications where lower water quality could be used. This offers recycling opportunities. Often 50 per cent or more of the water intake to an industrial plant may be used for the purpose of process cooling alone, a need that can often be met with lesser quality water. On the other hand, some industries (such as the pharmaceutical industry) require water of exceptionally high quality. In such processes, additional water treatment is carried out on the water, which is received from the local water utility, or withdrawn from groundwater or surface waters, in order to further improve the water quality before it is used.

There are cases in industry where water is used inappropriately, where a completely different approach could be taken to save water in water-scarce areas. An example of this would be switching to using pneumatic or mechanical systems for transportation, instead of using water, as is often done in the poultry and other food industries.

Water recycling on site

Water recycling is the primary means of saving water in an industrial application : taking wastewater which would otherwise be discharged, and using it in a lower quality application (often after treatment). Each cubic meter of water which is recycled on site represents one cubic meter which is not withdrawn from a water source. Water can be used many times over. In such cases, where for instance a given cubic meter of water is used 10 times over in the process (a "recycle ratio" of 10 to 1), this represents nine cubic meters which are not withdrawn from a water source. Increased water savings can be made by raising the recycle ratio. The industrial water productivity of the product (in terms of industrial value added per cubic meter of water used) is also greatly increased thereby, as far less water is used to produce the same quantity of product.

The way in which water recycling is done on site must be governed by the principle of matching water quality to use requirements, as mentioned above. This is dependent on the nature of the manufacturing process, as well as on the degree of wastewater treatment which is carried out on the site. Processes such as heating, cooling and quenching are the most common applications for lower quality water. It can also be used as washdown water, and for site irrigation.

A second consideration in recycling industrial water is the cost of treating the wastewater to the level required, and the cost of the new pipes and pumps required to be laid, compared to the cost of "raw" water supplies (freshwater). Where the quality of freshwater locally is declining, or where freshwater supplies become unreliable due to water scarcity in the region, droughts or declining groundwater levels, industrial water recycling on site becomes an increasingly attractive option. Water recycling on site can be regarded as a component of industrial risk management, since it contributes to reducing the risk related to unreliability of freshwater supplies.

As one example, the micro-chip manufacturer Intel established the Corporate Industrial Water Management Group to improve water-use efficiency at its major manufacturing sites, which use large amounts of highly treated water for chip cleaning. The group includes representatives from fabrication sites, corporate technology development experts, and regulatory compliance staff. Intel set an initial goal to offset by 2003 at least 25 per cent of its total incoming fresh water supply needs with recycled water and more efficient systems. In 2002, the company exceeded this goal by achieving 35 per cent water savings through recycling water and efficiency gains.

Using reclaimed water

Water recycling occurs on one industrial site, but water reclamation refers to reusing wastewater that was produced elsewhere (with a treatment step in between, if necessary). Again, the principle of matching water quality to use requirements must be followed. The availability of the wastewater at the times when it is needed, and its variability in terms of quality, also need to be considered. For instance, an industrial plant could use wastewater from a nearby municipal sewage treatment plant. This reclaimed water is sold to industry by municipalities in many countries, including Australia and the USA. The most common uses are for industrial cooling and power generation, followed by boiler feed and quenching. The use of reclaimed water by industry eases the pressure on scarce water resources in the region.

In the Durban metropolitan region of South Africa, an innovative public-private partnership has been supplying reclaimed water to industries since 1999. The Southern Sewage Works of the Durban Metro Water Services treats over 100 Ml/day of domestic and industrial effluent (through primary treatment only), prior to discharging it to sea through a long sea outfall. Projections showed that the capacity of the sea outfall would soon be reached, due to the growing population and industrial water discharges in the area. A secondary treatment plant with a capacity of 48 Ml/day was built which was allowed to discharge water into a canal, flowing over the beach into the sea. A nearby paper mill then contracted to take 9 Ml/day of the treated water. However, it was found that tertiary treatment would be required to sell reclaimed water to other industries in the area, who need higher quality water. Since it was not economically feasible for the municipal water utility to construct and operate such a high-tech plant, the tertiary treatment works (which currently treats and sells up to 30 Ml/day of reclaimed water to local industries) was built through a public-private partnership.

Agricultural irrigation and urban irrigation (of parks, sports fields and golf courses) are also major applications for reclaimed water, which is important since irrigation is usually the largest water user in any region. Israel currently reuses 84 per cent of its treated sewage effluent in agricultural irrigation. The World Health Organization has laid down guidelines for the use of reclaimed water in irrigation, as there may be health implications where reclaimed water is sprayed in the open. Reclaimed water is also used for aquifer recharge, for instance to avoid saline water intrusion into the aquifer, or simply to augment the groundwater supply. In the Adelaide region of Australia, it has been found that half of the city's water demand can be met through reclaiming water by aquifer storage and recovery.

In construction applications, reclaimed water can be used for dust control, soil settling and compaction, aggregate washing and concrete making. Domestic applications for reclaimed water include fire fighting, car washing, toilet flushing and garden watering. Supplying non-potable water in urban areas requires two sets of piping, one for potable and the other for reclaimed water – termed "dual reticulation". The laying of dual reticulation is usually done in new housing developments, as laying it retrospectively may be prohibitively expensive. The Tokyo Metropolitan Government in Japan has long encouraged the fitting of new office blocks and apartments in Tokyo with dual reticulation. There are even a few cities in arid regions, such as Windhoek in Namibia, where reclaimed water is treated to a very high standard and then reused directly to augment the potable (drinking) water supply.

The virtual water trade in industry and manufacturing

The concept of the virtual water trade applies both to trade in crops and food products, as well as to manufactured products. A particular product embodies the volume of water which is used to produce it. This can be calculated as m3 per ton of product, or as m3 per $ of added value. By looking at the imports and exports of each type of product, it is possible to calculate the virtual water flows into and out of the region that this trade represents. In water-scarce regions, it makes sense to focus upon the manufacture of products which use little water in the manufacturing process, and hence only to export products with a high water productivity. This minimizes the amount of virtual water which is exported. On the other hand, water-intensive products and products with low water productivity, such as aluminium and beer, should be imported into water-scarce regions, as this represents a way of indirectly importing water.

Policy instruments and economic incentives

Industrial water management strategies with the intention to minimize water consumption and minimize wastewater generation, and to improve water productivity, can be either internal or external. Internal strategies are those measures that are required to be taken at a factory level in order that water consumption and wastewater generation are controlled. These measures as described above can be taken more or less independently of external strategies.

External strategies are measures that are required at the industry level, or are taken in the context of local, regional or national water management in industries. Generally, the factory management does not control these strategies, although in most cases some measures are required at factory level in response. The nature and number of a particular type of industry present in a locality or a region can significantly influence these strategies. Some of these strategies are summarized as follows:

1. Grouping of industries in a particular site (industrial parks) and having combined treatment methods and reuse policies.
2. Rationing or target-setting for water use within industry, so that each process uses a defined quantity of water.
3. Applying economic instruments such as penalties, water charges, subventions, credits and grants.

National water conservation policy, also called water demand management, is the key factor in water recycling and reuse in industries. It forms an important component of national water efficiency plans. In some developing countries, industry is not charged for water nor for wastewater services; in other words, both industrial water withdrawals and wastewater discharges are still free and unregulated. Both regulation and the imposition of stepped water tariffs according to the volume of water used are key instruments for governments to use in these situations. Compliance with stringent effluent requirements can force industries to implement new technologies to reduce effluent discharges. Fines for non-compliance and the threat of closure for repetition of non-compliance can also significantly achieve higher recycling and reuse. Higher charges for raw water can be applied to industries using large volumes of water. An example can be seen in Singapore, which levies a 15 per cent water conservation tax on operations using more than a specified amount, and new factories needing more than 500 m3 of water per month must apply for approval from the City Council during the planning phase. A fertilizer plant in Goa, India cut water demand by 50 per cent over a 6-year period in response to higher water prices. Dairy, pharmaceutical, and food processing industries in Sao Paulo, Brazil reduced water use per unit output by 62 per cent, 49 per cent and 42 per cent respectively.[1]

Given proper incentives, it is generally found that industry can cut its water demand by 40 to 90 per cent even with existing techniques and practices (Asano and Visvanathan, 2001).[2] However, water conservation policies need to be fair, achievable, and enforceable. Economic incentives should be given to industry to comply with standards and policy and to reduce raw water intake. Furthermore, such incentives could include:

- Subsidies for industries implementing innovative environmental technologies, and
- Financial and advisory support for industries funding new research.

Both regulatory policies and economic incentives can dramatically increase industrial water productivity. They often go hand-in-hand with policies for reducing wastewater discharge and industrial water pollution, which leads us to the second major opportunity for industrial water use: zero discharge.

3.2. Opportunity #2: closing the loop with zero discharge

Zero discharge is a key target both for reducing water withdrawals by industry, and for reducing pollution to the environment. All the effluent that would normally be discharged is treated, recycled or sold to other users. Without going into detail, I wish to note that there are a range of techniques which can be used to facilitate moving in this direction, including:

- stream separation
- raw material recovery from waste
- energy recovery from waste
- reuse of waste (in a different form)

Reducing the volume of effluent discharged back into the water environment by industry is essential to closing the gap that exists between water withdrawals and actual water consumption, as we noted earlier. Once no more water is discharged from an industrial installation, its overall water consumption will equal its water withdrawal from source. In practice, this means that water withdrawals by industry will gradually decline, as levels of water recycling increase, down to the point where withdrawals equal consumption. This process has already begun in Europe, as we saw in Figure 4a, which showed by the declining water withdrawals by industry over the past 25 years. Moving towards zero discharge can be done at the level of the individual enterprise; at the local level (say by a group of companies operating in an industrial park); or at a district or municipality level.

The city of St Petersburg in Florida, USA, is the first municipality in the world to have achieved zero effluent discharge to its surrounding surface waters. Situated on a bay, which is a major tourist attraction, the city has laid an extensive dual-reticulation system. All the domestic and industrial wastewater generated is treated to a high standard. The reclaimed water is then reused for irrigation and industrial cooling applications by thousands of customers, accounting for nearly half of the city's water needs of 190 Ml/day. By substituting reclaimed water for potable water in many applications, the city has eliminated the need for expansion of its potable water supply system until the year 2030. Equally importantly, there is no pollution of the beaches and marine ecosystems by municipal wastewater, and no unsightly sea outfalls.

It should be noted in this context that irrigating city parks or agricultural land counts as reuse of water, as these are applications where more freshwater would have been taken out of the natural cycle, had the wastewater not been available for use. It is not counted as discharge. However, strictly speaking, some of this water might seep through into groundwater and run off into streams and drains. On balance, irrigation of land with wastewater is a technology, which purifies wastewater and can be regarded as an additional and sustainable treatment step.

Materials recovery and waste reuse

There is a growing understanding worldwide that we need to find ways to make our industrialized society more cyclical in its use of materials and resources. At present the uses of materials and other inputs to industrial processes (such as energy and water) are primarily linear. Resources are mined, products are manufactured, wastes are generated and then disposed of at the end of the process. The products themselves sooner or later end up as waste to be thrown away. At present much environmental protection is still based upon "cradle to grave" thinking. By contrast, the "cradle to cradle" concept is a vision of cyclical flows of materials. The materials, which go into making up products could be reused over and over again, if products are designed in such a way as to facilitate materials recovery. This approach seeks to eliminate the whole idea of waste, and hence it is much closer to the way things are done in nature.

The "cradle to cradle" type of thinking is developed through initiatives such as chemical leasing, whose business model is based upon providing a service rather than selling a product. The chemicals remain the responsibility of the chemicals leasing firm, while the customer, the industrial enterprise, purchases services such as cleaning, coating, colouring and greasing. This business model aligns the incentives for both the customer and the supplier to reduce the amount of the chemical used. The implication for industrial water management is that much more attention is paid to ensuring that the chemical in question does not enter the process water streams in the first place, or is efficiently stripped out again if it does.

In order to recycle or reuse materials effectively from waste streams the various material flows to be kept as distinct as possible, according to the principle of stream separation mentioned earlier. This may require *process* re-design or modification. Developing products and markets from waste streams can also require innovative *product* design. The clear benefits here for water management are through reducing the effluent load. A case study of cheese production in El Salvador provided by UNIDO demonstrates this very effectively.

A typical dairy company in El Salvador was using 10 litres of milk (and about 80 litres of water in the process) in order to produce one kilogram of cheese. Nearly 9 litres of whey were produced as a byproduct, and were simply discharged into the wastewater. Whey is a highly concentrated organic liquid, containing proteins and lactose. Large dairy companies use ultra-filtration plants to produce pure lactose, additives for ice cream and other food products from this byproduct. However, this technology is not affordable for small and medium-sized companies.

The solution proposed by the National Cleaner Production Centre in El Salvador was to process the whey in order to produce a marketable whey-fruit drink. Such drinks are available on the European market and are popular with consumers. No additional investment was required by the company in order to process the whey. The estimated benefits were found to be as follows:

- 11.5 per cent reduction in the volume of wastewater
- 40,000 mg/l reduction in BOD level in wastewater

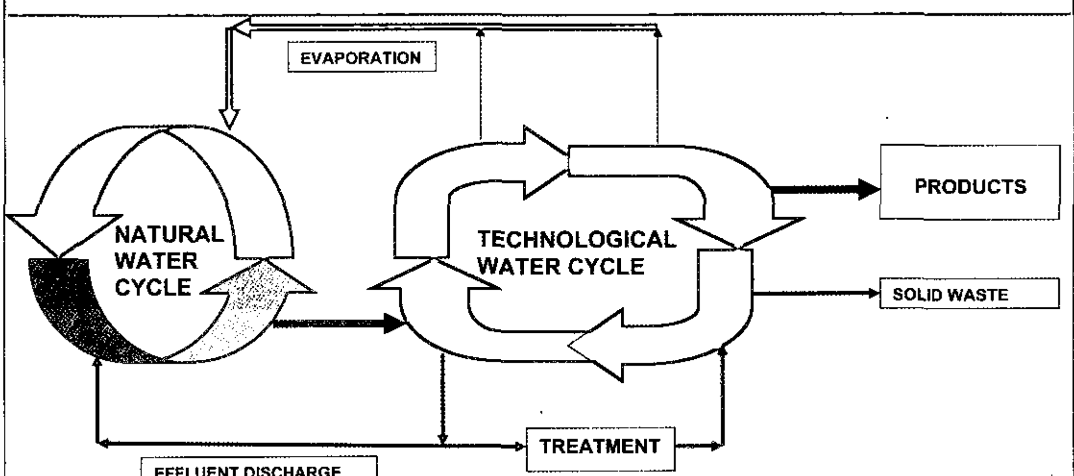
- 60,000 mg/l reduction in COD level in wastewater
- US$ 60,000 per year saving in wastewater treatment costs

Other dairy companies in El Salvador are starting to produce this product, and similar programmes are being developed in Guatemala and Mexico. This case study shows that there are substantial financial benefits to be found in waste recovery, hand-in-hand with the goals of reducing pollutant loading and wastewater discharge.

Towards zero discharge

Implementing zero discharge to the water environment ensures that water once used by industry must stay within the technological cycle, except for that fraction which evaporates and is thereby returned to the natural water cycle, free of contaminants. Through zero discharge, abstraction of water from the natural water cycle is kept to a minimum. The water, which is abstracted is reused over and over, or consumed in various ways. There should be no residual effluent or wastewater, which needs to be disposed of to a river, to a stream, or to a marine outfall. In this way we are protecting the environment, ensuring our future water security, and maximizing industrial water productivity at the same time.

Figure 5. The natural water cycle and the technological water cycle



Going "all the way" to zero discharge places great emphasis on water recycling and water reuse within the factory or enterprise. The cleaner the wastewater stream, the simpler and cheaper are the treatment methods that need to be applied in order to reuse it. However, often there are simply not the resources, nor the applications within one single enterprise, or within a group of enterprises, where lower-grade water can be treated and reused. Also, economies of scale can be achieved by treating larger volumes of wastewater. In these situations, achieving zero discharge on a local or district level requires the building of partnerships and linkages between industries and local government, and also may necessitate some innovative financing mechanisms.

4. Conclusion

Of course there are many intermediate steps to be taken to reach the ultimate goal of zero discharge, just as there are varied mechanisms, which will improve and increase industrial water productivity over time. Many policies and regulatory strategies need to be worked out in order to implement the vision; much research and development, innovation, and technology transfer needs to take place; and partnerships aiming to achieve these ends need to be built and strengthened, locally, nationally and regionally. These will be the subject of other papers and workshops during the course of this conference. However, I trust that this paper will have set out some of the fundamental challenges for the technology foresight process and the decision-making: how precious our freshwater is; how industry has a major responsibility and a major role to play in protecting and conserving this resource; and finally, how close at hand are the opportunities that we have to ensure our future water security and the sustainability of water use in industry.

Notes

[1] Kuylenstierna J. and Najlis P., "The comprehensive assessment of the freshwater resources of the world - policy options for an integrated sustainable water future", Water International 23(1), 17-20, 1998.

[2] T. Asano and C. Visvanathan, "Industries and water recycling and reuse", in *Business and Industry - A Driving or Braking Force on the Road towards Water Security*, 2001 Founders Seminar, organized by Stockholm International Water Institute, Stockholm, Sweden, pp.13-24.

Saving Water and Increasing Industrial Water Productivity

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Biographical Note

Jerzy A. Kopytowski is a consultant in technology management, part time working with the Industrial Chemistry Research Institute (ICRI) in Warsaw, Poland. He is providing services in establishment of the development programs of the chemical industry, preparation of the feasibility studies and revamping of the technological units. During last 15 years he prepared 46 different studies and technology assessment. In years 1985-1992 he was a staff member of UNIDO, in position of Senior Interregional Advisor providing services to the industry in developing countries in particular advising on business opportunity selection in chemical and linked industries. Important chemical industry centres have been constructed in developing countries following his advise and assessment studies. From 1998-2006 he was an elected member of the CHEMRAWN IUPAC (International Union of Pre and Applied Chemistry) Committee and in years 2004-2006 was a Secretary of this Committee. He initiated and carried out important IUPAC activities in the field of innovative processes i.a contributing with papers and concepts on Union priorities.

He has broad managerial experience, being the President-Managing Director of largest Polish Engineering Company PROSYNCHEM (presently Fluor SA) and Director General of the biggest Polish research institute (ICRI). In period of 1972-1980 he was Assistant Professor in Silesian Polytechnic University lecturing on system engineering and industrial management at its Management Department. He is an author of numerous publications and patents. He has MSc degree from Lomonosov Chemistry Institute in Moscow (1956), ad PhD degree in chemistry from Lodz Polytechnic University (1964).

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Introduction

It is difficult to overestimate the importance of water for the survival of humanity. As a result, numerous organizations and scientific communities frequently discuss the issue in specialized papers at conferences and at high level ministerial meetings.
Every year over several million papers and at least five or six scientific/industrial/ international conferences and symposiums are organized concerning the industrial use of water. The list of international worldwide conferences carried out during recent years is attached in Annex I.

Notwithstanding the intense interest, real progress in increasing water productivity is very limited. There are many reasons for this situation: the most important is that the water cycle (USGS, 2005) is one of the most complex systems and water has many uses influencing life in significant ways. Therefore, progress may be expected if an analytical review of every important use is carried out in relation to the overall water cycle, paying particular attention to the likely future uses.

This paper discusses the industrial uses of water and considers projections for increased future consumption. As a result, it is hoped that there will be some progress in increasing industrial water productivity.

1. Industrial Water Systems

1.1. World Water Resources and Main Consumers

The United Nations hydrological investigations from the early seventies (Shiklomanov, A., 1974) were well organized and conducted in a systematic way. This resulted in the establishment of a list of numerous variables (over 70) collected by national authorities under the guidance of international methodologies.

1.1.1. Value of Statistical Data

It is not the purpose of this paper to evaluate water resources and all its main uses. In principle the amount of water on the earth is stable. The only change is the increased total withdrawal of water from circulation as a result of consumption by various uses. However, in discussing industrial water use and its productivity, it is necessary to have a view of the total water assets, and to analyse the proportions between the various uses and the consequences of water withdrawal.

Statistical data on water resources are derived from national statistics. The UN, World Bank, FAO, UNICEF have made large scale efforts to achieve uniformity and credibility in the published data (UN, 2005). During the late 1990s and in the first decade of present millennium they carried out numerous workshops, conferences and prepared guidelines to improve the quality of water statistics. Some of the international organizations active in the field are reported in Annex II.

Despite these efforts, not all data are compatible and comparable for use in qualitative analytical exercises. As a rule, water systems are supervised by several national authorities who investigate hydrology and consumption in different ways.

Therefore, the statistical data are of limited use as can be seen by analyzing published data from different sources. In this paper, the source of information on hydrology and uses of water is primarily based on AQUASTAT data (AQUASTAT FAO) wherever available.

1.1.2. Definitions

The FAO has cited, in its description of the different aspects of the water cycle, about 50 variables (European Commission; European Environmental Agency) of which the majority are of hydrological importance. For the purpose of discussing industrial water productivity, several variables must be used, therefore a list and definitions of the most important variables is given below.

1.1.2.1. Actual Renewable Water Resources – ARWR (total and per capita)

Total Actual Renewable Water Resources (ARWR) is the theoretical maximum amount of water actually available for each country. It is the sum of Internal Renewable Water

Resources (IRWR) and External Renewable Water Resources (ERWR), which is the inflow from upstream countries and border lakes or rivers. ERWR may be positive or negative depending on the flows.

The amounts given in statistical tables for countries cover the period from 1960-2005 and only one number, the most recent, is given. Updating is carried out when the FAO conducts local studies. The value is given in km^3/year or 109 m^3/year.

Per Capita ARWR is a value of ARWR on a per capita basis and is calculated using the 2006 UN Population Division estimates. The value is given in m^3 per year per person.

The information provided by these numbers should be analysed with care because not all water included in these amounts is accessible to humans. It is derived from water cycle analysis and comprises the content of all rivers, lakes and underground water.

1.1.2.2. Internal Renewable Water Resources – IRWR (total and per capita)

Total Internal Renewable Water Resources comprises the value of the average annual flow of rivers and recharge of groundwater generated from endogenous precipitation. Natural incoming flows originating from outside of a country are not included. IRWR is calculated in the following way:

IRWR= surface water resources + groundwater resources - overlap

Data were collected from 1960-2005 and are given as one number.

Updates are made when the FAO conducts local studies. The value of IRWR is given in km^3 per year or 109 m^3 per year.

Per Capita IRWR is a value of IRWR on a per capita basis calculated using the 2006 UN Population Division estimates. The value is given in m3/per capita.

The information provided by these numbers should be analysed with care because not all water included in these amounts is accessible to humans. It is derived from water cycle analysis and comprises the content of all rivers, lakes and underground water.

1.1.2.3. Water Withdrawals (total and per capita)

Annual Total Water Withdrawal (ATWW) is the gross amount of water extracted from any source, either permanently or temporarily for a given use. It includes consumptive use, conveyance losses and return flow. Data presented by the World Resources Institute are the most recent values originating from a period from 1998-2002. The total water withdrawal is the sum of estimated water use by the agriculture, domestic and industrial sectors. The value of ATWW is given in km^3 per year.

Per Capita ATWW is a value of ATWW on a per capita basis calculated using the 2006 UN Population Division estimates. The value is given in m3/per capita.

The water withdrawal is the sum of estimated water use by the agriculture, domestic and industrial sectors.

Percent of Water Withdrawals Used for Agricultural Purposes is estimated on the basis of the special methodology developed by the FAO. The sectoral share is calculated by dividing agricultural water withdrawals per year by the annual total water withdrawals. The information was compiled by AQUASTAT in 2003 from a period of 15-25 years. The data presented by the World Resources Institute are the most recent. The information is given in per cent share value.

Percent of Water Withdrawals Used for Domestic Purposes is collected from national resources or international research centres or FAO special studies. The sectoral share is calculated by dividing domestic water withdrawals per year by annual total water withdrawals. AQUASTAT has scaled the data according to the GDP per capita assuming the full proportion in the increase of the water withdrawal and GDP per person growth for developing countries. For the high income countries a decreasing proportionality factor is used. The information is given in per cent share value.

Percent of Water Withdrawals Used for Industrial Purposes refers to the proportion of total water withdrawals that is allocated to industrial use. The current AQUASTAT database provides data per 5-year period if available. Data presented by the World Resources Institute are the most recent. The industry sectoral share is calculated by dividing industrial water withdrawals per year by the annual total water withdrawals. AQUASTAT has linearly scaled the increase of industrial withdrawals according to increase in GDP for developing countries and as flat for high income countries. The information is given in per cent share value.

Consumptive Use is an irreversible loss of water from water withdrawal from a given water flow or basin. This water may be evaporating in the recycling system, or used as solvent in products and drinks, or as moisture content in various products etc.

Consumption Coefficients (direct or cumulative) are the units of use of a given resource per unit of variable analysed. The consumption coefficient may be direct or cumulative.

The direct consumption coefficient relates to one analysed product, while the cumulative consumption coefficient relates to a final product obtained in the sequence of raw materials and intermediate products, and is given as multiple of the direct consumption coefficients of the products from the analysed sequence.

Wastewater is the portion of withdrawn water which has been polluted by industrial use and must be treated to the regulatory levels before reaching other water sources.

Water Productivity represents the ratio of value of the withdrawal of water, expressed in m3 (or in m3 per capita), to the value of output from the industrial activities using this water, expressed in monetary terms. The value of output may be measured in industrial value added or GDP per capita (when macroeconomic patterns are discussed).

The amount of water used by a given industrial process is defined as *direct water productivity*. In the case when the consumption of water is related to the complete industrial process, from raw materials to consumers products, then this water productivity is defined as *extended (cumulative) water productivity* (or sometimes *technological water productivity*).

1.1.3. Water Resources and Main Consuming Outlets

Tables 1 and 2 below present water resources by regions as well as the water withdrawal by sectors of use as reported by the FAO (World Research Institute, 2006).

Table 1. Regional Water Resources (Internal Renewable Water Resources)

Region	IRWR km^3/year	% of world fresh water resources	IRWR per capita in 2003 m^3
Africa	3,936	9.0	4,600
Asia	11,594	26.6	3,000
Latin America	13,477	30.9	26,700
Caribbean	93	0.2	2,400
North America	6,256	14.3	19,300
Oceania	1,703	3.9	54,800
Europe	6,603	15.1	9,100
World total	43,659	100.0	6,900

Table 2. Regional Water Withdrawal and Use (FAO, 2003)

Region	Total withdrawal km3/year	Domestic withdrawal km3/year	Industrial withdrawal km3/year	Agricultural Withdrawal km3/year	Withdrawal as % of IRWR
Africa	215	21	9	184	5.5
Asia	2,378	172	270	1,936	20.5
Latin America	252	47	26	78	1.9
Caribbean	13	3	1	9	14.4
North America	525	70	252	203	8.4
Oceania	26	5	3	19	1.5
Europe	418	63	223	132	6.3
World total	3,830	381	785	2,264	8.8

The method of analytical evaluation is related to the 2nd UN Water Conference from March 2006. There is a clear relationship between industrial water use as a function of industrial development and income. The data for 2003 are given in Table 3 (AQUASTAT FAO).

Table 3. Industrial Water Withdrawal

Region / income status	Total use m^3/per capita/year	Industrial as % of total
World	632	20
Developed countries	–	41
Developing countries	–	11
High income	970	44
Low income	556	5
Middle income	–	20

The projections of future water demand growth assume both growing populations and the development of industrial structure in low and middle income countries. The projections assume an overall growth of up to 20 per cent of total withdrawal for industrial water, and growth in domestic use with growing population. The expected use of water for industrial purposes reported by the World Bank in 2001 was 1170 m^3/year/per capita worldwide.

It is not the purpose of this paper to produce projections of industrial water use, given among other things the imperfect statistics and the various definitions of water use. This paper is concentrates on the possibilities of saving water and increasing water productivity.

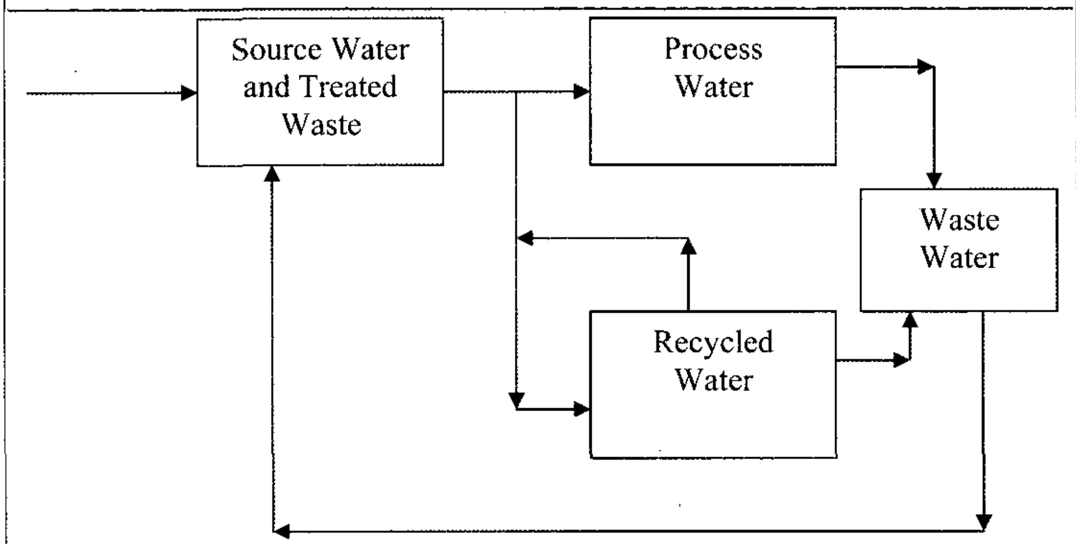
1.2. Industrial Water Systems (UNESCO, 2006)

Raw water originates from withdrawals from rivers, lakes and deep underground water sources. The majority of the water is a renewable resource except wastewater, which when it is not fully utilized, can be the reason for excessive raw water use in adjusting wastewater quality to the legislated concentration level of the pollutants. The cycle of industrial water treatment is shown on Figure 1.

Raw water from a source is clarified by means of sedimentation, filtration and partial chemical treatment to adjust its quality to the requirements of the unit processes operated in a given industry. In most cases, the impurities comprise organic matter and sometimes living organisms and, in almost every case, include calcium, magnesium and other salts. Even from the start of consumption, the treatment of industrial water produces waste, for example simple filtration at the intake point may produce waste from living organisms. Oxidation treatment with ozone and chlorine in principle acts in a bacteriological way by coagulating the organic matter allowing further filtration. The calcium and magnesium salts are removed to acceptable levels by combined treatment with acids, soda and calcium oxide. This process produces sludge which after sedimentation and filtration produces waste materials. The third level of water purification is ionic treatment using cationic and anionic resins as ion exchange carriers. The ion exchange resins require regeneration by treatment with acids and salts which again produce a certain amount of wastewater.

There are numerous companies specializing in water treatment processing providing the necessary know-how, equipment, and special water additives to reduce the amount of wastewater originating from water treatment. These companies have grown to become significant factors in the industrial water market and are the reason why more and more industrial water consumers are outsourcing their industrial water treatment needs.

Figure 1. Sequence of Industrial Water Treatment



Before presenting the basic data for the detailed assessment of industrial water productivity, several comments are necessary to clarify the value of the information as well as the validity of the projections.

1.2.1. Industrial Structure

Regional industrial structure is no longer stable. The impact of globalization on water withdrawal and use (Pacific Institute, 1998) starting in the early 1990s, was not considered in earlier projections. In high income countries, the development of secondary industries and the information / communication sectors influenced industrial water use by stabilizing or even decreasing it. Moreover, legislation governing access to water and its use, in particular reducing the amount of wastewater and the concentration of pollutants, has also led to stabilized or reduced consumption. However, the expected feature of the Kuznets function (UNESCO, 2006) has not yet been clearly observed.

On the other hand, many primary industries using large quantities of water have moved to developing countries. Furthermore, accelerated industrialization of large countries such as China, India, Indonesia, etc. has increased the use of industrial water in those areas.

1.2.2. Water Recycling and Recovery from Wastewater

The majority of statistical data on water withdrawal and use do not include the amount of recycled water. The recycling of cooling water is typical for large scale industrial establishments in high income countries, in particular in power generation, although many countries are now using direct water for cooling purposes. Therefore, the true water consumption on a macro scale can not be assessed and compared.

1.2.3. Technological Water End Use

It is very rare that the upper management levels of a chemical company would question a plant's water consumption. Before the construction of a chemical plant during the design period, the local government would impose conditions concerning the water use of the future plant. In the majority of cases this would follow the national guidelines and legislation, perhaps adding some local requirements. The majority of chemical processes require from 10 -120 m^3 of cooling water per ton of product. When the current price of water varies between 5 -15 cents per m3, this means that less than US$ 20 is charged per ton of product. This is from 1 per cent - 5 per cent of the price for the majority of chemicals.

There are many other cost elements more critical for the price of the product which require managements' attention. However, in a macroeconomic sense, the unit water consumption in a process does not reflect the true value/cost of water for the chemical industry. The cumulative branch cost should be evaluated to decide what water consumption controls should be applied and what options are available for water savings.

The results of such an analysis should be the only criteria for approving the operation of a chemical plant, both by the local authorities and the investors. In this paper the cumulative branch coefficients of water consumption, both as physical and cost parameters, are assessed and compared with the value added.

This assessment shows that water is a valuable resource and requires the attention of the management with regard to production profile and process selection. The cumulative consumption is also important for the future development of industry, due to the scarcity of water resources in many regions.

The chemical industry should be an example for the analysis of water use in other branches of industry. This should indicate the macroeconomic value of water in the national economy for today's operations as well as for future development, in particular for countries where industrialization is still in its early stages.

1.2.4. Dependence of Utilities on Water Use

Countrywide statistical data usually presents the total use of industrial water (World Bank, 2001). However part of the industrial water is in fact for domestic or agricultural use. All energy produced by power stations is divided between industrial, domestic and agricultural use. Therefore, water used to produce each kWh (about $10m^3$) is also divided between different uses, which is not shown in the statistics. Also, statistics on industrial water use by certain technological processes do not reflect the full amount of water used, which comprises direct and intermediate use from the production of electrical energy, steam, neutral gases, compressed air etc. In this concept, all high energy consuming processes (electrolysis, electrothermic etc.) are also high water consuming processes, but only through the consumption of the power station. This is not reflected uniformly in the statistical data, and sometimes energy production is noted parallel to industrial use. In other cases, e.g. when bottled water is produced, it is noted as industrial use when it actually goes to domestic use.

Therefore, management when assessing water demand by a certain technology may not be fully aware of the consequences of a given production process. When strategic decisions are taken, the water use by the whole network of industrial processes from basic raw materials (crude oil, natural gas, mineral ores etc.) to the final consumer product (e.g., fertilizers, plastics tubes, films etc.) should be considered. Several examples are given in Table 4 showing the difference between the full network and individual water consumption.

Table 4. Comparison Direct and Cumulative Water Consumption

Petrochemicals	**Direct m^3/t**	**Cumulative m^3/t**
LLDPE	160	446
HDPE	157	472
PCV	30	668
PS	78	110
Fertilizers	**Direct m^3/t**	**Cumulative m^3/t**
Urea	80	124
AN	6	137
DAP	10	165

1.2.5 Anthropogenic Changes in Global Climate and Water Resources

The projections of the withdrawal and use of water, which were begun in an organized way in early 1970s, were based on the assumption of stable climatic conditions. In that period, the existing information about global warming was ignored by politicians and, in particular, by hydrological academic institutions, notwithstanding the Kyoto agreement.

However, in recent years obvious climate changes, in particular worldwide and regional temperature increases, have attracted attention and hydrologists have discussed different scenarios involving the expected impact of climate change. Obviously there is not a common position regarding the qualitative parameters of global warming resulting in the increase of average temperatures. However, the rational position proposed by Shiklomanov 26) is convincing enough to be widely accepted.

First, it should be stated that the annual trends of the general water cycle will remain unchanged as it is not possible to change the general water circulation on the globe. What is significant is that large scale seasonal changes are predicted which will have an impact on water management principles and practices. The occurrence of droughts and flooding will change the water availability for all uses, including industrial use. In a period of draught water would not be available, and in a period of flooding water would be wasted due to limited potential storage capacity. Also the quality of water in a period of flooding is basically different from that in normal river or lake conditions. Therefore, all projections should be revised considering the predicted new patterns of water availability. This will lead to completely new principles of water management. In particular, industry should take a lead in developing new methods of water use, which will obviously change not only patterns, but also water cost.

1.2.6. Impact of Population Growth

The withdrawal of water in comparison with IWRI and AWIRI in many countries is at safe levels. However, a large number of countries are at a critical level. These are countries, such as India or China, with population growth in the range of 1 per cent - 2 per cent annually. Even if water withdrawal for irrigation purposes remains stable, the demand for human use and industrial use will expand with the population growth as well as with industrial development. The demand for water with growth of population and industrialization may not be linear, considering achievable health levels and standard of living as well as outsourcing the majority of high water consuming industries to developing countries. However, these principles are not valid for all periods: the population since1950 has doubled while water consumption has tripled.

1.3. Sources of Industrial Wastewater and Treatment

1.3.1. Sources of Wastewater

There are many sources of industrial wastewater (UNCSD, 2004) and they are differentiated by unit amounts, composition and origin. They may be classified as follows as wastewater from:

a. industrial water supply
b. industrial water recycling
c. direct use of industrial water
d. process waters
e. rain harvesting by sewage systems

In Europe there are over 2400 wastewater treatment plants and numerous small size treatment facilities for small and medium size industries. Every one has certain particularities related to the properties of waste incorporated in the water. According to EU regulations for the standards for wastewater, 40 industrial categories are recognized with limits regulating the discharge of 120 pollutants.

A standard water treatment plant consists of at least four processes:

- primary treatment to remove coarse floating materials
- chemical treatment to remove inorganic impurities
- biological treatment to remove organic derivatives
- disinfection treatment to remove microbes

1.3.2. Treatment Processes (ECOPROG, 2006/2007)

Every stage of treatment has a combination of necessary unit processes. The basic treatment processes used to remove certain pollutants are given in Table 5 below.

Table 5. Treatment Processes to Abate Systemic Pollutants

Pollutant	Treatment Processes	
Bio-Chemical Oxygen Demand	Activated sludge Trickling filter or Rotating Biological Contactors (RBC)	Aerated lagoon Oxidation ditch
Total Suspended Solids	Sedimentation Screening	Flotation Chemical precipitation
Nitrogen	Nitrification/denitrification Breakpoint chlorination	Air stripping
Phosphorus	Chemical precipitation Biological treatment	Air stripping
Heavy metals	Biological treatment Chemical precipitation	Evaporation Membrane process
Fats/oils and greases	Coagulation Biological treatment	Flotation Membrane process
Volatile Organic Compounds	Biological treatment Carbon adsorption	Air stripping
Pathogens	Chemical disinfection	UV radiation

The treatment processes have critical operation parameters which should be adapted to particular wastewater qualities as noted in Table 6 below.

Table 6. Critical Operation Parameters of Wastewater Treatment Processes

Treatment Process	Critical Operation Parameters
Screening	Build-up on the screen, clogging
Sedimentation	Flow rate, short circuit of flow, absence of sludge, scum removal system
Centrifuging	Overload, clogging, water flooding
Air stripping	Blocking of piping, freezing problems
Neutralization	pH monitoring, feed ratios, mixing
Precipitation	Feed system, mixing, contact timer
Coagulation	Feed system, mixing, contact timer
Adsorption	Regeneration system,
Disinfection	Feed system, mixing timer
Activated sludge	Aeration bubble size, air distribution, concentration monitoring uniform distribution
Trickling filter	Positive air circulation, filter media dosing
Rotating biological contactors (RBC)	Steady shaft rotation

The typical wastewater pollutants by category of industry are given in Table 7 below.

Table 7. Water Pollutants in Selected Industry Categories

Industry	Wastewater Pollutants	Treatment Process
Textile	BOD, TSS, alkalinity	Neutralization, chemical precipitation, biological treatment
Leather Goods	BOD TSS, chromium	Sedimentation, biological treatment
Laundry	Alkalinity, BOD, turbidity	Screening, chemical precipitation, adsorption
Detergents	BOD, saponified products, soaps	Flotation and skimming, chemical precipitation
Brewed Beverages	BOD	Centrifuging, biological treatment
Meat & Poultry	BOD	Screening, sedimentation, biological treatment
Bakeries	BOD, FOG, detergents	Biological treatment
Soft Drinks	BOD, TSS, alkalinity	Neutralization, screening, biological treatment
Pharmaceuticals	BOD, organic compounds	Evaporation, drying
Pulp and Paper	High/low pH, TSS, inorganic compounds	Sedimentation, neutralization, biological treatment
Metal Plating	Acidity, heavy metals	Neutralization, sedimentation, chemical precipitation
Plastics and Resins	High/low pH, volatile organic compounds, TSS	Neutralization, evaporation, biological treatment

BOD= biological oxygen demand
FOG= fats, oil and grease
TSS= total suspended solids

Such different processes and mixtures of pollutants require specific chemicals for treatment processes. There are more than 400 chemical products used in wastewater treatment in medium and large tonnages. Beyond this, there are more than 1200 chemicals used in the analytical testing of different stages of wastewater treatment.

The categories of these wastewater treatment chemical products (ACCEPTA, 2007) are as follows:

- Inorganic coagulants
- Organic coagulants
- Antifoamers/defoamers
- Anionic polymers
- Cationic polymers
- Enzymes
- Microbes
- Cationic flocculants
- Anionic flocculants
- Liquid anionic polymers
- Liquid cationic polymers
- Odour control chemicals / adsorbents.

1.3.3. Standards for Wastewater Treatment

There are many standards for wastewater treatment and some are legally accepted by Agenda 21 (Chapter 18) and EU directives: 93/793 EEC and 76/464/EEC. In regard to water treatment systems the following standards are considered:

- Industrial water use WP-8
  (indicator measures total water abstraction by industries)
- Water pollution and water resources pressure WP5B
  (indicator measures the ratio of total wastewater treated to total water quantity used by industries)
- Water pollution and water resources WP5
  (indicator measures quantity of wastewater treated to total wastewater collection)

In the USA the EPA regulations (US EPA, 2006) stated by the Clean Water Act establish effluent limitations, guidelines and standards, in particular:

- Best Conventional Pollution Control Technology (BCT)
- Best Practicable Control Technology Currently Available (BPT)
- Best Available Technology Economically Achievable (BAT)
- New Sources Performance Standards (NSPS)

1.4. Depletion of Water

There are many definitions used in the description of water systems. The principal factor in water system analysis is the withdrawal of water from local resources. This parameter provides the proportion between the estimated amount of the resource and the periodic (e.g., annual) use of water. Withdrawal statistics are collected and some are presented in Table 3 above.

Withdrawal is limited by depletion of the water resource. In other words, the amount of withdrawal diminishes the resource. The country (regional) industrial water consumption indicator shows net use of water by local industry. In the majority of cases industry uses more water than officially shown by the statistics of withdrawal for industrial purposes (process water, cooling water, intermediate energy carrier etc.) The gross consumption of industrial water includes recycled water (cooling towers), rain harvesting and sometimes wastewater used after treatment. The water cycle on the Earth is closed which means that amount of water on Earth is fixed. However, only 0.1 per cent of the water present on the Earth is accessible to humans and this portion of water also is included in the water cycle. However water depletion occurs because of human activities. The reasons for this phenomenon are discussed widely at hydrological conferences and other meetings related to the changing environment and sustainable development.

Areas under the risk of depletion, or already under the process of depletion, are not suitable for industrial development without measures to return water back to water sources in these locations. This means in these areas that, at present, sustainable development can not be achieved. A list of depleted resources or those under depletion (Earth Policy Institute) are given below (Tables 8, 9 and 10). This list highlights only large scale areas with water scarcity, but perhaps in every country in Europe there are villages or small towns under similar water stress. Therefore, the location of industries together with the benefits of local increases in manufacturing value are limited to areas with water availability.

Table 8. Major River Systems under Stress

River or Water Basin	Depletion Features
Amu Darya and Syr Darya (Kazakhstan, Uzbekistan)	Diversion of the flow of these two rivers and intensive use for irrigation purposes has reduced the area of the Aral Sea by 75% and the nearest sea port is 150 km from the water side. The Aral Sea is divided into two small lakes.
Colorado River (USA)	Water from the Colorado River is withdrawn and during the year rarely travels all the way to the Gulf of California.
Fen River (China)	The Fen River has disappeared due to the source springs drying up and the river no longer reaches the Yellow river.
Ganges (India)	450 million population has nearly drained the Ganges basin.
Indus (India, Pakistan)	The Indus River rarely reaches the ocean because of intensive irrigation.
Nile (Sudan, Ethiopia, Egypt)	Following the doubling of the population in Sudan and Ethiopia predicted by 2050, the Nile will not reach the Mediterranean Sea.
Yellow River (China)	In 1997 because of drought, the river did not flow for 265 days.

Table 9. Depletion of Major Aquifers

Basin	Depletion Feature
North China Plain (China)	Water table falling by 2 - 3 m per year.
Southern Great Plains (USA)	Ogalla aquifer is drastically shrinking and irrigated areas in Texas, Oklahoma and Kansas are endangered.
Punjab (Pakistan)	Water table falling in three provinces.

Punjab, Haryana, Rajasthan, Andra Pradesh, Maharashtra, Tamil Nadu (India)	Water table falling 1 - 3 m per year. Extraction is double the recharge.
Chenaran Plain (Iran)	Water table was falling 2.8 m per year but after drilling to supply City of Mashad dropped by 8 m.
Yemen (whole country)	Water level dropped by 2m and in Sana region by 6 m per year.
State Guanajuato (Mexico)	Water table falling 1.8- 3.3 m per year.

Table 10. Disappearing Lakes and Shrinking Seas

Lake or Sea	Depletion Features
Aral Sea (Kazakhstan, Uzbekistan)	Aral Sea lost 1/5 of its water from 1960.
Baikal (Russian Federation)	Lake Baikal contains 1/5 of the Earth's fresh water and is polluted by discharges of chemicals from a large industrial complex making paper.
Lake Chad (Chad, Niger, Nigeria)	Lake shrunk from 23,000 km^2 to 900 km^2 and is now entirely inside the Chad borders.
Lake Chapala (Mexico)	Lake lost 80% of its water, level dropped 4 m and size from 1048 km^2 to 812 km^2 due to the use by 5 million people from Guadalajara.
Dal Lake (India)	Lake shrunk from 75 km^2 to 25 km^2, level dropped by 2.4 m parallel to rivers from Kashmir Valley.
Dead Sea (Israel)	Lake level dropping 1 m a year and length shrunk from 75 km to 55 km and divided into two smaller lakes.
Dorian Lake (Greece, Macedonia)	Lake level dropped 3.5 m and is only 1.5 m deep transforming itself into marsh.
Sea of Galillee (Israel)	Lake shrinking and becoming salty.
Man Char Lake	Diversion of Indus deprived lake of water, lake became salted and fisheries were depressed.
Lake Nakuru Kenya	Lake shrunk from 48 km^2 to 37 km^2 and is very polluted due to lack of sewage treatment.
Lake Owens (California)	Total area of 518 km^2 became dry due to the diversion of flow to Los Angeles. The dust from lake is dangerous for the city.

2. Economic Features Of Industrial Water Use

2.1. Industrial Water Consumption by Country and Industry

Water consumption can be assessed from two different aspects:

a. Macroeconomics, which considers the water withdrawal by industries in a given country by amounts as well as percentage of the total water withdrawal (Table 11);

b. Microeconomics, which considers the water use in a given branch of industrial production (Table 12).

Comparison of these two aspects is very difficult because of differences in statistical methodology as well as the multiple technologies of production (European Commission, 2006). Also frequently final product consumption only is taken into account and omits the amount of water used for the treatment of raw materials and intermediate products.

Table 11. Macroeconomic Information on Water Use by Country in Europe (AQUASTAT FAO)

Country	ARWR km^3	Withdrawal km^3/year	% of Industrial Withdrawal
Albania	41.7	1.71	11
Austria	77.7	2.11	64
Belarus	58.0	2.79	47
Belgium	18.3	9.03	86
Bulgaria	21.3	10.50	78
Czech Republic	13.2	2.58	57
Denmark	6.0	0.017	25
Estonia	12.8	0.158	38
Finland	110.0	2.476	84
France	203.7	39.69	74
Germany	154.0	47.05	68
Greece	74.3	7.77	3
Hungary	104.0	7.64	59
Ireland	52.0	1.13	77
Italy	191.3	44.37	37
Latvia	35.4	0.30	33
Lithuania	24.9	0.27	15
Moldova	11.7	2.31	58
Netherlands	91.0	7.94	60
Norway	382.0	2.19	67
Poland	61.6	16.20	79
Portugal	68.7	11.26	12
Romania	24.9	23.18	34
Russia	4507.3	76.68	63
Spain	111.5	35.63	19
Sweden	174.0	1.04	54
Switzerland	53.5	2.57	74
UK	147.0	9.54	75
Europe	7771.3	418.325	53

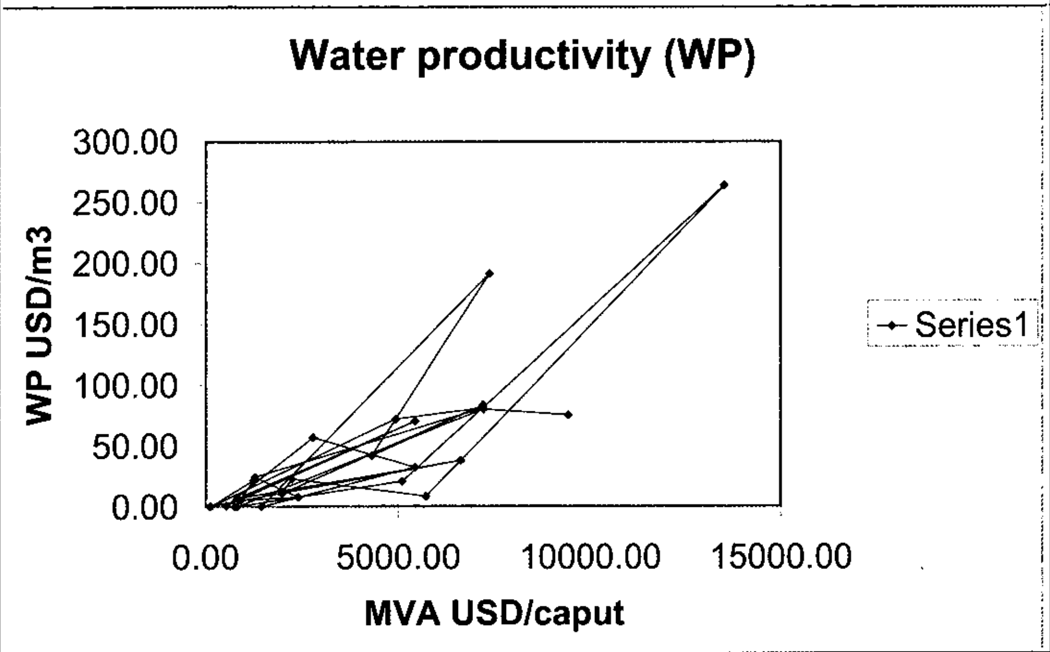
Table 12. Microeconomic Information on Water Use by Industry

Industry	Unit Reference	Water Consumption m^3/unit
Soft drinks	m^3	1.3 - 3.8
Beer	m^3	5.5 - 7.1
Cheese	t	4.2 - 5.8
Edible oils	t	5.3 - 7.7
Brick	t	15 - 30
Cement	t	3.8
Laundries	t	9.0
Leather tanning	t	40 - 67
Polymers	t	1.7 - 37
Paper	t	35
Semiconductor wafers	m^2	5.6 - 546
Textile	t	600 - 800
Steel	t	3 - 62

The differences in the ratio of water withdrawal for industrial purposes should be dependent on the existing industrial structure in each country. For the purposes of qualitative measurement, this should have an obvious impact on the relationship between the MVA and water withdrawal. However this relationship is not strictly quantitative.

The published data are given for the industrial MVA and the total MVA for given country (World Bank, 2001). The data for Europe (2005) are given in Figure 2.

Figure 2. Relationship between MVA and Water Productivity



The top productivities are observed in Denmark and Greece without any particular patterns common for two countries. Instead of a general clear functional dependence, three levels of water productivity are observed common for certain development patterns.

2.2. Price and Value of Water

2.2.1. Value of Water

The value of water is a multi-faceted variable. It has several aspects such as:

- social
- economic
- environmental

Social value of water is mainly related to domestic use. There are many estimates of the minimum/optimum domestic use of water. The usual ranges are between 30-150 l/person per day, but in many developing countries, in particular in Africa, these amounts are far from achievable in reality. In the majority of countries the price for domestic water is subsidized.

Economic value of water is related to its productivity and competitive use. The realistic economic value of water is very difficult to asses because it is different regionally and countrywide. Water in most of its uses has no substitute, therefore the highest level of pricing is established based on the level of cost recovery. This level is never achieved in countries with a high ratio of withdrawal to water resource.

Environmental value of water is assessed by the treatment cost of wastewater. Although in many countries there are limits for the loads and concentrations of pollutants, the wastewater quality is never comparable to fresh water quality. In fact, the costs of full recovery of wastewater have not been established.

Therefore, the prices of water established by public authorities, or owners of the sources are always undervalued and established to large extent voluntarily, even if they are based on research results.

2.2.2. Price of Water (OECD, 2003)

The sources of industrial water are diverse and usually local and regional government can not influence the direct price of water, although it is obtained from local sources such as groundwater.

Several research projects have shown that given the cost of water is unrelated to the local sources, the price may have little influence on conservation measures. Therefore, the price of water should be related to the manufacturing value added in a way that a balance is kept between low productivity (overuse) and potential outsourcing of the product. The slow adoption of this concept from local to regional to countrywide levels may keep this balance.

There is little information about the price of water and even published references do not indicate what source of water is involved. Given below in Table 13 are the prices of public water in several countries, without any indication of the water quality (OECD, 2003).

Table 13. Prices of Public Water in Several Countries (OECD)

Country	Price in 2001 USD/m^3
United Kingdom	0.90
Turkey	1.71
Canada	1.61
Hungary	1.53
Portugal	1.17
Spain	1.08
Netherlands	1.08
France	0.90
United States (?)	0.45

The price formula for different kinds of industrial water is derived from the following price elements:

a. Raw Water. This value can not be calculated objectively and is established on the basis of opportunity costs for users of water in given country or even geographical area, or particular site. The price of the raw water comprises fees established by the local authority and costs of water delivery from water sources to the treatment plant.

b. Clarified Water. The price is based on the cost of treatment (transportation cost, sedimentation, filtration, and in some cases chemical treatment).
c. Treated Water (in some cases softened). The price is based on the cost of treatment (chemical costs and separation).
d. Recycled Water. Here the price comprises the costs of the recycling system and the supplementary softening, involving evaporation and necessary treatment to keep the mineral concentrations at an acceptable level.
e. Process (often demineralized) Water. The price is based on the cost of partially softened water and anionic treatment costs.
f. Withdrawn or Used water. There may be additional charges based on the pollutants and their concentrations in the wastewater.

An example comes from Spain where the respective charges were established by the Agencia Catalona de l'Aiqua (Soler, M.A., and Planas, J.M., 2003). The price composition in Catalonia is therefore the sum of the following charges:

- general charge: 0.1091 €/m^3
- specific charge: 0.4276 €/m^3
- fresh water cost: 0.5367 €/m^3

Pollutant charges added to the water price (e.g.):

- suspended matter 0.3095 €/kg
- oxidable matter 0.6190 €/kg
- nitrogen 0.4699 €/kg
- phosphorus 0.9400 €/kg

All charges are given net before the adding VAT.

It must be stressed that treatment of the water produces wastewater which requires extensive treatment technology.

2.2.3. Price of Industrial Water (in €/m^3) for Large Scale Installations

The results of case studies in which all types of water have been evaluated are given below (Table 14).

Table 14. Price of Water (€/m^3) in Case Studies (VENTURES SC.)

Water Class	Industrial Case	Industrial Case	Industrial Case	Industrial Case

	A	B	C	D
Raw water	0.2	0.38	0.1	0.37
Decarbonized water	0.54	2.59	0.32	0.55
Recycled water	0.10 (93% recycled)	0.18 (90% recycled)	0.03 (95% recycled)	0.06
Process water	1.16 (85% recycled)	2.9 (60% recycled)	1.55 (75% recycled)	2.16 ?

Examples from the above table show a big difference between the water prices of specific applications from case to case. It is not the purpose of this paper to investigate the reasons for such differences, but it has been found that in every case different principles of bookkeeping were applied. It seems that Case A is the most representative one.

2.2.4. Minimum Size of Water Recycling Installations

The principle of water recycling in industrial installations seems to be most effective measure for saving water. Evaluation of the advantages of recycled water use is possible only on the basis of comparable rules of cost calculation.

For this purpose, a case study was undertaken considering:

a. Different prices of raw water;
b. Different capacities of the recycling system.

The calculations were made using the following assumptions:

- The price of water was established for the case of an outsourcing company, therefore it contains a 12 per cent (SRR AT) profit margin for each kind of water;
- Two cases for the price of raw water were evaluated:

  0.1 €/m^3
  1.0 €/m^3

- The electricity price was taken at 0.05 €/kWh;
- The amount and prices of chemicals for water treatment were taken arbitrarily from practical examples considering that dozen of systems exist and a low cost one was chosen.

The results are shown in Table 15 and Figures 3 and 4 below.

Table 15. Clarified Water Prices (€/m^3) Based on Technological Profiles

Capacity of Treatment Plant	10 000 m^3/h	1000 m^3/h	100 m^3/h
Raw Water Price	1.000	1.00	1.00
Clarified Water Price	1.590	1.64	1.80
Raw Water Price	0.100	0.10	0.10
Clarified Water Price	0.382	0.45	0.86

Figure 3. Clarified Water Price (Raw Water Cost of 0.1 €/m³)

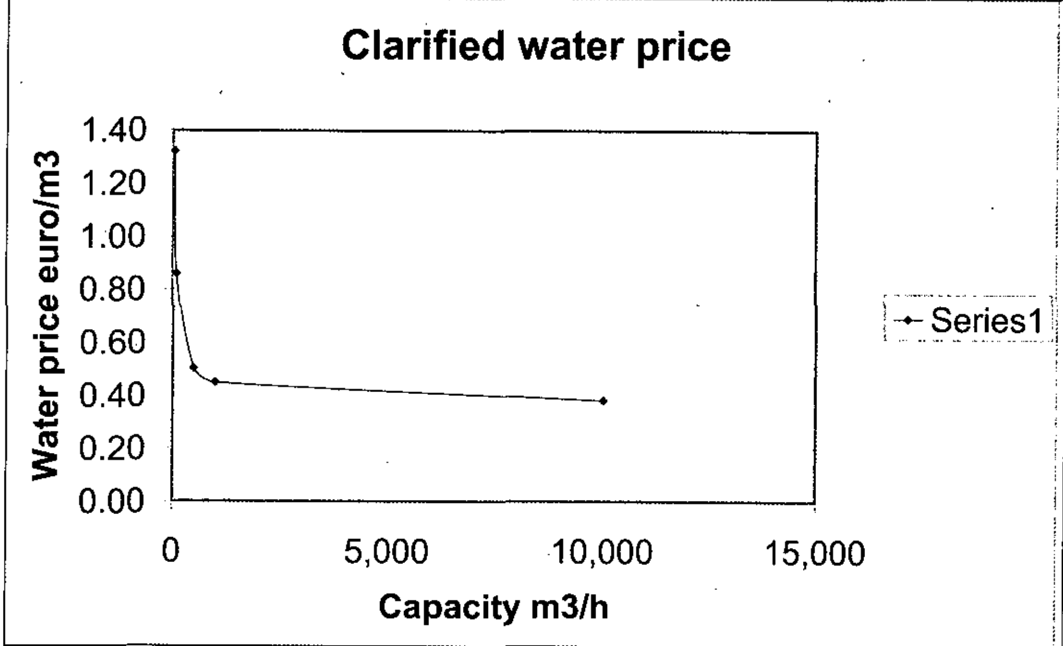
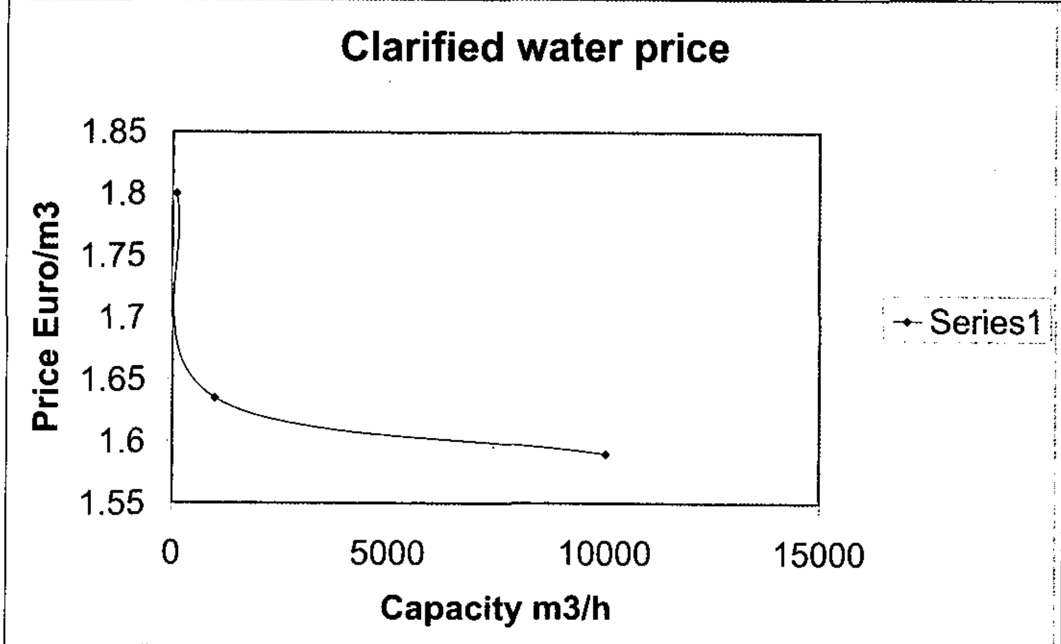


Figure 4. Clarified Water Price (Raw Water Cost of 1.0 €/m³)

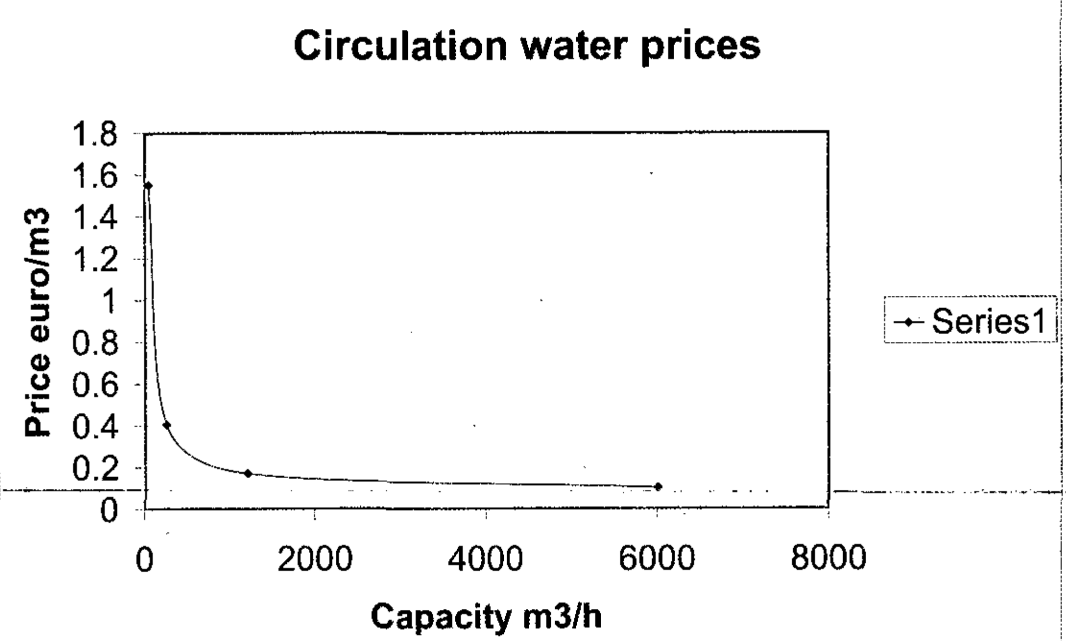


Clarified water is used as a feed for recycled water. As a function of climatic conditions, the amount of clarified water supplement to recycled water is between 3 per cent - 6 per cent. Evaporation of the water causes an increased concentration of salts in circulation and requires purging of 2 per cent - 5 per cent of the recycled water. For the purposes of calculating the price of recycled water, a 5 per cent supplement was considered to cover evaporation and purging losses. The results are shown in Table 16 and Figure 5 below.

Table 16. Price of Recycled Water (€/m³) Based on Technological Profiles

Capacity of Circulation System	50 m³/h	250 m³/h	1200 m³/h	6000 m³/h
Clarified Water Price	1.65	1.650	1.650	1.650
Recycled Water Price	1.61	0.470	0.235	0.168
Clarified Water Price	0.45	0.450	0.450	0.450
Circulation Water Price	1.55	0.405	0.170	0.102

Figure 5. Recycled Water Price (Cost of Clarified Water 0.45 €/m³)



Raw water costs differ significantly and are not predictable. No relationship between water prices and amounts used is observed.

Considering the impact of the cumulative industrial water cost on the profitability of industry, the minimum economic capacity of clarified and recycled water is approximately 1000 m3/h. This impact is considered in the section on water productivity.

2.2.5. Process Water Economic Parameters

Process water is the most treated type and used for example in:

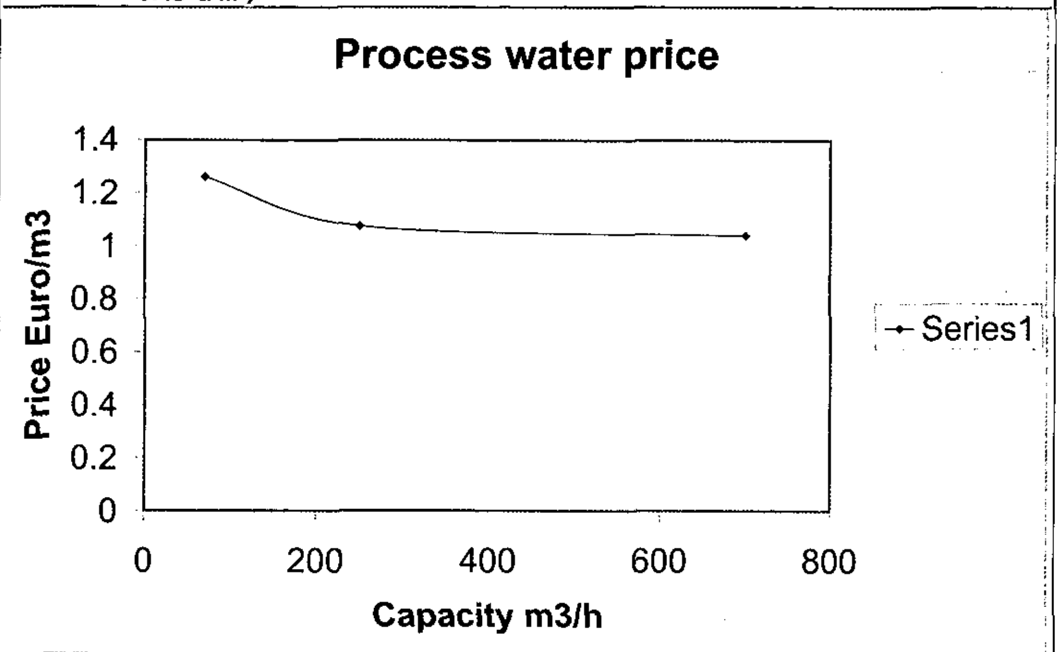
- Power production;
- Bio technologies;
- Food processing (drinks, beer);
- Textiles, chemical industry etc.

Process water is produced from clarified water by further chemical and ionic exchange treatment. The technologies are multiple and all are advanced in terms of the purity of process water produced. The basic difference between processes is the activity of the ionic resins and amount of regeneration solutions (salts, acids). The price of process water calculated on the basis of technological profile and considering the 12 per cent SRR AT is shown in Table 17 below.

Table 17. Process Water Price (€/m^3) (Cost of Clarified Water 0.45 €/m^3)

Capacity	50 m^3/h	250 m^3/h	700 m^3/h
Clarified Water Cost	0.45	0.450	0.450
Process Water Price	1.26	1.075	1.038

Figure 6. Process Water Price as Function of Treatment Capacities (Cost of Clarified Water 0.45 €/m^3)



2.3. Value Added and Water Consumption

2.3.1. *Water Productivity in Selected Branches of the Chemical Industry*

Worldwide sales for the chemical industry are approximately US$ 1.trillion. This figure is more or less equally divided between the USA, Europe and Asia / Pacific (each about 30 per cent, with the balance divided among other regions) and is similar in regard to technological structure. The data related to the consumption coefficients of water using MVA as a basis for particular industries are not available. Country data are available but they are from different statistical years and therefore difficult to compare. Furthermore, due to the different structure of industry from country to country, these data have limited value to determine effective measures for water saving strategies and policies. The available data were discussed in the preceding sections. The data originates from a study in South Africa and gives some insight into the structure of water consumption by major production branches. Therefore, to discuss the pattern and types of industrial water productivity, and measures for saving, two examples were evaluated:

- fertilizer production and consumption worldwide and by regions; and
- the petrochemical industry in Europe.

2.3.2. Methodology

Every technological process can be evaluated by a chart of parameters similar to the SRI structure. ICRI with VENTURES and UNIDO have developed similar charts which at present have about 1000 technological profiles. The form of the profile is given in Annex III. The consumption coefficient of cooling water is given as one of the parameters parallel to the energy and process water consumption. To evaluate the relationship between the physical and economic parameters of the technology two methods were applied:

a) The energy used was recalculated to the water consumption by considering that $10m^3$ water is used per kWh of electrical energy consumed. The amount of process water and steam used was recalculated to the water consumption by multiplying by 1.5 and both added to the cooling water consumption. This water consumption coefficient was related to the ton, MVA of the product or sales (price) value of the product, and expressed in €/ton or €/m^3.

   By using this method, the overall water consumption by the chemical industry in 2005 was 152 km^3.

b) The principle of cumulative consumption coefficients was applied. For each final product the sequence of processing technologies was evaluated, and using ratios of raw material or semi-product to the final product, coefficients were found giving the water consumption in full product sequences. The resulting consumption figures are much higher than direct consumption figures, and show the real value of all parameters related to the water productivity.

2.3.3. Fertilizers Example

Fertilizers are high tonnage products of low value and high unit consumption of energy and water. The production of fertilizers in 2006 (IFA, 2006) is shown in Table 18:

Table 18. Worldwide Production of Fertilizers (M t/year)

Region	Urea	AN	CAN	AS	MAP	DAP	TSP
Central Europe	2.3	1.1	7.7	0.8	0.1	0.1	0.2
Eastern Europe	15.4	1.2	2.8	0.2	0.3	0.1	0.2
North America	5.2	4.4	0.5	0.5	2.3	1.0	0.2
South America	4.4	2.6	0.0	0.7	5.1	4.6	0.5
Africa	2.2	0.4	0.0	0.3	0.9	0.0	0.8
Near East	0	0.4	0.4	0.0	0.7	1.0	1.5
Asia	6.6	0.5	1.0	0.1	0.0	0.6	1.1
East Asia	16.4	0.2	0.5	0.2	0.0	2.3	0.7
Oceania	20.4	1.1	0.1	0.1	5.0	2.3	1.0
Various	0.2	0.4	0.0	0.0	0.2	0.3	0.0
Total	**73.1**	12.3	13.0	**2.9**	14.6	12.3	**6.2**

AN - ammonium nitrate
CAN - calcium ammonium nitrate
AS - ammonium sulfate
MAP -mono-ammonium phosphate
DAP -di-ammonium phosphate
TSP - triple superphosphate

Considering the cumulative consumption coefficients (VENTURES SC.), the consumption of water by the fertilizer industry is shown in Tables 19 and 20.

Table 19. Water Consumption by Type of Fertilizer in Europe

Fertilizers	Production M t/year	Water Use m^3/t	Total km^3/year
Urea	17.7	124	2.19
AN	2.3	137	0.32
MAP	0.3	187	0.06
DAP	0.2	165	0.03
CAN	10.8	150	1.62
Other	1.5	153	0.23
Total	**32.8**	–	**4.45**

Table 20. Water Consumption by Type of Fertilizer Worldwide

Fertilizers	Production M t/year	Water Use m^3/t	Water Use km^3/year
Urea	73.1	124	9.06
AN	12.3	137	1.69
MAP	14.6	187	2.73
DAP	12.3	165	2.03
CAN	13.0	150	1.95
Other	9.1	153	1.39
Total	**134.4**	–	**18.85**

The productivity parameters evaluated were as follows:

- Water use expressed in m^3/t
- MVA of product (cumulative)
- Productivity expressed as the cumulative ratio of price and water use in €/m^3 (SV/m^3)
- Productivity expressed as the ratio of MVA and water use in €/m^3 (MVA/m^3)
- Profit at SRR AT of 5 per cent and a water price of 0.5 €/m^3

The results are given in Table 21.

Table 21. Water Productivity by Fertilizer Type Worldwide (Shiklomanov, A., 1974)

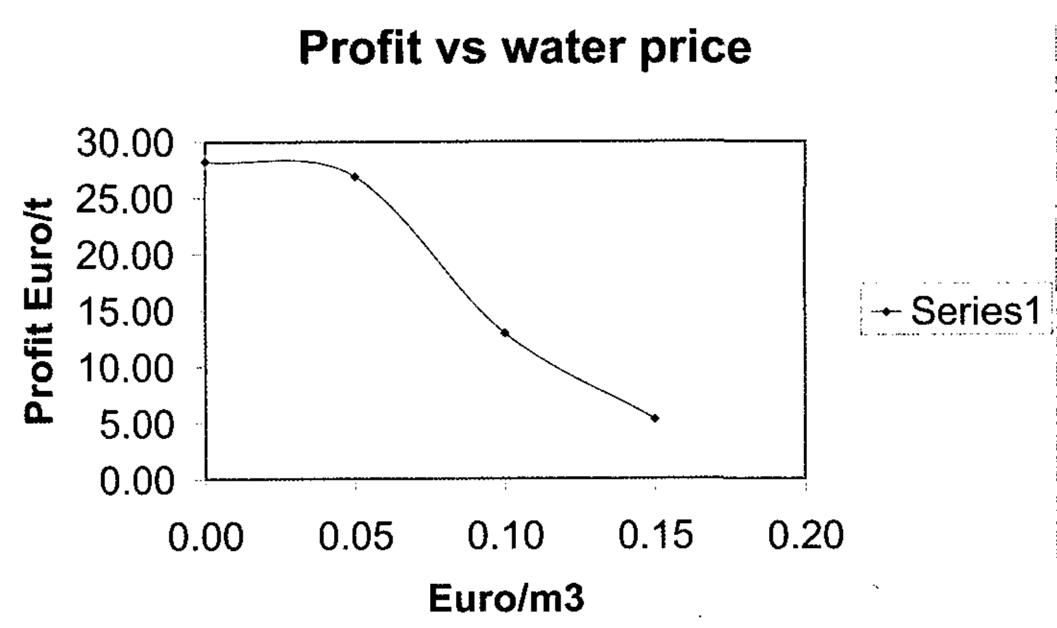
Products/ Variables	Sales Value €/t	MVA €/t	Water €/t	MVA/m^3	SV/m^3	Profit €/t
Urea	232	109	124	0.88	1.87	26.80
AN	226	120	137	0.87	1.65	31.40
MAP	494	134	187	0.72	2.65	25.00
DAP	460	130	165	0,79	2.79	26.51
CAN	276	114	150	0,76	1.84	24.63

The analysis of cumulative coefficients shows a pattern which is not seen by the traditional evaluation of direct water use. It shows that there is a limiting price that plants can pay for the water used in the sequence of technologies leading to the final product, i.e. fertilizer. An evaluation of the impact of water prices on profitability for new factories producing fertilizers is given in Table 22.

Table 22. Impact of Water Prices on Fertilizers' Profitability

Products/Variables	Water Use m^3/t	No Charge for Water	Water Price 0.05 €/m^3	Water Price 0.1 €/m^3	Water Price 0.15 €/m^3
Urea	124	28.14	26.80	15.74	9.54
AN	137	32.97	31.40	19.27	12.42
MAP	187	26.25	25.00	7.55	-1.80
DAP	165	27.84	26.51	11.34	3.09
CAN	150	25.86	24.63	10.86	3.36
Other	153	28.21	26.87	12.95	5.32
Average		28.21	26.87	12.95	5.32

Figure 7. Fertilizers' Profitability versus Water Price



Fertilizers being high tonnage products with low profitability are very sensitive to water price. Therefore, it is important to use recycled water in this industry and this substantially influences water productivity. The results of a review of the impact of the rate of recycling on water productivity are given in Figures 8 and 9.

Figure 8. Function of Increased Water Productivity (SV/m3) due to Rate of Recycling

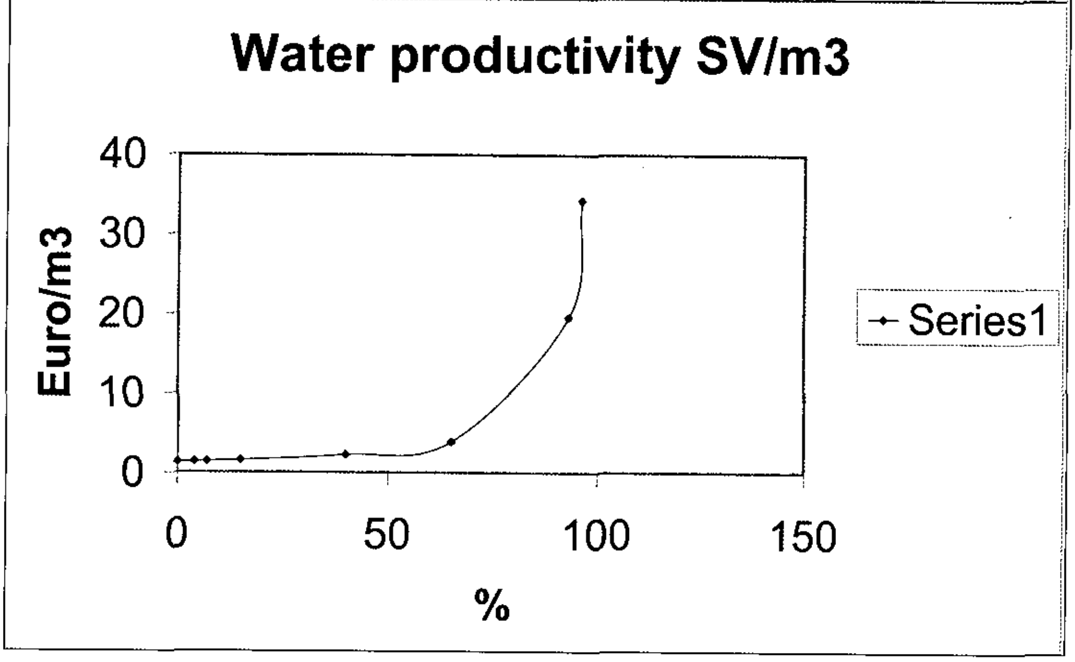
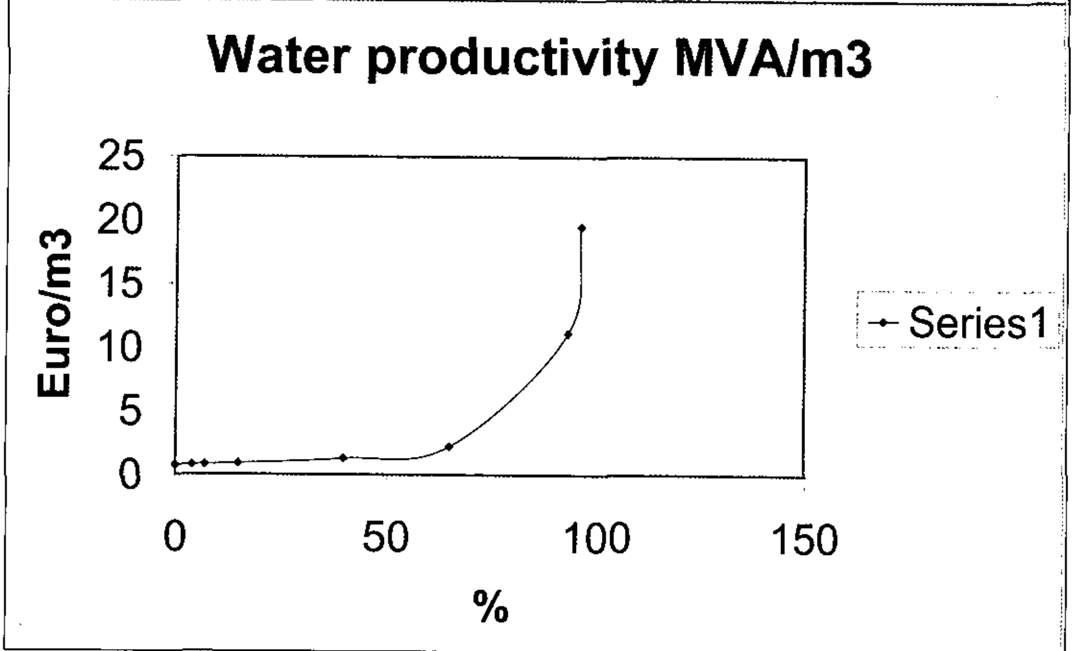


Figure 9. Function of Increased Water Productivity (MVA/m3) due to Rate of Recycling



2.3.4. Petrochemical Example

Petrochemical processing is also a high tonnage industry (APPE, 2001-200; Chemical and Engineering News, 2006) but, with much higher prices and profits, it is more representative of the chemical industry as whole being responsible for about 60 per cent of the total output.

The production of major petrochemicals in 2005 and the cumulative water use in Europe is given in Table 23.

Table 23. Consumption of Water by the Petrochemical Industry in Europe (2005)

Product/Variables	Production t/year	Unit Water Use m^3/t	Total Water Use $km^3/year$
LDPE	7,116,000	447	3.18
HDPE	5,110,000	472	2.41
PS+ABS	2,459,000	110	0.27
PCV	6,050,000	668	4.04
EO	2,397,000	306	073
EG	1,637,000	436	0.71
Rother	2,476,900	407	1.01
PP	9,368,000	429	4.02
Acrylonitryl	830,000	663	0.55
Okso alcohols	526,000	338	0.18
PO	2,338,000	300	0.70
PG	2,179,000	556	1.21
Other	2,286,150	457	1.05
Total			**20.06**

The water productivity parameters evaluated for the petrochemical industry are the same as those previously assessed.

The productivity parameters evaluated were as follows:

- Water use expressed in m^3/t
- MVA of product (cumulative)
- Productivity expressed as the cumulative ratio of price and water use in €/m^3 (SV/m^3)
- Productivity expressed as the ratio of MVA and water use in €/m^3 (MVA/m^3)
- Profit at SRR AT 5 per cent and water price of 0.5 €/m^3

The results are given in Tables 24 and 25.

Table 24. Ethylene – Water Productivity

Product/Variable	Units	LLDPE+ LDPE	HDPE	PCW	PS	EO	EG
Water use	m^3/t	447	472	668	110	306	436
MVA, industrial case C	€/t	338	1020	744	176	253	343
Price, industrial case C	€/t	2183	2400	4323	3059	2333	1947
Productivity gross t	€/m^3	4.89	5.09	6.73	27.72	5.47	4.57
Productivity net	€/m^3	0.76	2.16	1.11	1.6	0.59	0.81
Profit (water at 0.05 €/m^3)	€/t	235	257	178	176	267	280

Table 25. Propylene – Water Productivity

Product/Variable	Units	PP	Acrylonitryl	Okso-alcohols	PO	PG
Water use	m^3/t	429	663	338	300	556
MVA C	€/t	308	450	455	375	454
Price C	€/t	2649	2816	2645	2532	4210
Productivity gross	€/m^3	6.18	4.25	7.54	4.55	7.56
Productivity net	€/m^3	0.72	0.68	1.35	1.25	0.82
Profit (water at 0.05 €/m^3)	€/t	208	265	237	243	279

Considering the much higher prices and profits in the petrochemical industry, this may support higher prices for water. The evaluation of this relationship is given in Table 26.

Table 26. Impact of Water Prices on Profitability in the Petrochemical Industry

Product	Water Use m^3/t	No Charge for Water	Profit at 0.05 €/m^3	Profit at 0.25 €/m^3	Profit at 0.5 €/m^3
LDPE	447	257	235	146	34
HDPE	472	281	257	163	45
PS +ABS	110	184	178	156	129
PCV	668	209	176	42	-125
EO	306	282	267	206	129
EG	436	302	280	193	84
Other	407	252	232	151	49
PP	429	450	429	343	236
Acrylonitryl	663	241	208	75	-90
Okso alcohols	338	282	265	197	113
PO	300	252	237	177	102
PG	556	271	243	132	-7
Other	457	299	276	185	71
Average		274	253	167	59

The limited profits also show that in the petrochemical industry recycled water would be preferred to stabilize the profits and prices of petrochemicals.

3. Policy Measures for Improving Industrial Water Productivity

3.1. Issues for Policy Making for Industrial and Administrative Organizations to Increase Water Productivity

The aim of this section is to summarize the more efficient policy measures (UNCSD, 1998), based on working examples, rather than recommend new policy measures. The results of some applied measures were discussed in previous sections.

Management of any of operational system requires:

- Establishing the strategy of operation and development;
- An existing or planned operational structure;
- Policies and measures aimed at achieving strategic goals by optimizing operational structure.

3.1.1. Strategy

There is no uniform strategy for a water management system, although it is assumed by most people that saving water will increase its productivity. The strategies are different for developed countries (high income countries) and developing countries (low and medium income countries).

a) High Income Countries

For high income countries the consumption function is trending to the Kuznets form, due to the outsourcing of industries consuming large amounts of water and the development of a secondary industrial structure. This provides an opportunity for the full recovery of industrial water leaving only a limited quantity related to the physical loss during production such as evaporation from circulation towers, untreatable wastewater, water containing products etc. This means that all wastewater will be treated and reused.

b) Low and Medium Income Countries

In developing countries where the basic water consuming industries have been transferred from developed countries, there are specific features for future use:

a) In principle, only new advanced alternative technologies are transferred, which have lower water consumption than the historical use in high income countries;

b) Water treatment technologies are much more advanced than they were during the industrialization boom in the 1970s. In fact the technological level achieved allows full reuse of industrial water, again except for the physical loss during use such as evaporation.

Therefore, the preferred strategy for industrial use is the full reuse of wastewater, limiting the withdrawal and use only to physical loss. The projected use of water by industry by

2025 is about 20 per cent of total withdrawal, thus the need for industrial water may push the water crisis into the second part of this century. There are additional elements supporting this "zero" discharge strategy:

a) Each litre of discharged wastewater pollutes 3 to 8 litres of fresh water (even if the concentration of pollutants is limited).

b) There are regions where the industrial use of water is not possible due to the water balance. The "zero" discharge strategy would allow development of industries in arid areas.

3.1.2. Industrial Structure

The existing industrial structure and its level of complexity are more or less stable. It would require large scale investment to substantially change the industrial structure worldwide. This existing situation would permit the development of a uniform series of policies and measures for any industrial operation worldwide.

3.1.3. Policies

The conventional methods of policy making divide it into two approaches:

a. Command Measures;
b. Economic Measures.

3.1.4. Command Measures

Establishing Water Targets
In many cases local water resources are limited and overuse leads to their depletion. It is the role of the scientific community to assess the needs and quantities of water for all uses. Local research will be necessary because there is no statistical relationship between water use and a country's macroeconomic parameters. On this basis local governments would establish quota limits. This will be useful information for investors in industrial sites to select appropriate technologies and products. Productivity limits and quotas should be established jointly to avoid conflicts. The existing "step by step" method of approvals does not ensure local optimization of the economic structure.

Establishing Wastewater Quotas
In the majority of cases, water withdrawal for industrial as well as for human purposes (use) has a low critical value. Moreover, industrially used water returned to the water cycle is not of high enough quality to allow untreated use downstream. It is well documented that the amount of industrial wastewater produced is 3 to 5 times the volume used for industrial purposes. This ratio becomes even larger when regulations are based on concentrations of pollutants instead of overall pollutant loading. Therefore,

establishing legal quotas on wastewater is a necessary action to prevent the degradation of water quality downstream from industrial use.

Effluent Standards

Legislation typically establishes effluent standards. Regulations in many cases only deal with the concentrations of pollutants, which tends to increase the total amount of wastewater. It is also necessary to provide legislative limits on the total load of different pollutants. Another obstacle to the implementation of this kind legislation is the large number of new chemicals in use that have unknown impacts on human health or the environment.

Establishing the Rate of Recycling

A large number of industries, in particular power generation, require recycling of cooling and process water. This is also valid for the domestic use of water. Large scale industrial complexes such as the metallurgical, chemical and pulp and paper industries, in principle should have installed cooling water recycling and full collection of heating steam condensate. Installation of circulation towers, depending on local climatic conditions may decrease water withdrawal by 25 to 30 times. However, the introduction of water recycling is difficult in the case of widely dispersed industrial sites for example, plastic manufacturing and pharmaceuticals, which are, in most cases, small and medium sized industries. However, while enforcing regulations with respect to the permitting of industrial parks is desirable, it is very rarely carried out. In addition to the dispersion of industry, another obstacle to water recycling is the cost of low capacity systems. This point will be discussed later.

Research and Development Support in Water Management

Water withdrawal and corresponding legislation to limit the effects of over withdrawal and effluent impacts require many levels of management. Modern scientific instrumentation and analytical techniques must be applied with technology to clarify raw water and to treat wastewater. Medical evidence indicates the growing impact of poor water treatment. Therefore, the mandate of legislators, local and central governments should be to support research and development at scientific institutions.

If regulations are made without consulting the scientific community, it only serves to create bureaucratic obstacles to the real improvement of water management. In this case, outsourcing research and development from the developing to developed countries is of great importance.

Detailed Analytical Review of Technology

This issue relates to the full understanding of the problem of water productivity by a particular industry. Water consumption must not only consider direct use (e.g. as cooling or process water), but also the energy component (e.g. water used by electrical energy and steam production). This review must consider the full technological process from basic raw materials to the final consumer product. Such an audit may indicate the necessary measures to increase water productivity by changing the sequence of technologies or a particular technology. Progress in water productivity will depend on the split in financing and execution responsibilities between industry and its administration in preparing the audit, and the necessary design improvements and their implementation.

Licensing Water Management Systems
Contractual licensing of water management in given area is one outsourcing measure. Typical contracts have been discussed in the section on the water pricing system above.

3.1.5. Economic Measures

Tariffs on Water Supply from All Sources
Each source of industrial water withdrawal may have a different legal status for example:

- Public Sources
- Private Underground Water Extraction
- Open Reservoirs with Free Access

In practice, tariffs are only charged by local government for publicly owned sources. This situation not only biases the statistics on water use, but also is irreversibly depletes the underground resources. There is little information available concerning attempts to charge industry for all the water it uses. In the case of industry the tariff price should comprise three elements:

- A Universal Charge (monetary units/m^3)
- A Specific Charge (monetary units/m^3)
- A Pollution Charge dependent on the pollution in the wastewater (monetary unit/ pollutant unit)

Charges for Wastewater
Charges for wastewater should be related to the amount of the wastewater produced in relation to water use. Reduction should be considered in cases when:

- Wastewater leaving an industrial estate is of better quality than the original withdrawn source water
- The water is used in a closed cycle

3.1.6. Water Management Systems

An established and organized management structure is necessary to implement policies for the effective and economic use of water (Frost & Sullivan, 2006) to fulfil strategic goals. There are many options for water management and, in practice, all are used as a function of local government legislation or management culture. Given below in Tables 27 and 28 is a comparison of different management systems.

Table 27. Management Systems based on Semi-Public Assets Property

System	Advantages	Disadvantages
Service contracts	Transparency of operational cost	Local budget responsibility for assets
Management contracts	Short term responsibility of contractor for operation of the system	Lack of improvements and modernization of technology
Lease agreements	Long term contracts ensuring renovation of assets	*Difficulty in establishing of the price* formula
Concession	Full responsibility of contractor	Possibility of monopolistic actions

Table 28. Management Systems based on Change of Assets Property

System	Advantage	Disadvantages
Build, operate, transfer	The technology is selected by the administrative authority	Long periods of construction; budgetary difficulties
Build, own, operate,	The investment cost is under control of the administrative authority	Long term difficulties in establishment of price formula
Joint-venture between contractor and authority	Continuous control of the water operational cost	Participation in renovation cost of assets
Outright sale	Full responsibility of contractor for the investment recovery cost	Possibility of monopolistic actions

This short summary of various water management systems does not indicate that a unique optimal solution exists. There are examples of the full outsourcing of water management systems which are functional and satisfactory for both parties: the water management company and the consumers. The most important aspect of outsourcing water management is continuous improvement and upgrading based on the implementation of advanced technology using the latest research and development. Water management companies may also operate several plants which will favourably influence the cost/price structure for the local water authority and end users.

References

ACCEPTA, 2007, *Waste water chemicals*. Product Information Water Treatment.

AQUASTAT Food and Agriculture Organization of the United Nations (FAO), *Information System on Water and Agriculture Countries and Regions Database.*

Association of Petrochemical Producers in Europe (APPE), *2001-2005, Petrochemistry: Facts and Figures. Capacity and Production Data. Ethylene and Derivatives, Propylene and Derivatives.*

Chemical and Engineering News, 2006, *Facts and Figures No. 59.* July 10.

Earth Policy Institute, *Water Resources Indicator Data Major Rivers Running Dry; Disappearing Lakes and Shrinking Seas; Underground Water Depletion in Key Countries.*

ECOPROG, 2006/2007, *Market Study, Municipal Waste Water Plants in Europe. Frauenhofer Institute.*

European Commission, *Theme 8. Environment and Energy: Towards environmental pressure indicators for the EU.*

European Commission, 2006, *Practical Challenges in Waste Water Reuse. DG Environmental Service. March.*

European Environmental Agency, *Water use by Industry.* Indicator Fact Sheet, Conchita Lallone, Chonchita Marcuelli, Subindicator WQ 3c.

Food and Agriculture Organization of the United Nations (FAO), 2003, *Review of World Water Resources by Country.* Water Report 23, Rome.

Frost & Sullivan, 2006, *Water Reuse and Recycling,* 19 December. Prabhu Sethuraman.

International Fertilizer Industry Association (IFA), 2006, *Fertilizer Production by Regions, Statistics.* October.

Organization for Economic Co-operation and Development (OECD), 2003, *Industrial Water Prices No 236.* Observer. March.

Pacific Institute, 1998, *The World's Water. Fresh Water Withdrawal by Country and Sector, Table 2.*

Shiklomanov, A., 1974, *Water Consumption World Wide.* State Hydrological Institute St. Petersburg. United Nations Educational, Scientific and Cultural Organization (UNESCO).

Soler, M.A., and Planas, J.M., 2003, *Insufficient price policy to control demand....* Universitat Politecnica de Catalunya (UPC).

United Nations (UN), 2005, *Work session on water Statistics.* Intersecretarial Working Group on Environmental Statistics. UN Statistics Division, Vienna.

United Nations Commission on Sustainable Development (UNCSD), 1998, *Role of Governments in regulating industrial water activities.* Peter Rogers, Harvard University.

United Nations Commission on Sustainable Development (UNCSD), 2004, *Role of Industrial Water Management.* Workshop Report to the Sustainable Development Roundtable. Bhasher Dove, (Onda Nalco).

United Nations Educational, Scientific and Cultural Organization (UNESCO), 2006, *Water, A Shared Responsibility.* The United Nations World Water Development Report 2, UN-WATER/WWAP/2006/3.

United States Environmental Protection Agency (US EPA), 2006, *Industrial Water Pollution Control.* October.

United States Geological Survey (USGS), 2005, *The water cycle.* USGS Science for Developing World.

VENTURES SC. *Technological Profile Data Bank.*

World Bank, 2001, *Executive Summary of WWDR.* Washington D.C.

World Research Institute, 2006, *Earth Trends: Water resources, water withdrawal and use.* Washington D.C.

Annex I

List of Major International Events on Water

Conference	Date	Place
UN Conference on Water	1977	Mar del Plata
International Drinking Water Supply and Sanitation Decade	1981 -1990	-
Global Consultation on Safe Water and Sanitation for the 1990's	1990	New Delhi (UNDP)
International Conference on Water and the Environment	1992	Dublin (WMO)
UN Conference on Environment and Development	1992	Rio de Janeiro (Earth Summit)
Ministerial Conference on Drinking Water Supply and Environmental Sanitation	1994	Nordvik
International Conference on Population and Development	1994	Cairo
UN Conference on Human Settlements	1994	Istanbul (Habitat II.)
1st World Water Forum	1997	Marrakesh
2nd World Water Forum	2000	The Hague
United Nations Millennium Declaration	2000	New York
International Conference on Freshwater	2001	Bonn
World Summit on Sustainable Development	2002	Johannesburg
3rd World Water Forum	2003	Kyoto
International Water Year	2003	-
4th World Water Forum	2006	Mexico
International Decade for Action "Water for Life"	2005-2015	UN

Annex II

List of Major Institutions involved in Water Demand/Use Assessment

- World Resources Institute
- World Bank
- Pacific Institute
- St. Petersburg State Hydrological Institute
- University of Hampshire
- US Geological Survey
- FAO
- UNESCO
- UN Commission on Sustainable Development
- OECD
- EU Commission

Annex III

Table 1.		Technological profile		Year 2007		
Product		**Urea**		**Company**	**Europe**	
Process		**STAMICARBON**		**Installation**	**Planned**	
Annual resource time		[h]	8000			
Production		[m³/h]	*450,000*	FCI	101,761	[mln €]
Sales		[m³/h]	*450,000*	BLC	59,860	[mln €]
Calculated capacity		[m³/h]	*492,750*	Off-sites	41,902	[mln €]
Product price	144.00	[€/m³]	56.25	Unit investment cost €/m3		226.14
Reference installations	1,000,00 0	[t/year]				
FCI	150	[mln €]	WZSFCI	0.66		
BLC	85	[mln €]	WZSBLCC	0.66		
Cost elements		**[Unit]**	**[Unit/M³]**	**Unit price** [€/unit]	**Unit cost** [€/t]	**Annual cost** [€/year]
Raw materials						
- Ammonia		[t/t]	0.57	150.00	85.500	38,475,000
- Carbon dioxide		[t/t]	*0.7550*	*1.00*	0.755	339,750
- Catalysts		[€/t]	*1.0000*	*1.00*	1.000	450,000
- Sub-total					86.255	39,264,750
- Purchase cost	3.00%				2.588	1,164,443
By-products					**0.000**	**0**
Raw material cost					**88.843**	**40,429,193**
Utilities					**5.000**	**2,250,000**
- Electrical energy		[kWh]	*22.00*	*0.05*	1.100	495,000
- Cooling water		[m³]	78	0.05	3.900	1,755,000
- Process water		[m³]	0.1	0.25	0.025	11,250
- Steam		[t]	0.93	12.00	11.160	5,022,000
Salaries					2.150	967,680
- Labour	24	[h/t]	*0.128*	*12.00*	1.536	691,200
- Social security	40.0%				0.614	276,480
Total direct cost					**99.893**	**44,951,873**
Department overheads					**28.551**	**12,847,878**
- Management	4	[h/t]	0.021	*20.00*	0.427	192,000
- Laboratory	16	[h/t]	0.085	*5.00*	0.427	192,000
- Maintenance (labour)	16	[h/t]	0.085	*6.00*	0.512	230,400
- Social security	40.%				0.546	245,760
- Maintenance materials	3.00%	[€]	6.784	1	6.784	3,052,838
- Depreciation BLC	10.0%	[€]	13.302	1.00	13.302	5,985,957
- Depreciation off-site	5.0%	[€]	4.656	1.00	4.656	2,095,085

- Local taxes	2.00%	[€]	0.001	1	0.001	254
- Environment tax	2%	[€]	1.777	1	1.777	799,584
- Other department costs	1,00%	[€]	0.120	1	0.120	54,000
Total direct cost		[€]			128.444	57,799,750
Factory overheads		[€]			1.294	582,498
- Management	1%	[€]			1.284	577,998
- Sales costs to own units	1%	[€]	0.01	1	0.010	4,500
Production cost		[€]			**129.738**	**58,382,248**
Sales		[€]			144.000	64,800,000
EBIT		[€]			14.262	6,417,752
Income tax	19%	[€]			2.710	1,219,373
Profit net		[€)]			11.552	5,198,379
ROI (PAT - SRR)		[%]			5.11%	
Rentability		[%]			8.02%	

Matching Water Quality to Use Requirements

John G. Payne

Abstract

The focus of this paper is on the quality of sources of water as input for various uses, particularly industrial. It provides an overview perspective, and highlights the main issues and trends of matching appropriate water quality to use, discusses possible solutions, and provides some conclusions. It is intended to provide an introduction to more detailed discussions on the various aspects of this specific subject.

Address

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Biographical Note

John Payne is a Manager in the Environmental Division of SNC-Lavalin in Toronto and has over 30 years of Canadian and International consulting experience. He has overall responsibility for the management and technical direction to a staff of environmental specialists including engineers, scientists, hydrogeologists and remedial designers and for direct liaison with clients to ensure satisfactory delivery of services. One of his primary areas is related to environmental and groundwater quality site assessments, cleanup and remedial design and implementation. He has worked extensively on both groundwater and surface quality issues in Ukraine including the Identification and Analysis of Sources of Pollution (Hot Spots) on the Dnieper River for UNIDO. Recently he is coordinating the hydrological aspects of the Environmental Protection and Sustainable Development of the Guarani Aquifer System which covers a significant area including parts of Brazil, Argentina, Paraguay and Uruguay.

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1. Introduction

The balance between sources of water and uses of water is a precarious one. The quality of the source water is a major concern but other significant issues frequently involve adequate quantity, location, cost, regulation, ownership and security of supply. It has been implicitly taken for granted in the past that most natural supplies, such as groundwater, are of reasonable quality or at least economically treatable for their intended use. With the increasing demand on water supplies as population and industry continue to grow at accelerating rates, the assumption that good quality supplies are always to be found and are essentially limitless no longer holds. This creates a need to match lower quality water to uses that can accommodate it.

2. Sources of Water

In most areas of the world, natural water sources, perhaps more correctly termed resources, are the primary supply for most water withdrawal. Secondary sources include previously used water from industry and municipalities. There is a process of degradation as water moves downstream from either the primary or the secondary source depending on the particular water use. The degree of treatment required, and several other factors discussed later, determines how much water is returned to the industrial system or how much is discharged as effluent. This represents the difference between actual water withdrawal and water consumption.

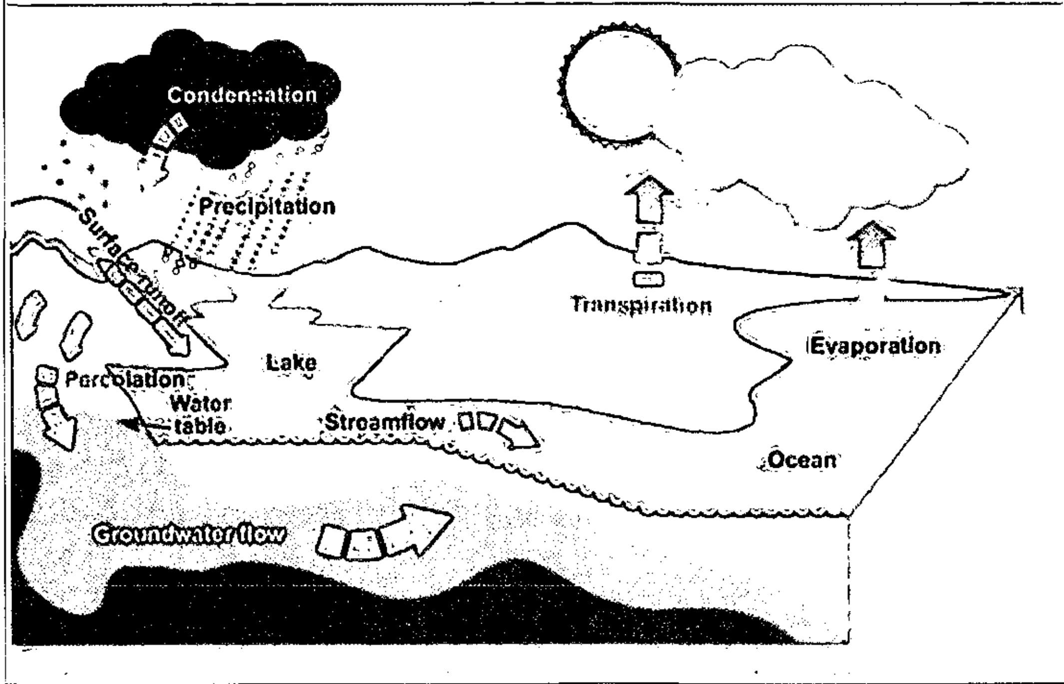
The broad types of source water are listed in Table 1 with some related information about quality and quantity (USGS website). It is notable that the most accessible primary water sources usually have less quantity globally (surface water) or require the most treatment (sea water). Secondary sources are generally limited in both respects, except in some local situations.

Table 1. Sources of Water

Natural (Primary) Sources	Quality In-situ	Quantity
Groundwater Aquifers Spring Water Thermal Water	Usually good for most uses but can be easily contaminated.	Variable depending on location. Easily depleted. Approximately 1.7% of global water. About 30 % of freshwater is in the ground
Surface Water Rivers Lakes	Variable depending on human and biological impacts.	Can be locally significant. Globally insignificant about 0.09%. Lakes comprise about 87% of surface water.
Ice Caps and Icebergs	Very good.	Locally insignificant yet approximately 1.74% of global water and 68.7% of freshwater.
Sea Water	Saline.	Huge. Approximately 97% of global water.
Rain Water	Generally good.	Limited – based on local collection (harvesting).
Municipal Sources	**Quality**	**Quantity**
Stormwater	Mediocre depending on local regulations.	Climate and infrastructure (for collection) dependent.
Sewage Water	Poor	Infrastructure dependent.
Industrial Sources	**Quality**	**Quantity**
Non-Contact, e.g, Cooling/Heating	Dependent on primary source.	Can be significant on a local basis.
Contact, e.g. Process Effluent	Moderately to highly contaminated.	Can be significant on a local basis.

Water is thought of as a renewable resource and natural sources are interrelated in the well known hydrological cycle (Figure 1). Water's passage through the hydrological cycle takes time and generally has a purifying effect, rather like treatment. Its journey may be significantly delayed and interrupted by human activities, such as being dammed up in large hydroelectric projects or being incorporated into food and beverages or industrial products.

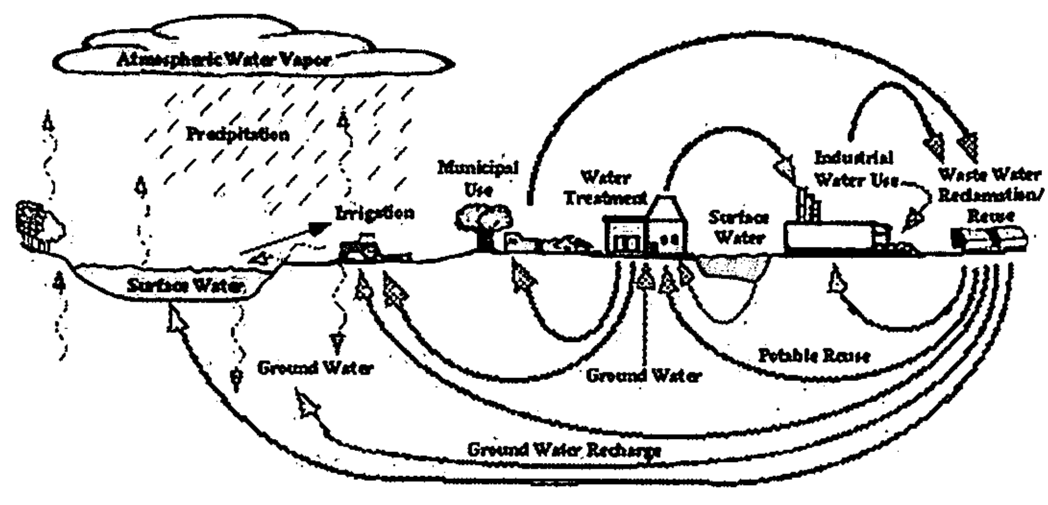
Figure 1. The Hydrologic cycle



From: Environment Canada Freshwater Website: Properties of Water: http://www.ec.gc.ca/water/en/nature/ prop/e_ cycle.htm

More significantly, these human interventions are often represented by industry, and have lead to contamination and overall degradation in natural water quality in many areas. The hydrological cycle now includes significant human intervention such as effluent discharge into surface water bodies, infiltration of contaminants to groundwater, and the atmospheric distribution and fallout of contaminants into water bodies. Loops of recycled and reclaimed water are now included the hydrological cycle (Figure 2). They may rejoin the cycle after much delay or perhaps never, if zero discharge becomes a reality. Zero effluent discharge is the ultimate goal for water quality (UNESCO, 2006).

Figure 2. The Role of Engineered Treatment, Reclamation and Reuse Facilities in the Cycling of Water Through the Hydrologic Cycle (Asano 1998)



From: Australian Academy of Technological Sciences and Engineering, 2004.

3. Uses of Water

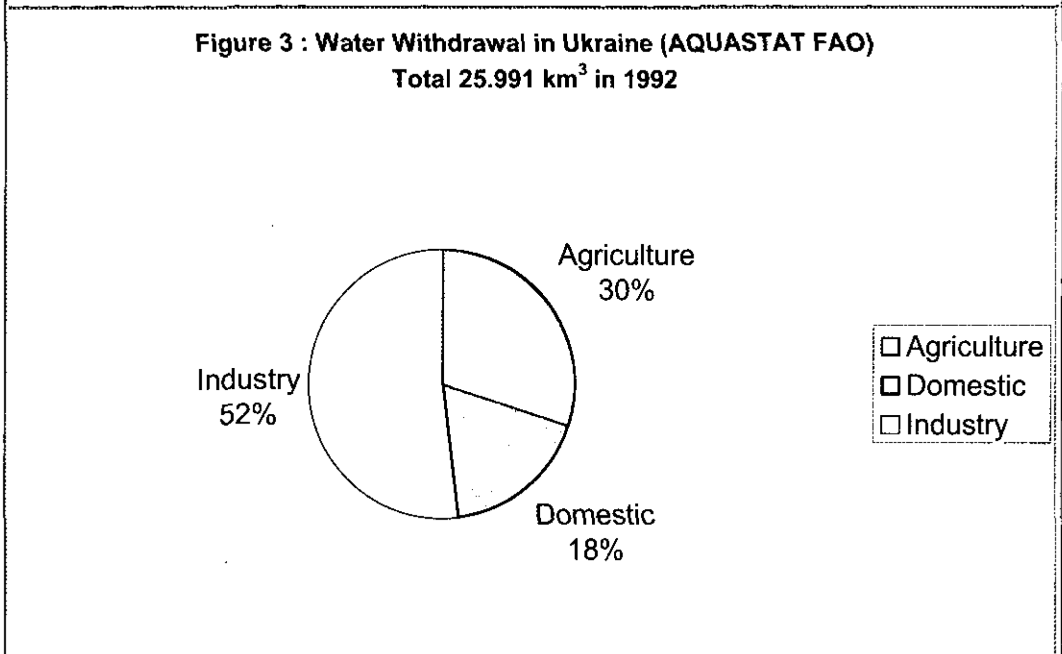
In a general sense, human use of water may be either consumptive or non-consumptive (California Department of Water Resources (CDWR), 2005). Consumptive uses include industrial, agricultural and municipal, and non-consumptive may be hydroelectric power generation, navigation, and recreation. A list of some of the more common uses is in Table 2.

Table 2. Common Uses of Water

Consumptive	Typical Uses	Quality	Quantity
Municipal - Potable	Drinking Water	Highly regulated.	Significant
Municipal – Non-Potable	Toilets & Showers Watering Lawns & Gardens Fire Fighting	Usually the same as for potable water in developed countries.	Significant
Agriculture	Irrigation	Crop & livestock dependent. Some regulations depending on the country.	Very large if commercial, less if local.
Industrial – Manufacturing Needs	Process Water Cooling Water Heating Boiler Water Solvent Cleaning Wash Water Transporting Substances	Quality ranges from very high (ultra pure) to low dependent on equipment needs and pre-treatment options and costs.	Can be large locally.
Industrial – Product Needs	Raw Material Ingredient e.g. Food & Beverage, Bottled Spring Water Pharmaceutical	High to very high quality.	Moderately high.
Non-Consumptive	**Typical Uses**	**Quality**	**Quantity**
Hydroelectric Power	Impounded reservoirs	In-situ	Very large.
Geo -Cooling/Heating	Recirculation of water for residential and commercial use	In-situ	Small
Fishing	Commercial Recreational Aquaculture	In-situ but must be good quality for aquatic habitat.	N.A.
Recreation	Boating Swimming Thermal Springs and Spas	In-situ but must be acceptable for human health Individual & Unique	N.A Small.
Navigation	Commercial and Private Shipping and Boating	In-situ	N.A.

According to the Worldwatch Institute (website), agriculture accounts for about 70 per cent of world water use, with industry at 22 per cent, and towns and municipalities 8 per cent. However, the industrial use in developed countries averages 59 per cent versus 10 per cent in developing countries. This is illustrated in the case of Ukraine (Figure 3). It is significant to note that less than 1 per cent of water treated for human use is actually drunk (The Environmental Benchmarker & Strategist (TEBS), 2007).

Figure 3. Water withdrawal in Ukraine (AQUASTAT FAO)



4. Industry's Relationship to Water

The optimum scenario for water supply and use is to have the right quality of water, in the right quantity, in the right place, for the right use at the right time. However, it is the quality of water that frequently undermines the efficiency of this equation. For example, it is not uncommon for industry to use higher quality water than is required, often because there is a conveniently located local supply, either natural (groundwater, river or lake) or municipally supplied.

According to the California Water Plan Update 2005 (CDWR, 2005), "Matching water quality to water use is a management strategy that recognizes that not all water users require the same quality water." This idea of water management links to water productivity, which has been defined as "the amount of water needed to produce a certain good, service or societal value." (Alberta Government website). The challenge is to obtain more productivity out of each litre of water as it passes through the system, in other words to maximize every molecule. Water productivity provides a benchmark for tracking progress. Matching water quality to use is one strategy to improve water productivity.

Much of the following summary and discussion on matching water quality to use draws on information and ideas from the 2006 UNESCO Report: Water, A Shared Responsibility, The United Nations World Water Development Report 2 (UNESCO, 2006), and in particular the Chapter on Water and Industry by UNIDO. In addition, the

California Water Plan Update 2005 (CDWR, 2005) is a large document that addresses somewhat similar issues. Also, several useful studies originating in Australia were also sourced, in particular Water Recycling in Australia (Australian Academy of Technological Sciences and Engineering (AATSE), 2004) and Industry Water Recycling Background Study (Kinhill, 1999).

5. Industry's Effect on Water Quality

Currently the use of water in industry is essentially linear. Withdrawal of water is made from a suitable source, maybe the water is pre-treated, then the product is manufactured, the process possibly cooled and the waste is washed away with or without treatment. This sequence of events, which obviously wastes water, also has the potential to magnify the problems of poor quality in primary water sources. For example, the discharge of effluent upstream into a river affects water being used as a primary source downstream. In the US it is estimated that on some major river systems, water is used and reused 20 times on its way to the sea (TEBS, 2007). This situation was assessed on the Dnieper River (UNESCO, 2006) where the influence of pollution Hot Spots was prioritized to a large extent by their influence on downstream use. Water quality issues ranged from drinking water abstraction to non-consumptive uses such as fishing.

The problem is made worse when the discharges are not adequately treated and the receiving body becomes increasingly contaminated. This not only affects the potential for further withdrawal of this water for industrial applications but has profound effects on the environment. The problems range from inorganic contaminants, which may affect sediments, to organic contaminants encouraging slime and bacterial growth. Agriculture as an industry is responsible for large discharges of fertilizers and manure into water bodies. Even physical effects occur such as hot water causing "thermal pollution". In addition, the combined effects of different pollutants can further worsen the degradation and complicate treatment.

Indeed, depending on the concentrations of contaminants, much larger volumes of water may be affected than simply the amount of initial discharge. The "dilution effect" is relied on to reduce contamination to acceptable levels but increasing industrialization with accompanying increased discharges is serving to negate this effect. Moreover, if the contamination is irregular or periodic the resulting degradation may be variable. The problem is further compounded by more widespread effects downstream and across international boundaries. Transboundary loading is an issue of particular significance as, globally, there are 260 major river systems that cross 145 national boundaries (TEBS, 2007).

A similar situation occurs in the case of groundwater where large volumes of water in aquifers can be contaminated by small volumes of contaminants. As with surface water, the contamination may be organic or inorganic, but the migration is considerably slower through soil and bedrock. Typical sources are direct discharges to the ground or infiltration through lagoons, though leachate from landfilled solid waste can be significant. The effects are most noticeable with drinking water but industrial uses may be compromised by water containing, for example, solvents or hydrocarbons. The remediation of groundwater presents its own unique problems and may result in contaminant management rather than contaminant elimination.

Atmospheric pollution also contributes to worsening water quality. It is well known that surface water can become acidified through NOx and SOx emissions. Numerous lakes in North America and Europe suffered from the effects of acid rain, which was recognized many years ago. However, other chemicals emitted to the atmosphere can become widely dispersed and also enter the water cycle. It is well known that PCBs have migrated from industrial areas in North America to the Arctic.

Industrial disasters produce immediate and large effects on water supplies. There are incidents of tailings dam failures contaminating large areas of river systems in Romania and Guyana. Fires discharge emissions into the atmosphere and spills infiltrate to the groundwater and migrate to the surface water. Even agriculture has had its disasters. In Ontario, drinking water became polluted by *Escherichia coli* bacteria as a result of manure entering poorly protected wells. Several people died and many became seriously ill as a result.

More recently a new form of impact has been recognized, a Natech disaster. This is a situation where a technological disaster is triggered by a natural hazard. Earthquakes and hurricanes are the most obvious case and can result in releases of hazardous materials under the worst of circumstances for successfully containing them before water supplies are affected.

In short, industry contributes to polluting its own primary supply of water. Chemical pollutants join the hydrological cycle through many routes. Significant sources of natural or primary water are being degraded and are not recoverable as part of the natural purification of the hydrological cycle, resulting in less and less good quality source water.

6. Industry's Requirements for Water Quality

With the increasing degradation of primary water supplies, it becomes imperative that good quality water is reserved for priority use, such as drinking. Lesser quality water may be perfectly adequate for many other industrial uses. This may be recycled or reclaimed water from other uses. Many, seemingly interchangeable, terms are used regarding increasing water productivity. The generally accepted definitions are as follows in Table 3, which is based on AATSE, (2004) and UNESCO (2006).

Table 3. Definitions

Potable water: Water suitable for human consumption without deleterious health risks.	**Non-potable water:** Water which does not meet drinking water standards, but which may be fit for other specifically defined purposes.	
Water Reuse: Beneficial use of reclaimed or treated water for specific purposes such as irrigation, industrial or environmental uses. Water reuse can be done directly or indirectly.	**Water Reclamation:** The treatment of wastewater to make it reusable, as reclaimed water, for one or more applications. It commonly refers to municipal wastewater though it can also apply to industry.	**Water Recycling:** Water recycling involves one use or user. It is the reuse of industrial effluent (generally treated and reclaimed) that is generated by a given user for on-site use by the same user, and is predominantly practiced in industry.
Direct Reuse: Reuse of water directly from the treatment plant to the reuse site, usually by pipes. **Direct Potable Reuse:** Water that is highly treated for human drinking water use, and is conveyed directly from the treatment plant to the water supply system.	**Indirect Reuse:** The subsequent beneficial use of water after it has been discharged from a treatment plant or as an effluent into a natural receiver, such as a surface water or groundwater body, from which further water is taken, sometimes in an unplanned manner.	**Unplanned Indirect Potable Reuse:** The subsequent use of reclaimed water after it has been treated and then discharged into surface waters or groundwater from which further water is taken for human 'drinking water' supplies. This is a major health and aesthetic concern, particularly in urban areas at the end of major rivers.

While the focus of this paper is on industrial water quality in the sense of industry and manufacturing, it seems appropriate to mention agriculture as this industry accounts for the majority of the world's water use. While irrigation provides about 10 per cent of the water used for world agriculture, it is the largest user of freshwater resources and commonly the largest water user in a region (UNESCO, 2006). In fact, a search for information on water productivity results in a huge predominance of hits relating to increased agricultural production using less water.

This is particularly important in areas of limited supply and where drought is common, such as California and Australia. For example, the California Water Plan Update 2005 (CDWR, 2005) mentions the salinity and concentration of boron which can inhibit yields of some crops, and strawberries and avocados are salt-intolerant. Gypsum can be added to water with low levels of salts to improve percolation. Suspended particulates may need removal to avoid clogging irrigation systems and reducing infiltration. The EPA in Victoria, Australia (EPA Victoria, 2003) has defined Classes A to D of reclaimed water quality (after treatment) and defined the uses of each for various agricultural activities, non-potable urban use and industry. The objectives cite values for *Escherichia coli*, turbidity, BOD, SS, pH plus chlorine residual for the highest quality water.

For drinking water, the highest quality source is the most desirable. Regulations for drinking water quality are found in many jurisdictions and have chemical, biological and physical parameters, which in turn relate to human health and aesthetic considerations.

It is very often public health perceptions that limit the supply of drinking water to naturally occurring sources rather than secondary recycled water. More recent concerns include the presence in potable water, often in very low quantities, of endocrine disruptors, pharmaceutical chemicals (xenobiotic contaminants), disinfectant by-products and organic industrial chemicals. Other domestic applications such as fire fighting, car washing, toilet flushing and local irrigation in the form of garden watering are all amenable to a lower quality water supply.

For the food processing industry the water quality requirements are often more demanding than drinking water and may present a problem as local municipal supply may require further treatment. Shown in Table 4 below (Agriculture and Agri-Food Canada, 2000) is a comparison for food and beverage industry water quality guidelines with those for Canadian drinking Water Quality.

Table 4. Water Quality Guidelines for the Food and Beverage Industry Compared with Guidelines for Canadian Drinking Water Quality

Areas in grey can be of concern for specific food processing industries in Saskatchewan (modified from Canadian Council of Ministers of the Environment 1987)

Parameter	Concentration (mg/L)								
	Drinking water guideline	Baking	Brewing	Carbon-ated beverages	Confect-ionary	Dairy	Food canning, freezing, dried, frozen fruits, vegetable	Food process (general)	Sugar manufact-uring
pH	6.5-8.5	-	6.5 to 7.0	<6.9	>7.0	-	6.5 to 8.5	-	-
Colour (Hazen Units)	15	<10	<5	<10	-	ND	<5	5 to 10	-
Turbidity (NTU)	1	<10	<10	1 to 2	-	-	<5	1 to 10	-
Taste, odour	concern	low	low	ND[a]	low	ND	ND	low	-
Suspended solids (mg/L)	concern	-	-	-	50 to 100	<500	<10	-	ND
Dissolved solids (mg/L)	500	-	<800	<850	50 to 100	<500	<500	<850	-
Calcium (mg/L)	concern	NS[b,c]	<100	-	-	-	<100	-	<20
Magnesium (mg/L)	concern	-	<30	-	-	-	-	-	<10
Iron (mg/L)	0.3	<0.2	0.1 to 1.0	<0.1	<0.2	0.1 to 0.3	<0.2	<0.2	<1
Manganese (mg/L)	0.05	<0.2[d]	<0.1[d]	<0.05	<0.2[d]	0.03 to 0.1	<0.2	<0.2	<0.1
Copper (mg/L)	1	-	-	-	-	ND	-	-	-

Table 4. Water Quality Guidelines for the Food and Beverage Industry Compared with Guidelines for Canadian Drinking Water Quality

Areas in grey can be of concern for specific food processing industries in Saskatchewan (modified from Canadian Council of Ministers of the Environment 1987)

Ammonium (mg/L)	concern	-	-	-	-	trace	<0.5	-	-
Bicarbonate (mg/L)	concern	-	ND	-	-	-	-	-	<100
Carbonate (mg/L)	concern	-	<50	<5	-	-	-	-	-
Sulphate (mg/L)	500		<100	<200	-	<60	<250	-	<20
Chloride (mg/L)	250	-	20 to 60	<250	<250	<30	<250	-	<20
Nitrate (mg/L)	10	-	<10	-	-	<20	<10	-	-
Fluoride (mg/L)	0.3	-	<1	0.2 to 1.0	-	-	<1	<1	-
Silica (mg/L)	concern	-	<50	ND	-	-	<50	-	-
	Concentration (mg/L)								
Parameter	Drinking water guideline	Baking	Brewing	Carbon-ated beverages	Confect-ionary	Dairy	Food canning, freezing, dried, frozen fruits, vegetable	Food process (general)	Sugar manufact-uring
Hardness (mg/L)	concern	NS[b]	<70	200 to 250	-	<180	<250	10 to 250	<100
Alkalinity (mg/L)	concern	-	<85	50 to 128	-	-	30 to 250	30 to 250	-
Hydrogen sulphide (mg/L)		<0.2	<0.2	<0.2	<0.2	-	-	-	-
Oxygen consumed (mg/L)	concern	-	-	<15	-	-	<1	-	-
Carbon tetrachloride extract (mg/L)		-	-	slight	-	<10	<0.2	-	-
Chloroform extract (mg/L)		-	-	<0.2	-	-	-	-	-
Acidity		-	-	-	-	-	ND	-	-
Phenol		-	ND	ND	-	-	ND	-	ND
Nitrite		-	-	-	-	-	ND	-	-
Organic matter	concern	-	trace	trace	-	-	-	-	trace

a) not detected = ND, b) some required for yeast action, c) not specified = NS, d) Total Fe and Mn

The construction industry needs water for dust control, soil settling, compaction, aggregate washing and concrete production. This does not have to be top quality but certain quality will be required to protect the environment. However, the pharmaceutical industry and high technology industries (such as micro chip manufacturers) require very high quality and further treat the water from their primary supplies.

In the United States, thermal cooling water for power plants comprises 39 per cent of all water withdrawals (Brown 2003). Cooling water for production can usually be of lower quality. This is a significant fact as 25 to 50 per cent or more of a plant's intake may be for this purpose (Kinhill, 1999). Boiler feed, heating and quenching are also uses for lower quality water. The quality of water for most industry, depending on its source, needs to be adjusted to account for typical problems (Table 5).

Table 5. Typical Industrial Water Quality Problems

Problem	Comment
Scaling	Water lost by evaporation during repetitive recycling during heat transfer increases the concentration of mineral impurities such as calcium, magnesium, sodium, chloride and silica. This leads to scale formation when soluble salts are precipitated and deposited. It is related to hard water.
Corrosion	The primary factor is dissolved oxygen in cooling water though ammonia, manganese, iron and aluminium may all promote corrosion because of their oxidation potential. Other variables include temperature, carbon dioxide content, and pH.
Biological Growth	Algae, fungi and bacteria are common problems related to high nutrient content and can produce large masses of organic material. Some bacteria form slimes and utilize soluble iron and deposit insoluble iron oxide as a slime around their cells, some reduce the sulfate content of water to make it more corrosive.
Foaming	This is associated with detergents.
Pathogenic Organisms	These are not only an issue with drinking water but also in industry where workers can be exposed to spray. Bacteria such as Cryptosporidium, Giardia and Escherichia coli, viruses, protozoa and helminthes are typical problems.

Sources: UNESCO (2006); Kinhill (1999)

Some regarding industrial water use, quality and treatment are summarized in Table 6.

Table 6. Wastewater Treatment Requirements as a Function of End-Use for Industrial Water Supply			
Industrial Water Use	Nitrogen and Phosphorous Removal	Chemical Precipitation	Filtration
Cooling Tower Makeup	Normally	Yes	Yes
Once through cooling			
- Turbine Exhaust Condensing	Sometimes	Seldom	Sometimes
- Direct Contact Cooling	Seldom	No	Sometimes
- Equipment & Bearing Cooling	Yes	Yes	Yes
Process Water	Yes	Yes	Yes
Boiler Feed Water	Requires more extensive treatment; use of reclaimed wastewater generally not recommended		
Washdown water	Sometimes	Seldom	Yes
Site Irrigation	No	No	Normally

From UNESCO, 2006
Source: Asano and Visvanathan, 2001.

7. Matching Quality and Use

A useful summary of possible water use versus sources and quality (AATSE, 2004) is provided in Figure 4. This summary is based on Australian practice but could apply almost anywhere. The central idea is the productive reuse (reclamation or recycling) of water. In other words, obtaining additional service (productivity) from a given amount of water rather than simply the original single use to which it was put. The benefit is that discharge (frequently as waste) back into the hydrological cycle is avoided after just this one single application. The intent is that water impacted by its first use should be put it back into service as economically as possible. This may be as straightforward as a direct application with no treatment, if the quality is fit for the intended use. On the other hand, if extensive treatment is required, its viability will need evaluating. In a similar way, primary sources such as groundwater and surface water that have suffered impacts will have economical uses other than restoring the supply for human consumption with expensive treatment.

Figure 4. Possible Water Use versus Sources and Quality

Table 18 National Water Quality Guidelines - Current Situation and Future Requirements (Rathjen *et al*. 2003)

	Functional Use Areas		Water Sources: Potable Water	Rain Water	Stormwater	Greywater	Quality of Recycled Water: Highly Treated	Medium Treatment	Low Treatment
Portable Substitution Uses	Residential / Commercial Indoor	Toilet Flushing							
		Clothes Washing							
		Showering / Baths							
		Hot Water System							
		Drinking / Food Preparation							
	Residential / Commercial Outdoor	Residential irrigation and other urban outdoor uses							
	Municipal Controlled Access	Parks & Sportsgrounds and Recreational Activities							
	Municipal Uncontrolled Access	Parks & Sportsgrounds and Recreational Activities							
	Fire Protection Systems								
	Industrial Process Waters	Open Systems							
		Closed Loop Systems							
New Water Uses	Agriculture	Food sold unprocessed and in direct contact with recycled water							
		Food processed and not in direct contact with recycled water							
		Pastures							
		Non Food Crops							

	Guidelines Non Existent or Require Major Work
	Guidelines Exist - Require Work

From: Australian Academy of Technological Sciences and Engineering (2004).

Another Australian study (Kinhill, 1999), based on an industrial survey, looked at viability and compatibility between water source and use. A model was developed for general assessment to provide a frame of reference in terms of relative ranking for the potential for reuse (the study uses the term recycling in this sense) for municipal and industrial water.

Source viability was defined by certain limiting criteria as follows:

- Proximity to reuse application
- Water quality
- Volume/consistency
- Cost reused versus cost potable
- Pre-treatment requirements
- Health risk

A ranking system was developed and the results indicated that internal industrial process water had the highest potential viability. Treated municipal water was a close second and external industrial process water somewhat further back, both being more dependent on limiting criteria.

Internal industrial process water reuse is recycling within a plant to reduce potable water requirements. External industrial process water reuse is the exchange of all or part of the process water from one plant for the equivalent potable water of another plant. The receiver may have to pre-treat the water.

The second factor was source/user compatibility defined as "the level of comparability between known process water outputs and known process water inputs for municipal, industrial and unit processes." The results were the reverse of viability in that external industrial process water, as a source, generally had the highest potential use. This is because primary process exchange water is compatible with other user quality requirements, being equal or better than potable water. Internal industrial process water was least compatible because the quality is process dependent.

Interestingly when the viability and compatibility results were combined, there was little difference between internal industrial process water, treated municipal water and external industrial process water. This does not distract from the merits of the approach, which provides a useful tool to evaluate different factors. However, the authors point out that the assessment ranking values must be determined for individual cases. Also it is worth noting that water quality is the largest overall factor in this approach as it really is the basis of compatibility and has only a smaller role in viability.

The study indicated that a few major types of reuse were feasible:

- Internal recycling by industry that uses a lot of water, as the distance between source and user is not a factor and the same organization controls supply and demand.
- Municipally reclaimed water for cooling water, as this is used in many industries and volume demand is large.
- Municipally reclaimed water for ancillary production, such as in foundries.

Overall, in looking at these factors the evaluation concluded that treated municipal effluent has the best potential for reuse. This was attributed to its known quantity and quality and the fact that it could replace potable water in a wide range of industrial uses. While internal and external industrial process waters have similar potential, they were limited by process quality and volume.

The practical question raised is how to accomplish the actual matching in the field and on site? Should this be on a local, regional or a national scale, recognizing that both water management strategies and engineering considerations come into play? It may take the form of matching water quality to supplying an existing use, or the reverse, where a corresponding use is made of an available supply of a certain quality.

With agriculture, crops are matched to available water quality in many areas where irrigation is practiced (CDWR, 2005). This is an important part of water quality management as these supplies are generally not treated.

California has done much work using water blending (CDWR, 2005). High quality supplies are blended with lower quality supplies. Treatment is matched to source water quality as required by regulation. This way higher salinity water becomes more usable and concentrations of bromide and organic carbon in other sources are reduced. Blending may even be done by using different water from different depths in the same reservoir. The blending may involve groundwater, surface water and imported supplies. For example, reclaimed stormwater from wetland systems and treated effluent can be blended for non-potable recycling systems (AATSE, 2004).

Water quality exchange is being considered to improve both quality and reliability of supply. Such exchanges may involve infrastructure improvements in exchange for access to better quality water. They may also be "no cost" arrangements, possibly on a seasonal basis where, for instance, urban areas could provide agricultural areas with surface water and thus save on groundwater supplies in periods of peak demand. The agricultural areas would return groundwater during the fall and winter when they have excess capacity. Moreover, similar to water exchange in agriculture, one industry could accept wastewater from a neighbouring industry or municipality, provided suitably consistent, not variable, quality is available. Common uses for reclaimed water are industrial cooling and power generation. However, in Israel over 80 per cent of its treated sewage effluent is used for agricultural irrigation (UNESCO, 2006).

For urban use, supplying reclaimed water requires two sets of piping, one for potable water and one for reclaimed water. However, this dual reticulation system is only economically feasible with new construction: retrofitting would be prohibitively expensive. It may be economically feasible simply to treat the reclaimed water to potable standards and add it to the supply.

Perhaps more controversially from public perception, reclaimed water may be used to recharge aquifers to augment the supply or resist salt water intrusion.

In industry, water management may take the form of internal or external measures (UNESCO, 2006). The internal measures are at the plant level and involve the principles of cleaner production. The nature of the process and the degree of wastewater treatment affects how water quality and use are matched. Typically such measures include, stream separation, raw material and energy recovery and reuse of waste and wastewater. In terms of product transportation, a switch from using water to pneumatic or mechanical systems will provide more water of improved quality. The implementation of the measures is based on a systematic assessment of their feasibility.

Stream Separation is based on the fact that it is more difficult and more expensive to treat wastewater containing several contaminants than wastewater containing only one. Mixing concentrated effluent with diluted effluent may not produce the desired effect and the resulting larger volumes may still require treatment. The diluted stream may be suitable for direct reuse or discharge, and the concentrated stream may have less volume and be easier to treat. The number of treatment technologies (discussed in the next section) now available may make stream separation a more viable option.

Unconverted raw materials may remain in liquid waste streams and their recovery may be economically attractive. The resulting effluent, less the raw materials, may then be easier to reuse. In a similar manner, wastewater containing oil, used solvents, starch and so on can be traded for its residual value or reused. Waste registers can be set up between adjacent industries to allow more productive reuse of such waste streams.

External measures will also factor in better reuse of water from industry. These are more in the line of water management strategies on a broader scale, often brought in by the government. The nature of industry in a region will influence these strategies. They include:

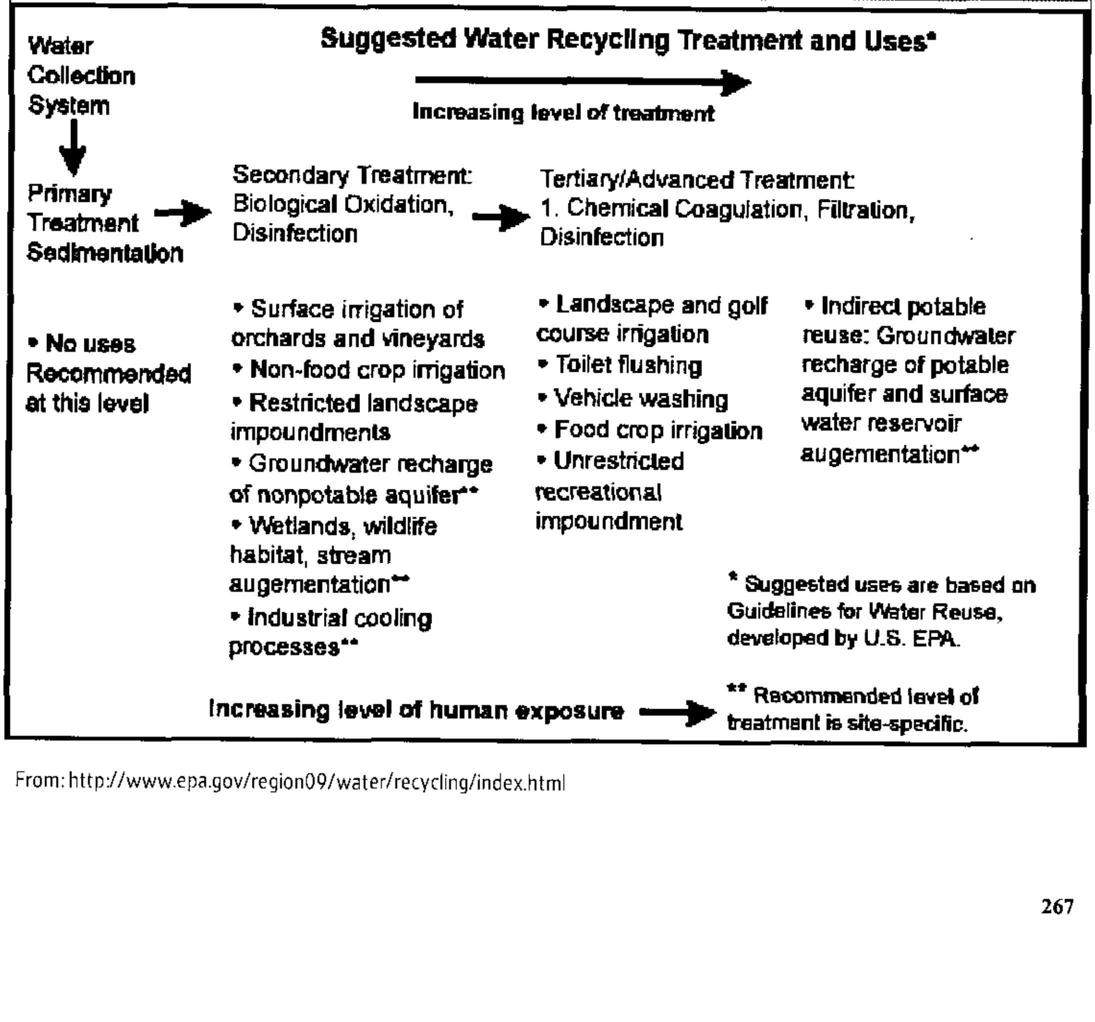
- Water recycling and reuse policies with associated regulations or guidelines;
- Grouping of industry to combine treatment and reuse methods;
- Budgeting or allocating water use;
- Economic incentives or penalties, such as credits and fines; and
- Water demand management and payment for water and discharges.

As can be seen these strategies are a variety of "carrot and stick" approaches that will either encourage or force industries into compliance. The results have generally been shown to be a win-win situation benefiting industry and conserving and improving water and its quality.

8. Treatment

Matching use to quality assumes that suitable treatment is available. The treatment may apply to recycled water or discharged water or as pre-treatment to supply water. The constraint on treatment relates to cost rather than technical capability to achieve high quality water. "A view has been expressed that any water can be made safely potable if strained through enough money." (AATSE, 2004). Revolutionary technological breakthroughs that will transform the treatment of water seem unlikely, but there are many incremental technological advances and continual cost reduction (TEBS, 2007). The idea is to commission the most economic system for the level of quality required. The US EPA (website) has presented a summary as follows in Figure 5.

Figure 5. Treatment Quality and Water Use



From: http://www.epa.gov/region09/water/recycling/index.html

There is a wide array of technology available that broadly falls into four categories:

- Physical treatment (e.g. settling, filtration, reverse osmosis);
- Chemical treatment (e.g. adsorption, flocculation, chlorination);
- Biological treatment (aerobic or anaerobic); and
- Specialized processes such as phosphate reduction and sulphate removal.

In addition, there are some more environmentally oriented treatment options such as natural attenuation of organic groundwater contamination and flow through constructed wetlands.

The technical evaluation of the science behind specific treatment technologies is beyond the scope of the present discussion. However, the criteria for technology selection and implementation have relevance as to whether the technology is implemented. Untreated water will be frequently wasted, whereas treated water has a wide variety of potential uses depending on the level of treatment. Significant factors including some from Marsalek, J, *et al* (2002) include:

Demonstrated History of Application and Effectiveness. This includes pilot testing requirements, full scale field testing and demonstrations, and showcasing to win public interest and government support.

Performance Criteria and Validation Protocols. Performance criteria are useful in producing the relevant water qualities and validation protocols that allow particularly innovative technologies to be validated against criteria accepted for various applications. Performance also includes being able to treat a sufficient quantity of water in an acceptable time frame.

Feasibility and Ease of Implementation. Commercial availability, the schedule and time to implement a technology, the constraints with respect to the local situation (both the local water to be treated and the logistical situation), and the relationship to infrastructure and its future improvements are all significant factors.

Regulatory Acceptability and Permitting Requirements from Various Government Levels. Regulations also encompass safeguards to address any concerns such as a demonstrated record of health and safety protection and environmental sensitivity.

Acceptable and Reasonable Costs. Costs are a life cycle expense and include permitting and licensing, pilot testing, implementation, equipment operation (energy) and maintenance, monitoring, as well as financing costs, anticipated revenue and payback time.

Social Acceptability. Acceptance by the public and end users is critical as much in the sense of perception than anything else. There is an inherent reticence, for example, to reuse treated water from sewage even though the quality is acceptable. Moreover, there is public concern over the potential presence of contaminants in the water for which there are no guidelines and hence no testing.

The standard and application of Best Available Technology (BAT) relates to all of the above considerations. Implementing BAT can incur significant costs and may take time, so transition periods are necessary and its implementation by regulation needs a thoughtful approach. The objective is to find the most effective technology which is technically viable, can be implemented economically and is reasonably accessible. It is felt by some that simpler approaches, such as sand filtration and enhanced wetland treatment, may be easier and cheaper to implement and may play a significant role to help solve the vast majority of the world's water shortages (TEBS, 2007).

9. Planning and Implementation

Once the guidelines, standards and technology are available, and in many places they are already well developed, it is the mechanism for getting them into action that is critical. This involves the policy planning that leads to implementation. It also includes legislation: regulation tends to produce a response from industry. It is a question of environmental governance. As with other aspects of this issue, the levels of mechanisms range from international to local, covering transboundary water issues to local watersheds.

At the international level, initiatives include agreements and conventions, Best Environmental Practices (BEP) and ISO 14001 certification. These have some force as a function of the economic competitiveness and international image of industries that abide by them. In many cases, their effectiveness depends on self-regulation.

On a country basis, water demand management is a key factor and is a main component of water efficiency plans (UNESCO, 2006). This is driven by policy decisions about charging or not charging for water and wastewater, about compliance and about financial incentives that include everything from subsidies to funds for research and development. Evidence from North America indicates that where water supply has developed independently of wastewater management, it has led to the inefficient use of water from a total water cycle perspective (AATSE, 2004). "A lack of integration in potable water, sewage, stormwater and groundwater resource management can result in irrational use of resources and failure of market forces." (AATSE, 2004).

On a local or plant basis, strategies form a structured protocol of evaluation whereby a plant and its processes are studied in a series of stages with respect to the feasibility of improvements. This applied economic analysis forms a Cleaner Production Assessment (UNESCO, 2006) that results in a plan of action.

Important at all these levels, but especially the local level, is public and community communication and consultation with a view to gaining acceptance. Public acceptance of using reclaimed water hinges on fears such as drinking polluted water, rather than on the scientific evidence. These factors may influence industry to avoid reclaimed water notwithstanding the economic benefits (AASTE, 2004). So public attitudes and resistance to change have to be understood and the process of stakeholder involvement may well be successful in this aspect as it has been in many other public arenas.

Cost and financing, as with most things, is the final arbiter of implementation. For example, in Canada, the low price of water serves as a disincentive to water reuse and innovation (Marsalek, J, *et al* (2002). The AATSE (2004) cites sixteen components identified by Mills and Asano (1998) that influence the market for reclaimed water. They could equally apply in most instances of matching quality to use and are condensed below in Table 7 with this in mind. It is interesting to note that many of these points would factor into any analysis of foresight with respect to the future direction of supply.

Table 7. Cost and Market Factors Influencing Supply

Component	Comments
Specific Potential Uses	Need to identify the market objective, e.g., saving potable water in industry, environmental improvement.
Location of Users	Piping infrastructure and pumping are expensive and distribution costs are proportional to the market.
Fluctuations in Water Demand	Recent and future needs should be compared.
Timing of Needs	Industrial markets have more regular demands than seasonal agriculture and are more compatible with the supply of sewage effluent.
Water Quality	Matching water quality to use. Without a definitive market water might be treated to a higher quality to provide better market opportunities.
Water Pressure	Unpressurized water supply, though cheaper, requires users to incur the costs of storage, pumping and distribution.
Reliability	Industry requires an uninterrupted reliable supply: agriculture may be more flexible.
Disposal of Wastewater	Will utilities provide this service in addition to supplying water?
Retrofitting Costs	May be significant. Can be relieved in part by discounting water cost and other measures.
Capital Investment and Operation and Maintenance Costs	Needs an economic analysis for further in house treatment of supplied water if only a basic quality is supplied.
Payback Periods and Rate of Return on Capital	Public funding may be affected by the costs of environmental benefits which are hard to quantify.
Cost of Present Water supply	The connection between water resource management and supply is a strong influence. Government control of both produces a different climate than private sector competition such as in North America. Price may be influenced by cross-subsidies.
Water User Acceptance or Resistance	Incentives. Competing alternative supply.
Economic Trends and Land-Use Changes	Industrial use may decline in increasingly knowledge-based economies. Industrial use may increase in developing countries and with agricultural use drop off.
Timing of New Developments	Synchronization of supply with actual use.
Demand Requirements and Market Projections	How to estimate the demand and its time frame? Establishing the size of the market by a survey improves the chances of a successful project.

From: Australian Academy of Technological Sciences and Engineering, 2004. Source: Mills and Asano, 1998.

The price of water is very low and especially low when compared to other liquids. In Canada the average price is about Can $0.086/L (City of Toronto, website) whereas gasoline is about Can $1.00/L and beer is about Can $3.00/L. However, it is generally recognized that this does not represent the true cost of water. It is felt that it is inevitable that water prices will continually rise, and that by paying more, efficient use will be encouraged and better infrastructure will result (TEBS, 2007).

Thus setting the price of water, based on some or all of the above considerations, is a major driver in its use. Pricing strategies are dependent on water management and influence water use. Low pricing encourages over use, and if reclaimed water is close to the same price as potable water or natural supplies, end users will prefer the latter (AATSE, 2004). In other words, matching water quality to use is as much, if not more, driven by economics than anything else in many situations. As Benjamin Franklin said, "When the well's dry, we know the worth of water". Only in cases of extreme shortage or very poor quality would cost be a minor consideration in supplying a population's need.

10. Summary and Conclusions

General

Some general observations concerning water quality and use are drawn from an Australian study (Kinhill Pty., 1999), with others from AATSE (2004), Maeselek *et al* (2002) and UNESCO (2006), and though they may be specific to certain circumstances, they would also appear to be generally applicable.

- Use and reuse (reclamation and recycling) of water are very dependent on quality. If the quality for a certain use is not available, then the water is likely wasted.
- Quality must be based on standards related to use. There is a need to reduce pollution.
- Good monitoring of quality is essential.
- New contaminants of concern, e.g. pharmaceuticals, are emerging and raising health issues about potable water.
- Across all industry sectors, the driving forces are to decrease environmental impacts and to reduce costs.
- Cooling and process water are significant water users in industry.
- The location of industries using large amounts of non-potable water should be matched to sewage treatment facilities, or vice-versa. However, in practice industry is located close to where the most available quantity and reasonable quality water is found, e.g. lakes, rivers and groundwater.
- For reuse the focus is to replace potable water requirements and reduce demand in the base resource.

- Water reuse can be cost effective in replacing the existing non-potable use of potable water in certain circumstances.
- The quality of treated discharge water is increasing because of stricter criteria; this in turn makes reuse more attractive.
- Advances in treatment technology are increasing its reliability and reducing its costs.
- Major impediments to reuse include water quality and the low cost and continuity of alternatives.
- The use of reclaimed water is still limited, e.g. urban parkland, golf courses, non-food crops. The same is true for stormwater.
- Wastewater effluent, stormwater and rainwater are best viewed as complementary resources rather than problems for disposal.
- All the aspects of the full hydrological cycle should be considered and evaluated in water management.

Actions

Management, Planning, Regulation

In the attempt to implement more productive ways of using water in industry, it is not the technical know-how that is the main impediment but the will and the economics, both in the private sector and the government. These involve water management strategies on a broader scale, often brought in by the government. The nature of industry in a region will influence these strategies. They include:

- The combination or separation of the ultimate management of water and wastewater resources;
- Resolving conflicts of mandates between Ministries and government levels;
- Water withdrawal, reclamation and recycling policies:
  Examples may include: "Water Resource Caution Areas", the mandatory use of reclaimed water for non-drinking water purposes in water stressed areas, the issue of water rights;
- Streamlining approval processes between agencies;
- Institutional Strengthening projects supported by international organizations for water agencies and ministries in poorer countries;
- Mandatory and voluntary standards, regulations and guidelines:
  These often require updating with the latest science and should be written for clarity and certainty in their application;
- Water quality monitoring requirements;:

May include mandatory reporting and enforcement of compliance if necessary;

- Budgeting or allocating water use;
- Economic incentives or penalties, such as credits and fines;
- Water demand management and payment for water and discharges:
  As water may be treated more like a commodity and less like a human right market based mechanisms may be required, such as watershed basin-wide pollution trading rights and tradable water withdrawal rights (TEBS, 2007).
- Grouping of industry to combine treatment and reuse methods:
  This may also involve locating new industries with large water demands of less than drinking water quality near existing or new sewage treatment plants;
- Communication of the benefits of various measures and policies to the public to increase awareness, encourage confidence in water safety and gain support.

As can be seen these strategies are a variety of "carrot and stick" approaches that will either encourage or force industries into compliance. The results have generally been shown to be a win-win situation benefiting industry and conserving and improving water and its quality.

Research

A powerful tool to start the process of water optimization would be the continued development of simple models and guidelines for the general assessment and ranking (prioritization) of potential for reuse of water. This could apply to various international and local circumstances and different countries.

Research is needed in:

- Integrated water cycle management;
- Effluent and stormwater reuse;
- Treatment processes to improve cost and efficiency;
- The long-term impacts of reclaimed water;
- Surrogate parameters for water quality monitoring;
- Incorporating rainwater into supply.

On a broader scale, research should also look at the longer term effects of climate change on supply and quality. Plans and actions that may look suitable for the short and mid-term may not fit well with longer term changes in the dynamics of the hydrological cycle in various parts of the world. "*The potential of global warming to shift the predictability, timing and extent of natural rainfall patterns around the world could truly wreak havoc in terms of water availability, agricultural productivity and food supplies.*" (TEBS, 2007).

Zero Discharge

Zero effluent discharge, according to UNESCO (2006), is a key concept in matching water quality to use. It seeks to find a use for all the effluent that would be discharged by recycling it or selling it on to another user. If an industry achieves this goal then its overall water consumption will equal its withdrawal. Practically, this means that withdrawal will decrease to meet consumption. Perhaps there is some evidence that conservation is working as rates of consumptive use seem to be stabilizing in the Great Lakes Basin, but the reasons are not completely understood (Brooks, Undated).

This is linked to the "cradle-to-cradle" concept (McDonough and Brungart, 2002) whereby manufactures provide a service to a customer who would use a product and return it back for the manufacturer to recycle. They put forward two flows of materials, biological nutrients which are biodegradable, and the other technological nutrients which are non-biodegradable. The earth's natural cycles will take care of the former and society needs to take care of the latter. The important point is to keep the two flows separate to avoid cross-contamination. Water is part of both cycles and not contaminating the quality of water in the biological cycle by the technological cycle is paramount for the concept to succeed. This is, of course, what happens routinely at present when, for instance, effluent is discharged to rivers. So it follows that recycling is critical and zero effluent discharge would mean that water would stay in the technological cycle once it is used by industry. Therefore, for industry to be open to and accept the changes required, the quality of the water and its use will need to be technically and economically well matched in perpetuity.

Closure

So as long as there are good supplies, and many places still have them, where is the incentive to do anything? In the National Geographic Special Edition of November 1993 it was stated, "*Except for floods and drought, we ignore water. .... It comes to our taps when called. It drains away to somewhere else .... Like good health, we ignore water when we have it. But like health, when water is threatened, it's the only thing that matters.*" It is well recognized that we are diminishing the quantity and quality of our water on every scale from global, to regional to local. The outcome is obvious and self evident and in many parts of the world the consequences are already present, namely lack of water, contaminated water, and the health and economic fallout from this. It's just a matter of time.

The recognition of this problem and its likely acceleration and disastrous results, and the ability to measure and track the status, provides a starting point to plan ahead and start a process of recovery. It is a matter of philosophy and this is where the foresight comes into play. We can see the problem, we understand it in many ways, we have the technical know-how – but putting solutions into action is the key. The stimulation and incentive to do this require innovative thought and foresight, will power, and persistence linked to sustainability.

References and Websites

References

Asano, T., 1998, *Wastewater reclamation and reuse.* Water Quality Management Series Volume 10, CRC Press, Boca Raton, FL, USA.

Asano, T. and Visvanathan, C., 2001, *Industries and water recycling and reuse.* Business and Industry – A Driving or Braking Force on the Road towards Water Security. Founders Seminar, organized by Stockholm International Water Institute, Stockholm, Sweden, pp. 13-24.

Australian Academy of Technological Sciences and Engineering (AATSE), 2004, *Water Recycling in Australia.*

Brooks, D.B., Undated, *Comparing and Contrasting Energy and Water.* Friends of the Earth, Canada Website www.foecanda.org

Brown, L.R., 2003, Plan B: *Rescuing a Planet under Stress and a Civilization in Trouble.* Chapter 7. Raising Water Productivity, Raising Nonfarm Water Productivity, W.W. Norton & Co., N.Y. and on www.earth-policy.org

California Department of Water Resources (CDWR), 2005, *California Water Plan Update 2005, Bulletin 160-05.* December 2005.

EPA Victoria, 2003, *Guidelines For Environmental Management, Use Of Reclaimed Water.* Publication 464.2. EPA Victoria, Southbank, Victoria, June 2003.

Kinhill Pty Ltd., 1999, *Industry Water Recycling Background Study.* Queensland Water Recycling Strategy, Department of Natural Resources, Brisbane.

Marsalek, J., Schaefer, K., Excall, K., Brannen, L. and Aidun, B., 2002, *Water Reuse and Recycling.* Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. CCME Linking Water Science to Policy Workshop Series. Report No. 3, 39pp.

McDonough, W. and Braungart, M., 2002, *Cradle to Cradle: Remaking the Way We Make Things.* New York, North Point Press.

Mills, R.A. and Asano, T., 1998, *Planning and Analysis of Water Reuse Projects.* In T Asano Ed., Wastewater Reclamation and Reuse, Ch 2. Technomic Publishing, Lancaster, PA.

The Environmental Benchmarker & Strategist (TEBS), 2007, *The State of the Water Industry 2007.* Winter.

United Nations Educational, Scientific and Cultural Organization (UNESCO), 2006, *Water, A Shared Responsibility.* The United Nations World Water Development Report 2, UN-WATER/WWAP/2006/3.

Worldwatch Institute, 2004, *Boosting Water Productivity Chapter 3.*

Websites

Agriculture and Agri-Food Canada, 2000, Agricultural Industry and Water Quality. http://www.agr.gc.ca/pfra/water/agrindwq_e.htm

Alberta Government, Environment, State of the Environment, Water, Sectoral Allocations. www3.gov.ab.ca/env/soe/water_indicators/26_sectoral_allocations.html

AQUASTAT Food and Agriculture Organization of the United Nations (FAO), Information System on Water and Agriculture Countries and Regions Database. http://www.fao.org/AG/aGL/aglw/aquastat/countries/ukraine/index.stm

City of Toronto. http://www.toronto.ca/water/kids/story_of_water/html/costs.htm

Environment Canada Freshwater Website, Properties of Water. http://www.ec.gc.ca/water/en/nature/prop/e_cycle.htm

Friends of the Earth Canada. www.foecanda.org

Statistics Canada, Canadian Environmental Sustainability Indicators. http://www.statcan.ca/english/freepub/16-251-XIE/16-251-XIE2006000.htm

United States Environmental Protection Agency (US EPA). www.epa.gov/region09/water/recycling/index.html

United States Geological Survey (USGS). http://ga.water.usgs.gov/edu/waterdistribution.html

Worldwatch Institute. www.worldwatch.org

Water Recycling and On-Site Reuse

Prof. Giuseppe Genon

Abstract

The possibility of using less water in technology and industry is obviously desirable. It reduces pressure on the environment from the point of view of both water withdrawal and discharges. To introduce recycling, reuse or multiple uses of water in industry, the feasibility of all aspects, from the process system to the effluent discharges must be evaluated including the cost of new plant infrastructure and operation costs. Environmental benefits must also be considered in their specific context of avoiding externalities and quantifying the results into fiscal measures. Based on these considerations, many full scale improvements involving industrial reuse have been carried out in Europe, and with respect to agriculture, in less developed countries. Discussion of these examples illustrates the value, feasibility and limits of water reuse.

Biographical Note

Giuseppe Genon holds a degree in Chemical Engineering from the Politecnico di Torino, and is now full professor in Sanitary Environmental Engineering. During all the period at the Politecnico he participated to different courses, in a first time in the field of Chemical Engineering, afterwards for the area of Environmental Engineering, with particular reference to treatment technologies and environmental dynamics. He participated also to the post-lauream Master of Politecnico in Environmental Engineering

The activity research concerns different subjects in the field: the main topics were evaluation of phenomena of environmental impact, data definition for applicative technologies, full scale verification of treatment plants. The studies permitted the preparation of more than 200 papers in Italian and international journals, and the participation with oral presentation to more than 60 congresses in Italy and abroad.

About these arguments of research many grants have been obtained from public or private institutions, and for these grants he was the coordinator.

Contents

1. Introduction

In developed and developing countries the problem of consumption of water resources from within the hydrological cycle by industrial activities is becoming an increasingly more important issue for both the public and private sectors. On the one hand, there is the problem of water shortages and on the other, the impact of both direct and indirect discharges to receiving bodies. These increasingly significant problems are being addressed either by feasibility studies to determine viable solutions or by the application of technology on different scales, from demonstrations to full scale applications.

End of pipe technology is frequently used to limit the environmental impact of industry. This can also apply to treating an original water source. If the quality of the source water is known, it is possible to set up a treatment train to reach a desired quality downstream. It is also necessary to consider the quality of discharge water and the standards required. This in turn allows a suitable design of process and treatment facilities to reach the desired performance.

Thus, while natural sources of water and the needs of industry are different they are interrelated. They have different quality standards relating to their different uses, for example, pre-treatment is required in one case and final treatment in the other. Treatment in turn is dependent on its feasibility, its cost and resource consumption. Moreover, the distances involved between source and treatment and final discharge are significant.

An immediate solution to these problems faces financial hurdles, not only related to the pre- and post-treatment required, but also to final charges/tariffs for the water. In trying to achieve these ends, the water balance of the resource must be maintained as much as possible, as well as the equilibrium of any receiver.

The problem facing both public (Regions, Water Authorities, Environmental State Administrations) and private organizations is that, as water resources are generally considered to be unlimited, they can be used but with increasing cost. This neither appears to be economic nor feasible unless significant imbalances are accepted. The alternative, which is becoming increasingly common (and which is the subject of this paper), is to limit withdrawal and to recycle and reuse the discharges and effluents. This reduces the impact on water resources and reduces the effluent loads.

Such processes will likely comprise closed loop or semi-closed loop cycles which take water from a certain point in the process, treat it and return it to the process to be passed through once again. To accomplish this end, the environmental, economic and managerial aspects must be considered.

In terms of technology the problem is to design a cost effective treatment process that will take low quality water and turn it into higher quality water. This is a similar problem to an open circuit except that the quality of the water at the beginning and end of the process is less well defined. In fact, it is necessary to evaluate effects of reuse on the process and the ultimate water quality. Moreover, in order for the polluted water to be reused a detailed evaluation of its quality is required. In addition, it is necessary to know the possible transfer of contaminants or their accumulation.

In addition to the industrial users, it is necessary to consider the management of environmental effects on potential bodies of receiving water. The understanding of the environmental and economic effects of withdrawal and discharge is complementary to understanding the industrial issues. The varying benefits that will derive from the different interrelationships between the two is an important objective.

Micro and macro-economic elements, both internal and external to industry, have been noted. Their significance in terms of increasing industrial costs and also optimizing environmental benefits leads to solutions that will be discussed later.

Finally, it is important to note operations. A traditional scheme of water withdrawal, pre-treatment, use of the water, assessment of its state of pollution, final treatment and discharge involves transmitting information from one professional to another involved in the process. Each professional manages his/her part in the water cycle based on information provided by the others. However, there is no need for interdependence as in the case of a closed loop water cycle where each stage is either the consequence or the cause of others, and also affects them. This increased integration requires more coordination which is one of the big challenges for reuse policies.

As a starting point, it appears that in general free water withdrawal combined with end-of-pipe solutions is not the best option. Recycling and reuse with closed loops appear to be viable but their application requires planning.

The problems noted above form the basis of this paper. The intention is to highlight the possibilities, methods, problems, environmental advantages and, in certain situations, the economic advantages of reuse. Some examples are given to more clearly illustrate the significance of the approach.

2. Quality of Discharge Water from Different Origins

A complete analysis is the first step to determining the fate of any discharge. The results will determine where it can be discharged, the feasibility, the treatment necessary and the associated costs.

It is important to understand that industrial wastewater transports residual contaminants. The water removes any raw material not used in the process as waste. This washing and transport function is very obvious in galvanizing operations, the mechanical industry and the textile industry. It can also be seen in the use of cooling water to remove thermal energy (as heat) that can not be utilized.

A plant operator must be able determine when and how to reuse wastewater (and the problems and costs of doing this), or to discharge it. Good analytical data is important to establish the relationship between the process and the effluent generated.

There are many references in the literature concerning the relationship between effluents and the processes that generate them. However, there is much variability in the analytical data which is a function of the process, the raw materials chosen and any additives used in the production. A general approximation can be found in the literature but these values should be confirmed through testing.

From the point of view of chemical mass transfer, it is possible to trace the cause and effect relationship from the generation of a pollutant to its transfer to an effluent. However, specific numerical values can not be determined.

It is also important to note that the combined effect the main raw materials and the processes have on the generation of effluents is relatively well known, as there is almost a direct connection between them. This is evident from the presence of chrome in wash water discharge in the galvanizing industry, or dyes in textile wastewater, or COD in the sugar refining industry. It is more difficult to detect the presence of secondary components, such as additives in the raw materials, which can cause pollution. It is possible to consider the presence of mineral salts in animal feeds or the use of ammonia products in the textile industry and the consequences of these substances in the effluent. However, they are difficult to identify unless experimental means are used.

If the quality of the effluent is known and it is reasonably constant, it may be possible to use stream separation. If a particular contaminant is identified at high concentrations, it may be possible to treat it more efficiently. Indeed, useful material may even be recovered from such a process.

Stream separation is commonly applied to the separation of cooling water and process water. It is a very useful tool regarding treatment and reuse. Each stream can be characterized and reused, treated or discharged accordingly.

The quality of discharge water can be used to determine a more environmentally acceptable, and possibly cheaper, alternative such as recycling than end-of-pipe treatment.

Such operations require plant modifications and these in turn require feasibility studies and cost benefit analyses. Innovative reuse and recycling scenarios, particularly those looking at separate discharges, should be critically assessed. They should be considered as alternatives, and given preference, to conventional management that uses combined streams to save money and requires less plant modifications.

It should be emphasized that the scope of the analyses should be based on knowledge of the particular industrial process producing the effluent, and on the chemical characteristics of the substances involved in the process. This way useful results for treatment technology and discharge can be obtained. Close cooperation between the processing side and the treatment side of an industry is required.

Finally, it is important that the analytical results of effluent quality are used to improve the upstream process, the methods of stream separation and the types raw materials. If necessary changes could be made to the raw materials to change the quality of the process water discharges, especially regarding their possible reuse. Again it is worth stressing the importance of communication between the analytical, planning and production components. It is normal that they will have different objectives but only an overall evaluation will realize optimal gains

3. Recycling, Reuse and Multiple Use

The methods and policies discussed in this paper are aimed at reducing the overall consumption of water and the corresponding wastewater, given the original production conditions. This relates to the repeated and best use of the same volume of water with efficient treatment.

Reuse can be achieved in two ways. First, reuse for the same production process where treatment takes place before the water is used again. Second, reuse of water in consecutive compatible stages, gradually requiring less treatment but needing to be hydraulically balanced between the stages.

Recycling of water in the same industrial process with treatment in between appears to be conceptually simple. It makes sense hydraulically, it can be automatically controlled, it works through treatment in well established sequences and only needs limited modifications of the water system. However, without partial extraction and replacement of water, contaminants may accumulate limiting the quality of the water for reuse and reducing its value.

In general the advantages of recycling have outweighed the disadvantages, especially where secondary products can be recovered. For example, there are the washing operations in the galvanizing industry, and the recovery of pigments in the paint industry through ultra-filtration and the reuse of water.

An alternative is to recycle water that has been treated to various degrees from one production stage to another by meeting the qualitative requirements of the subsequent stages. Apart from a substantial natural resource saving, equal to the previous direct reuse strategy, there are different advantages and disadvantages for this solution. Advantages include the absence of contaminant accumulation, the possibility of intermediate reuse without treatment, and the broad possibilities of multiple use. Disadvantages limiting consecutive use include the need for hydraulic balancing between different operations, the necessity of engineering modifications to the water network to move the water around between processes, and the final effluent containing the mixed residues of different processes which is harder to treat.

Some multiple use applications, such as the sugar industry and the iron and steel industry, have had good results in terms of costs and benefits, but much less frequently than the direct reuse approach.

4. Technological Treatment Possibilities

As discussed in the following section, the water quality required for recycling or reuse is different to that acceptable for discharge, either into a surface water body or municipal sewers. In these latter cases, environmental concerns and public health and safety must be considered. However, for recycling and reuse, the quality depends on technical considerations. Treatment is designed with these standards in mind. However, the treatment must be easy to control and possibly recover contaminants for secondary uses. The generation of sludge or other residuals may provide an undesirable obstacle to treatment, particularly as their disposal is difficult.

Treatment systems such as activated carbon, sand filtration, ion exchange and membrane filtration meet the requirements of recycling and reuse noted above. However, chemical-physical coagulation systems or biological oxidation systems, though effective in final treatment, do not adapt well to automation and produce residual materials.

It should also be noted that all these systems basically lead to the segregation of depuratėd water flows that can be sent for reuse, as opposed to a concentrated flow (regeneration water, concentrated or counter-washing liquid eluates), which can also be evaluated for a secondary destination.

The cost of the treatment, including the equipment and operation, needs evaluation both from the company's business perspective and also the broader environmental benefits. These two aspects are not always compatible and a final decision on reuse will require public information and input.

From a company's point of view there are two costs that must be compared. The first is the cost of the connection to obtain primary source water plus the cost to discharge it. The second involves reuse where the cost of the water and its discharge are negligible but there is a cost for treatment. The financial comparison is easily done and provides a preliminary indication of the possible cost advantages of reuse.

The company must also consider other financial implications that are more difficult to assess. These include quantifying the performance value of water in the process, the savings or costs associated with discharge, and the difference in costs between open and closed circuits. There are no generalizations with regard to the results of such an analysis, but the evaluation is straightforward.

External costs must also factor in the comparison. These comprise the reduction in the existing charges for the supply of water from the system and the resulting discharges. The savings to industry are not easy to calculate but the reduction in revenue must be taken into account by the municipalities that provide these services. Municipalities have financial tools at their disposal, including incentives for reuse, and penalties for excessive use and discharge that can mitigate against the environmental consequences of industrial reuse or lack of it.

The evaluation of the reuse of cooling water is straightforward and the same method can be used for process water. In this case, the potential accumulation of contaminants in the system must be considered with the hydraulic and thermal loads.

A final point to consider is the necessity of partial extraction and re-filling in a closed loop system. A recycled flow cannot, by definition, have an efficiency equal to one and the efficiency is low or nil in terms of secondary products that are not treated, as treatment plants are generally designed for the main contaminants. In the galvanizing industry, for example, the removal of heavy metals is very efficient, but there is little or no removal of the salinity that concentrates in the recycling process. Similar observations can be made in the recycling of cooling water where there is efficient temperature reduction by evaporation through cooling towers, yet conductivity tends to increase.

In order to maintain steady-state water chemistry during recycling, cleaner water must be introduced to compensate for the withdrawal. The degree of this intervention depends on the amount of accumulation that is acceptable in the recycled water and the quality of the input water. Therefore, in general, recycling systems are semi-open systems whose calibration depends on the balance of accumulation within the process.

The importance of good analyses of water quality is again obvious with respect to contaminant accumulations. The feasibility and limits of reuse must be studied because the potential loadings resulting from a closed cycle are determined from even low concentrations of chemicals. Such low concentrations are not an issue in discharges but are significant in terms of accumulation in reuse.

5. Characteristics of Treated Water for Reuse

Treated water, from which most contaminants have been removed, may be recycled. It is put through the same process from which it was originally derived, or reused in a new way or different process.

Before recycling and reuse is discussed in terms of plant engineering, the necessary quality of the water and the standards will be examined. These in turn are related to the requirements of plant engineering and its costs. Thus, determining the quality of the water for reuse is of fundamental importance.

The following basic considerations are important regarding water quality for industrial use:

- The effect on the final products,
- The effect of the plant equipment,
- The health and safety of the workers.

Clearly it is important that the quality of the final product is not adversely affected by poor quality water. Such effects may occur through the process itself, washing, or contact with the raw materials or the product in various stages of production. The effects, such as the release of secondary pollutants, can only be determined by laboratory and pilot testing with water of varying quality.

It is also possible to use the quality of the industrial product as an independent variable in establishing the necessary quality of source water. Alternatively, it is probably more practical to balance the increase in cost, perhaps due to plant improvements, with the increase in benefits from more efficient production or more water reuse.

Such optimization requires evaluation of the industrial costs, the costs connected to the quality of the product and the costs connected to the environment. This is a clearly defined procedure. The basis of the analysis requires a correlation between the quality of the primary water and the quality of the product, or by increasing the cost to reach the desired quality. The correlation is specific to each case and indicates the feasibility and limits of reuse.

It is difficult to correlate contaminant criteria in primary water to different types of production. Production and its problems is industry specific with its own pollutants and chemical and physical conditions. Wide experimental analysis using good data on the primary water and the chemistry of production can produce satisfactory results.

There is some generic, broadly based evidence in the literature concerning the limits of product quality. This is generally valid for large industries, for example, textiles, paper, petrochemicals, and food. However, within this the requirements for water quality can be very different. Such values need confirmation by specific testing.

There is no experimental knowledge of the effect of contamination on the product. In the past it was usually simpler and cheaper to obtain primary water from good quality aquifers. Therefore there is no evidence of the effect of water quality on product based on previous information.

Finally in a plant, cooperation is needed between the production manager and the environmental manager, over optimizing the reuse of water.

The second constraint on water reuse and its quality are the possible effects of plant equipment. These include scaling, corrosion, deposits and general contact with the equipment. In this case, the range of the potentially critical water parameters is smaller (salinity, conductivity, suspended solids, precipitating ions) and the reactions that can take place have been widely studied and are well known. The biggest variable is the type of equipment used with such factors as the chemical strength of the materials, the presence of possible stagnation zones, and the necessity of thermal exchange.

This is a well known, well studied and well defined phenomenon in industrial engineering. Therefore a careful comparative examination of the water quality for reuse and of the structure in which the reuse will take place can quite easily be carried out. This will establish the limits and feasibility or, more generally, the necessity of at least partial cleaning and filling. This approach is fundamental for water used in cooling circuits, in thermal cycles and for all the water that does not directly come into contact with the product. The acceptable limits in these cases are quite easy to define and verify.

The last factor that may limit the acceptability of reused water more than any other, is its possible effects on plant workers. Different exposure pathways may be involved – contact, inhalation and ingestion. Whereas technological problems can be overcome in a variety of ways, occupational health and safety is often harder to deal with and may require expensive, time consuming solutions. In the workplace, it is difficult to establish the cause and effect of varying water quality with many contaminants on workers. It requires epidemiological studies, based on occupational health statistics, after the fact. In summary, while it is very difficult to establish safe limits for workers in contact with reused water, this situation should be well monitored.

6. Treatment, Recycling and Reuse Costs

When reuse is a possibility, the investment and changes in management costs must be taken into account. The infrastructure investment is easily calculated once the input water quality and the treatment parameters are known.

The modifications to the water circulation infrastructure are relatively simple in the case of direct recycling involving a single operation. Only a disconnection from the system is required, then the installation of a return system followed by a reconnection. The modifications are more difficult when the entire network is concerned involving a series of points and reconnections. This is a typical situation when an open circuit cooling system is changed to a closed loop system. Here a series of equipment for the general distribution and collection of water must be transformed into a dedicated network with an integral cooling system. Such hydraulic modifications may not be feasible in the case of old plants.

Similar problems exist for the multi-use of water. Here, water purified to a certain extent, must move from one operation to another requiring a different distribution system within the plant than an open circuit, which comprises the starting point for the modifications.

Sugar refining is a good example for evaluating the potential for reuse. The process uses water of different quality in many ways, e.g., washing the raw materials, diffusion, purification of the sugar. As most existing sugar refineries are complex installations, a radical change to accommodate the reuse of water would not only be difficult and expensive, but installation may take a great deal of time. In this respect, it is preferable to include reuse in the original design and construction of a plant, as modifications to old plants may be difficult to justify.

Water reuse also saves operating costs by eliminating source water and discharge costs. However, the costs for the disposal of contaminants that can not be recovered must be included. Given the overall lower water flows, there will be higher concentrations of contaminants requiring treatment. Such recovery is economically and environmentally desirable, but is moderated by the necessity for stream separation to produce effluents of suitable water chemistry to facilitate recovery.

Therefore from the point of view of industrial engineering, the cost of reuse may be acceptable and result in less water consumption. However, a major constraint is the need for a suitable water distribution network or the ability to carry out modifications at a reasonable cost based on experience.

An example of water savings and reuse in the electro-plating industry is reported in the BREF document for Surface Treatment of Metals and Plastics. By transforming from a the UK benchmarking plant to a plant optimizing "good practice", the water consumption dropped from 11,500 m3/year to 3,000 m3/year. The capital cost for the change was estimated at £23,300 with an annual savings of more than £40,000 and a payback period of 0.6 years.

For textile wastewater, the treatment cost using a biological system is estimated to be between 0.24 and 0.40 $/1000 L, while the corresponding cost with membrane ultrafiltration is between 0.60 and 0.80 $/1000 L. However, as ultrafiltration leads to a water saving of 0.30 $/1000 L, and a waste treatment saving of 0.60 $/1000 L, membrane systems typically can pay for themselves in 0.5 - 2 years. Moreover, they have the added advantage of better meeting increasing government regulations on wastewater treatment.

Even though general costs are difficult to estimate, as each plant situation is specific, the above examples illustrate the potential economies possible from water reuse.

7. Environmental Benefits

The greatest benefits of reuse and recycling are the lower demand on source water withdrawal, leaving it available for more appropriate uses, and less impact on surface water receivers. Surface waters themselves are also sources in the process.

An important objective for government is planning for the best present and future uses of water, by regulating withdrawals and discharges by financial or other means. It is difficult to regulate the quantity of withdrawal or discharge. However, qualitative criteria may be used to regulate discharges leading to more sophisticated end-of-pipe solutions. On the other hand, financial means can be used to deter withdrawal or to favour reuse to produce innovative treatment solutions, possibly with financial assistance.

The environmental consequences should be evaluated in advance of government regulation.

First the effect of different withdrawal systems and reuse must be studied in terms of their effect on both the qualitative and quantitative water balance. Then the evaluations must be translated into quantitative estimates of the resulting externalities. Finally, financial instruments must be devised to encourage desirable, cost effective solutions to overcome these externalities.

This kind of detailed study involves the following concepts:

- Definition of the externalities produced or avoided. It is possible to establish an economic value based on the effects, both positive and negative, to the quality and quantity of water resources. The evaluation involves the entire system of potential water users and is subject to great uncertainty with respect to definite numerical values. However, the relative difference in value is important and can be used to evaluate the economic effects of different practices.
- Translating the evaluations of the different externalities into taxes or incentives. Government planning strategy must establish how the external economic value of different water utilization practices can be translated into financial incentives for reuse, and disincentives for high withdrawal. This needs to be carried out in a logical process.

An alternative to the above discussion is to legislate standards into place that would limit withdrawal and discharge. Examples of this approach are the prohibition of the removal of water for industrial use from deep aquifers, or a maximum effluent load discharge to a surface water body. Such legislation should be based on consideration of its effects, its level of acceptability and its consequences.

The success of such legislation depends on enforcement and the ability to impose limitations on production, which might be economically and technically unacceptable. Overall it appears that financial incentives for reuse and disincentives for high withdrawal offer a better solution for improved industrial practices.

8. European Examples of Recycling and Reuse

In Europe, modified industrial practices, progressive policies and regulations have been widely applied. There are many examples of the gradual adoption of recycling and reuse and also of industrial areas where reuse has been achieved by installing redistribution networks for treated industrial water. In some industries the reuse of water is widespread.

For example, the galvanizing industry reuses process and washing water. The iron and steel industry and metallurgical sectors reuse cooling water from evaporation towers. However, in some industries, such as textiles and food, only limited adoption has been carried out because of the potential accumulation of deleterious substances that may come from reuse. In fact, the high quality necessary in the final products may limit the major reuse of water. The energy sector has also witnessed an important increase in water reuse because of increased power demands and the consequent need to deal with large quantities of cooling water.

In a regional industrial setting, the location of similar industries next to one another, such as the Prato area in the centre of Italy, has encouraged reuse systems. This has produced totally modified water distribution systems in comparison with the former practice of open consumption. In Prato a good example of reuse is a treatment plant built with a capacity of 5,500 mc/h. Its input wastewater is essentially from the textile sector (65 per cent of the volume and 85 per cent of the organic load). The treatment consists of biological and physio-chemical processes with a final stage of activated carbon. From here the treated water is sent for reutilization by the industries from which it originally came. This reuse experience has been a very positive in terms of performance (with the exception of the accumulation of chlorides), but limited by the economics of the situation. The substitution of treated water for primary water in industry is only feasible where local groundwater is scarce and the drinking water supply is obtained from the water works or tanks.

In Europe, reuse in general has been driven by the problems of effluent discharges rather than preserving primary resources. Local government water planning has focused on water supply by using regulation and cost measures to encourage reuse while preserving natural water resources, whereas industry has concentrated on discharges. However, companies have been encouraged to adopt water reuse by tougher discharge regulations and the increased cost of end-of-pipe treatment. In addition, the possibility if improved recycling systems to control residual concentrations of pollutants, and thus avoid emergencies and incidents with discharges, has been a further incentive.

Obviously, the cost of operations has played a role in this choice, above all in areas where there is less water available and the original cost of the resource is higher. In the future, an increase in water reuse and multi-use can be expected as part of industrial restructuring, while direct recycling also appears to be increasing. In general, there is no lack of input water so consumption need not be limited at this point but elsewhere as discussed below.

An important factor is the IPPC Directive to improve reuse policies. Many member states have adopted this policy and use it in permitting to require industries to use Best Available Technology (BAT). In many BREF documents (the documents that are the basis for identifying the right techniques for each industrial sector), like iron and steel, pulp and paper, industrial cooling systems, and many others, there are clear procedures for assessing an industry for reuse systems. It is also important to note that BAT techniques, as state of the art, are considered to be economically sustainable.

9. Recycling and Reuse Systems in Developing Countries

The reasons for reuse of water in developing countries are very different from those in other countries. The principal reason for reuse is the lack of primary water resources rather than the problem of disposal. The need is to substitute a natural source with a recycled flow. Significant pilot and full-scale tests in Israel, New Zealand, Australia, Brazil, South Africa, the Sultan of Oman and in various African countries are examples of this situation.

For industrial applications, saving primary water resources is important because they are limited. However, despite the availability of practical technology and studies to demonstrate its advantages, the actual savings and application of reuse are very limited, probably because of the substantial investment that is required.

On the other hand, the reuse of water for agriculture is very significant. In many countries outside Europe water is primarily used for agriculture and to a much lesser extent for industry. Reuse of water for agricultural purposes therefore has social and economic impacts. Moreover, water reused for agriculture sometimes is untreated. This raises the possibility of contaminants ultimately entering the food chain. Hence, effective ways of limiting contaminants in reused effluent are important.

Social acceptability of the reuse of water is very important. Demonstrations showing its feasibility and good quality (lack of contaminants) are of fundamental importance.

10. Conclusions

On the basis of the above discussion, some conclusions can be drawn.

- A developed technological structure exists for the on-site reuse of discharged water after the removal of pollutants. This technology, which is qualitatively different from that used for the final end-of-pipe treatment of a discharge, is intended on the one hand to produce purified water for reuse and on the other an effluent which allows the recovery of materials.
- Stream separation is important for reuse. Cooling water, process water and other streams can receive better final treatment this way.
- It is inevitable that reused water, and eventually the process water, accumulates contaminants either accidentally or from the raw materials that are not totally removed. Partial extraction and refilling can compensate for this and should be designed to meet the necessary quality of the primary water.

- The definition of the lowest acceptable quality for reused water that will not affect production requires specific assessment. Potential damage to process equipment is relatively easy to assess on a case-by-case basis but impacts to workers are much harder to determine.

- Multi-use of water is an alternative to direct reuse in many processes. Disadvantages include significant modifications to the system and the resulting effluent is very mixed. Advantages include no accumulations, less need for intermediate treatment and significant water saving.

- The advantages of reuse may be purely economic. Cost savings may be realized if the costs of water and discharges are high, even accounting for the cost of modifying the water distribution in a plant. The risks associated with discharges are also minimized. Overall a general economic benefit will accrue from the reduction in externalities, the conservation of water resources, and reduced impacts on receivers.

- The role of government planning is to judge the effects of consumption patterns and conservation polices on water resources and the environment. Based on this they should put regulatory, planning or fiscal instruments into place.

- Compliance legislation is generally reserved for the most critical situations. This may limit abstraction from high quality aquifers for uses other than drinking water, or effluent discharge into water bodies that can not eliminate contaminants.

- Economic and financial measures are the responsibility of government and have a great influence on decisions taken by others. Their effect can be evaluated in terms of preventing externalities and the translation of such benefits into fiscal measures and incentives for the private sector.

- Fiscal measures should include progressive taxation on water withdrawal from aquifers with different water quality. This moves the burden of cost from simply pumping to a more environmental cost. Incentives for financing technical improvements directed at reuse must also be considered.

- In Europe, water reuse is driven by the need to improve on discharges and save water resources. Even if this results in expensive practical solutions, it is a viable option because of the externalities that are avoided.

- In some non-European countries, the reuse of water is mainly for agriculture and is mainly driven by water shortages.

- More research is required in the areas of defining the lowest acceptable water quality for various uses, to developing more suitable technologies for recycling of water and also the materials in it, and for the more accurate determination of preventable externalities and their translation into tax or other fiscal incentives.

- Increased reuse could be promoted by government and international organizations by setting higher standards for surface and groundwater quality. This way water reuse could show demonstrable effects on the preservation of water resources.
- Pilot projects, both for industry and agriculture, could be encouraged by governments to demonstrate the feasibility of reuse.
- The high cost of modernizing water distribution networks is the main obstacle to reuse or multiple uses of water. Financial assistance from governments or international organizations could provide important support to encourage reuse.

References

General textbooks

D.R. Rowe, I.M. Abdel Magid "Wastewater reclamation and reuse" - Lewis publ. 1995

T.H.Y. Tebbutt "principles of water quality control" - Pergamon Press IVth ed.

Reviews

Advanced Wastewater Treatment, Recycling and Reuse - Milano, Sept. 1998, Proceedings

Center for Waste Reduction Technologies (1995) "How to implement industrial water reuse: a systematic approach" - AIChE, N.Y. (USA)

Specific articles

A.N. Angelakis, L. Boutoux "Wastewater reclamation and reuse in Eureau countries" - Water Policy 3 (2001) 47-59

Public documents

U.S. EPA Guidelines for Water Reuse EPA/625/R-92/004 Washington D.C.

State of California, Wastewater Reclamation criteria, California Administrative Code, Title 22, Division 4, California Dpt. Of Health Services

EU, IPPC Bureau, Reference Document on Best Available Techniques in Common Waste Water and Waste Gas Treatment, Febr. 2003

Using reclaimed water

Marek J. Gromiec

Abstract

The purpose of this paper on using reclaimed water is to provide a general review of two issues: matching water quality requirements and quality monitoring technologies.

The following aspects on matching water quality requirements are presented; water quality considerations, regulatory issues, water reuse, indirect reuse, direct reuse, water reuse for industrial applications, and support of water reclamation and reuse, particularly for industry. In addition, the quality monitoring technologies cover; water monitoring systems, requirements of water quality monitoring, sensors, existing on-line water measurements, and new developments in monitoring technologies.

Biographical Note

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Contents

1. Matching Water Quality Requirements

1.1. Definitions

Reuse is the use of treated water or wastewater for any beneficial purpose.

Planned reuse is the deliberate, direct or indirect use of reclaimed water without relinquishing control over the water during its delivery.

Indirect reuse occurs when water, already used one or more times for beneficial purposes, is discharged into fresh surface or underground water and is used again in its diluted form.

Direct reuse is the planned and deliberate use of treated water or wastewater for some beneficial purposes.

Indirect potable reuse is the planned addition of treated wastewater to water resources designated for potable use.

Direct potable use is the planned addition of treated wastewater to the head-works of a potable water treatment plant or directly into a potable water distribution system.

Reclamation is the treatment or processing of used water or wastewater to make it usable.

1.2. Water Quality Considerations

Abundant supplies of clean surface and underground water in the world have been taken for granted until recent years. Severe contamination of many surface supplies has occurred and increasing instances of groundwater contamination are being found. Thus, the relatively fixed volume of available water may become less and less usable. Adequate water pollution control measures must be taken and reclamation of water resources must become the rule.

The quality and quantity of wastewater produced by the community depends upon such factors as the source of supply, population density, industrial practices, and even the attitudes of the local population. The quality of the environment can be improved by reducing pollution at the source, providing adequate treatment of wastewater, and recycling and reusing wastewater. Public support and some changes in social behaviour will be required in most instances.

Water resources can be characterized by hydrodynamic features, physico-chemical properties, and biological characteristics. A complete assessment of the quality of water bodies is based on appropriate monitoring of above components. The quality of the aquatic environment shows temporal and spatial variations due to a number of internal and external factors related to a water body.

There are many parts of the world where good quality water is unavailable. Solving water quality problems involves a multidisciplinary approach in which the required water quality is related to municipal, agricultural, industrial and recreational requirements.

Water quality has an extremely broad spectrum of meanings. In general, the quality of a water environment can be defined by:

- A set of concentrations, and physical partition of inorganic and organic substances,
- *The type of aquatic biota (including bacteria and viruses) found in the water body.*

In addition, the continuing increase in socio-economic factors has been driven by a fast growth in pollution stress on the aquatic environment. This is mainly due to significant increases in municipal, agricultural and industrial wastewater. After treatment, wastewater can be either reused, or discharged to the environment, where it re-enters the hydrologic cycle. This wastewater disposal can thus be viewed as the first step in indirect and long-term reuse.

However, the desirable characteristics of water quality vary with its intended use. Therefore, from the user's point of view, the term 'water quality' is applied to define physical, chemical, biological, bacteriological and/or radiological characteristics by which the acceptability of water is evaluated. What constitutes a desirable use is a matter of considerable interaction between the social and political environment and the economic ability to improve the water quality of a given region.

Water quality and pollution are determined and measured by comparing various quantities and parameters to a set of standards and criteria. In this case, a criterion is a scientific quantity upon which a judgement can be based, and a standard applied to a definite regulation or limit established by an authority. Water quality standards are usually based on stream standards or effluent standards. The reuse of water or wastewater is becoming more attractive because more stringent standards are imposed on treatment plant effluents.

1.3. Regulatory Issues

To ensure the safety of water supplies, standards have to be applied. Standards for drinking water have been available for many years.

Although national standards may be set for drinking water, the qualities of river water, municipal and industrial effluents, and reused wastewater are the responsibility of a water management authority. Even so, the standards set must take into account the possible transport of pollutants and the effects of discharges on downstream water users.

As wastewater reuse develops, it is important that standards be set for specific reuse purposes. Standards' setting is a most difficult and critical job, with important economic implications, and an authority must be created to ensure that they are followed. Standards governing the quality of water in water bodies are common. In addition, there are standards directly applicable to effluents, though few countries yet have standards for the planned reuse of treated wastewater.

As wastewater (treated or untreated) has been reused in agriculture for a fairly long time, some countries have developed standards for this purpose. In the United States, particularly in California, quality standards for irrigation and recreational uses of reclaimed water have been established together with regulations relating to treatment reliability.

The U.S. Environmental Protection Agency (U.S. EPA) has formulated a number of criteria for reclaimed water used for recreational purposes. These criteria are as follows: dissolved oxygen concentrations must be above levels to support game fish, and the organic concentrations must not exert an oxygen demand which lowers dissolved oxygen concentrations in the water below acceptable levels. In addition, dissolved oxygen levels can be affected by heavy algal growth or the formation of an ice covering. Nitrogen and phosphate compounds stimulate algal growth and accelerate eutrophication. Ammonia can be toxic to fish. The level of toxicity depends upon other water characteristics, including pH, dissolved oxygen, and carbon dioxide concentrations. Fecal coliforms are indicative of the presence of pathogenic bacteria and viruses which can cause serious diseases.

Various criteria and guidelines for the use of reclaimed water in agriculture exist in countries such as the United States, Israel, South Africa and Federal Republic of Germany. Pollution limits for irrigation water have been recommended by the U.S.EPA, however these limits are only general guidelines and can not be used as absolute standards.

Water quality standards for industrial plants discharging effluent to recreational lakes, for example, have been established by regional water quality control boards in The State of California. The drinking water standards are presently comprehensive enough to be used with reclaimed wastewater.

1.4. Water Reuse

Water has always been used and reused by man. The natural water cycle, involving evaporation and precipitation, is one of natural reuse since the return of water and wastewater to water resources is a fact of life.

The unplanned reuse of water is not new, and the planned reuse of water for beneficial purposes has been done in some areas for many years. However, at the present time an increased effort for far greater beneficial reuse of wastewater is needed. The water available for reuse includes stormwater, agricultural return flows, and various wastewaters. Normally, agricultural return flows and stormwater are used without treatment. Reclamation involves treatment of municipal or industrial wastewater to make it usable.

Water reuse or wastewater reuse is the beneficial use of the treated water or wastewater. Wastewater reuse means the use of treated water for any purpose. The wastewater reuse can be divided into indirect or direct reuse. Indirect reuse of wastewater occurs when water already used one or more times for domestic or industrial purposes is discharged into fresh surface or underground water and is used again in its diluted form.

Direct reuse is the planned and deliberate use of treated wastewater for some beneficial purposes such as irrigation, industry, prevention of salt water intrusion by recharging underground aquifers, recreation, and potable use.

Potable reuse can be further divided into two categories as follows:

- *Indirect Potable Reuse* – the planned addition of treated wastewater to a drinking water reservoir, underground aquifer, or other body of water for potable use that provides a significant dilution factor;
- *Direct Potable Reuse* – the planned addition of treated wastewater to the head-works of a potable water treatment plant or directly into a potable water distribution system.

Usually the reuse of treated effluents is most applicable where large volumes of water are used. The possible transport of the reclaimed water is an important consideration. A wastewater reclamation plant need not always be located at the same place as the municipal wastewater treatment plant, nor should the reclamation process be dependent upon treating the total flow. Treatment processes work most efficiently and economically when dealing with a steady flow of wastewater rather than with the irregular flow normally experienced from urban sources, and this condition can be achieved by withdrawing only a part of the urban wastewater stream.

In any reuse application there are a number of points to consider. One very important question is whether the reuse will result in multiple rounds of recycling as this produces a build-up of refractory materials, especially inorganic ions, which may require the use of demineralization or other specialized processes. Reuses of municipal wastewater, except for domestic reuse, probably would not lead to multiple recycling. The reason is that less water volume is generally returned to the municipal wastewater treatment plant than is supplied by the municipal water system. Water losses in municipal systems are the result of water treatment, distribution (leakage) and use, and from the collection, treatment and disposal of wastewater. Such losses are quite significant in warm, dry areas where domestic reuse is likely to be more common. For example, in the United States it is estimated that these losses range from less than 20 per cent in humid areas to about 60 per cent in arid areas.

The disadvantage of these losses is the need for substantial additional fresh water sources. The advantage is that the steady state mineral concentration is reduced, and as a result, the likely degree of demineralization required. Also, there is the flexibility to demineralize either the reclaimed wastewater or the supplementary water sources.

Another consideration of reuse is the character of wastewater entering a treatment plant, especially with respect to industrial pollutants. Care must be used to exclude materials that would be detrimental to the reuse application. This is especially true for domestic reuse, but also applies to less demanding reuse applications. Some of these materials usually may not be considered toxic, for example, ordinary salt brines would be undesirable if demineralization was being carried out on the reclaimed wastewater. Water having heavy metal concentrations or high total dissolved solids are usually considered unacceptable.

The distribution of the reclaimed water must also be considered. A multiplicity of piping systems, each one containing different quality reclaimed water, will not usually be practical. There may be a number of large consumers in the vicinity of the treatment plant that would make distribution simple and inexpensive. However, if the consumers are widely distributed, one piping system in addition to the existing municipal water system is almost certain to be the most that will be economically realistic. The conclusion is that the reclaimed wastewater must be of a general quality to satisfy most of the customers without additional treatment. Treatment such as that necessary for boiler water feed would be excluded, since the present practice in water supply has shown that such treatment is more appropriately carried out by the user.

In recent years, considerable effort has been made to develop advanced wastewater technologies to reduce the problem of water pollution and to reclaim wastewater for planned use.

Wastewater is reused in many countries, and by far the largest reuse is irrigation. In some cases, untreated or mechanically treated sewage is used to irrigate grazing lands and grasslands, but this practice is not recommended. In addition to municipal water, discharges from breweries, starch factories, textile plants, dairy farms, and slaughter houses are used for irrigation purposes.

The industrial reuse of effluents is becoming more common, and recycling within plants is extensive. The term recycling is applied mainly to industrial applications, such as the thermal electric, manufacturing, and mineral industries. When effluents are reused in industry, it is common to use various treatment processes depending upon the quality of the water needed.

Recreational uses for wastewater are found in a number of countries in the form of artificial lakes and parks: golf courses are also watered with treated effluents. As would be expected, the driest countries with growing populations are the most likely to turn to reuse first.

Australia is regarded a dry continent and population concentrations cause some water resource problems. The City of Melbourne has developed a unique reuse for the city's treated wastewater to irrigate otherwise barren land to graze a large number of cattle and sheep. A master plan for water reuse has also been prepared.

In Mexico, where large areas are arid or semi-arid, wastewater reuse is vital. Treated effluents are used for irrigation and for industrial purposes.

Israel is a good example of country that is short of water and, by necessity, very active in the wastewater reuse field, particularly for agriculture.

South Africa has long recognized the importance of water reuse. The reuse of municipal effluents for industrial purposes is widespread. In nearly all cases, the major use is for cooling but some of the water can be used for steam generation and the remainder for processing.

Japan is well aware of the value of water and the possible reuse of wastewater. In addition, a Reuse Promotion Center at Tokyo has been established to promote the development and practical application of water reuse technology by reclamation of wastewater and desalination of sea water to cope with the very acute water demand.

The United Kingdom has made use of treated wastewater in industry. A particularly interesting case has been the development of the direct use of treated sewage effluent in the processing of wool textiles. The wool textile industry has some high water quality requirements, but extensively treated sewage effluents were found to provide an ample source of sufficiently high quality water.

In the United States, a number of wastewater reuse operations are mainly concentrated in semi-arid states, such as Arizona, California and Texas. The main use of reclaimed wastewater is for irrigation. In most operations, effluents reused for irrigation have undergone advanced secondary treatment and have a storage time of two days or more, and many irrigation sites are located up to ten kilometres away.

The reuse of municipal wastewater effluents by industry in the United States is about half of the total reuse volume. The major industries using municipal wastewater are power generation, petrochemical, mining and ore processing, and basic metal manufacturing. The predominant use is cooling in both once-through cooling and recirculating cooling systems. In a once-through system secondary effluent is used, but in recirculating systems shock chlorination, lime clarification, pH adjustment, corrosion inhibition, filtration, and softening are applied. In addition to cooling, wastewater effluent is used for boiler makeup and for processing purposes. The treatment steps used to produce satisfactory water for low pressure boilers include lime clarification, recarbonation, anthracite filtration, zeolite softening, and deaeration. Additional treatment steps are taken for high pressure boilers, such as reverse osmosis, demineralization through cation and anion exchangers, and mixing bed exchangers for polishing. Reclaimed wastewater effluents have also been used for processing purposes in the mining and steel making industries.

Treated effluents are also used in the United States for recreational purposes, particularly in California, Arizona, and Colorado. Very often biologically treated effluent is given additional treatment, for example coagulation, filtration, carbon adsorption, and disinfection. Wastewater effluent is used for the irrigation of football fields, landscaping purposes, stock watering, vehicle washing and road construction. In addition, reclaimed municipal effluents are used for groundwater recharge and/or salt water intrusion at various locations. The use of reclaimed wastewater for domestic purposes is highly controversial in the United States; however, it is used for flushing public toilets in some places.

Many countries such as South Africa and Israel have urgent needs for wastewater reuse. Some countries, such as the United States, are in the fortunate position of not having an immediate need to use wastewater as a direct source of usable water. Therefore, a relatively small amount of municipal wastewater is reused in the United States. In the future though, the reuse of wastewater will be a necessity in many parts of the world. Since it usually takes a long time to turn research results into practical use, the time to develop and provide full-scale reuse is short. Therefore, it is the responsibility of scientists and engineers around the world to provide the scientific and technological basis to permit reuse for all purposes.

1.5. Indirect Reuse

In terms of indirect reuse, the increasing proportion of wastewater in many rivers should be taken into account.

In a number of rivers in the United States, at periods of low flow, from 4 per cent to about 20 per cent of the water has passed through domestic water systems. If the volume of industrial effluents is also taken into account, it would be expected that 20 per cent to 40 per cent of the river water at low flow in some areas may be reused water.

In the Federal Republic of Germany, the Ruhr River has a reuse factor of 35 per cent half of the time and has reached 85 per cent under severe conditions. In the United Kingdom, the River Thames contains about 15 per cent sewage effluent when flowing at an average rate.

The present treatment methods for polluted river water are based on those historically used for relatively unpolluted river water. It would appear that not enough attention might have been paid to the increasing amounts of wastewater in many rivers. The inadequacies of these traditional methods are perhaps indicated by health problems in parts of the world, particularly during droughts. It appears, therefore, that the public health aspects of obtaining potable water from polluted rivers should be reviewed. When rivers contain a high proportion of effluent, the treatment of water from them should be regarded as analogous to the direct recovery of water from sewage or industrial effluent, and safeguards appropriate to this situation should be imposed.

There is also an increasing need to consider the optimum location for water treatment between wastewater treatment plants, rivers (self-purification), and water treatment plants that produce potable water. There are two limiting cases:

- Wastewater is discharged with little or no treatment, all the purification occurring in the river or at the water treatment plant,
- Wastewater is purified to as high a standard as that of the river water into which it is discharged.

In the first case, the practice was common in the past but is rapidly disappearing. In fact, raw sewage disposal into rivers is prohibited in some countries. Local authorities are requiring secondary treatment and, in some cases, removal of nutrients (phosphorus and nitrogen) because uncontrolled incidental pollution may well use up the natural purifying capacity of the river. In the second case, the type and degree of treatment required at the water treatment plant is no different from that which would be required in the absence of the wastewater discharge.

Almost certainly the optimum solution lies somewhere between these two extremes, and optimization studies are required to determine it, taking into account all the costs and benefits involved. This may be difficult in practice because some of the social costs and benefits externalities) can not be readily expressed in economic terms. Such optimization studies are likely to be most successful where a single river basin authority has control over the treatment and discharge of wastewater and the abstraction and treatment of potable water.

The unintentional reuse of wastewater also occurs widely as a result of using river water for agriculture, recreation, and industrial supply and, for these purposes too, there is a need for appropriate safeguards.

1.6. Direct Reuse

Treated wastewater may be intentionally used in a planned way for a variety of purposes. The direct reuse of municipal wastewater is becoming more attractive for two primary reasons:

- Regulatory agencies are imposing increasingly stringent standards on wastewater plant effluent,
- Population increases in many urban centres are placing an additional burden on traditional fresh water supplies.

However, it is not expected, nor it is desirable, that reclaimed effluents will be piped directly into potable water systems. In such situations, where the distance from effluents to potable water is short, not only will the effluents receive advanced treatment but also normal water purification procedures before the water is distributed. A variety of direct reuse applications of effluents has been demonstrated in many parts of the world.

1.7. Water Reuse for Industrial Applications

The original concept behind the reuse of water and wastewater was to conserve and better manage the general water supply for industry. However, the treatment and reuse of industrial plant effluents should also be considered as a positive means of reducing or preventing pollution in various water bodies.

Treatment methods for industrial effluents are numerous, and include, adsorption, electrodialysis, evaporation, solvent extraction, emulsion breaking, foam separation, freezing, hydration, oxidation, electrochemical degradation, oxidation, ion exchange, reverse osmosis, etc. Industry uses water in many ways, particularly as a buoyant transporting medium, a cleaning agent, a coolant, an ingredient in finished products, and a source of steam for heating and power production.

Therefore, the water quality requirements for industry vary greatly with the type of industry and the function of the water. For certain industries, quality requirements will frequently exceed even certain specified standards for public supplies. Normally, water quality criteria used in industry are based on recommended maximum concentrations of impurities. For example, hard water affects many industrial uses because scale deposits interfere with heat exchange in boiler and water cooling systems.

There are numerous examples of wastewater reclamation and reuse in industry, however only industrial cooling is presented as an example. Cooling water represents a very significant water use for many industries. For industries such as electric power generation, oil refining, and many other manufacturing plants, up to 50 per cent of the total water use may be cooling tower make-up water.

Since a cooling tower normally operates as a closed-loop system, using reclaimed wastewater for cooling tower make-up water is relatively easy. However, the effluent used for cooling tower operation has to be specifically and effectively treated. Water quality problems that are encountered in industrial cooling operations are scaling, biological growth, metallic corrosion, and fouling in heat exchangers and condensers. Therefore, effluent intended for cooling tower operations has to pass through advanced treatment to reduce the above problems.

In general, there is a considerable reuse of water by industry which will increase, especially where industrial development occurs in areas of water shortages or poor quality water.

1.8. Support of Water Reclamation and Reuse, Particularly for Industry

Water reuse must be planned on a broad basis and governments' role in supporting water reclamation and reuse is essential. As an example, official government support for water reclamation and reuse exists in the United States. The role of the U.S. Environmental Protection Agency (US EPA) and its predecessor organizations is stated in various acts.

Public Law 87-88, amending the Federal Water Pollution Control Act, directed the Secretary (at that time of Health, Education, and Welfare), "to develop and demonstrate practicable means of treating municipal sewage and other water-borne wastes to remove the maximum possible amounts of physical, chemical and biological pollutants in order to restore and maintain the maximum amount of the Nation's water at a quality suitable for repeated reuse". The Act gave impetus to a research programme on advanced waste treatment that develops new, and improves existing, wastewater treatment processes, thus permitting the maximum removal of contaminants and reuse of water.

Wastewater reuse has been specially recognized by Public Law 92-500 that recognizes the potentially large benefits if wastewater can be treated for reuse. Sections 201b, 201d, and 201g, 2B clearly require that the U.S.EPA:

- Provide for the application of best practicable waste treatment technology, including reclaiming and recycling water;
- Encourage the construction of revenue producing facilities that provide for reclaiming and recycling; and
- Allow for water reclamation and recycling technology application, to the extent practicable, at later date in plants considered for grant assistance.

Section 105a, 2, authorizes the U.S.EPA to make grants for demonstrating advanced wastewater treatment and water purification methods. Section 105d, 2, requires that the Administrator conduct, on a priority basis, an accelerated effort to develop, refine, and achieve practical application of advanced waste treatment methods for reclaiming and recycling water and removing pollutants.

The Safe Drinking Water Act also contains important provisions regarding treatment and recycling of wastewater. Section 1444 authorizes a development programme to demonstrate new or improved technology for providing safe water supply to the public and also to investigate and demonstrate the health implications involved in the reclamation, recycling and reuse of wastewater for producing safe and acceptable drinking water.

Therefore, there is a strong and clear legislative mandate for research development and demonstration of reliable, cost-effective technology for reclaiming and recycling wastewater for beneficial uses. In addition, the measures noted above indicate that wastewater reuse in the United States is being specifically addressed by legislation, and a great deal of research is directed toward some facet of reuse. A number of issues must be solved before planned reuse can be maximized. As a result, many wastewater reuse programmes have been initiated and carried out in the United States. The U.S. EPA in a policy statement on water reuse supports and encourages the development and practice of successive wastewater reuse.

The role of government has been outlined earlier in this paper and the responsibilities of local agencies and industry to support water reuse are very important. The role of local agencies in water reuse is as follows:

- Promote to the extent possible, consistent with water quality considerations, the treatment and reuse of used water;
- Determine the water reuse potential on area-wide basis.

Targeted work on reuse in specific areas would follow, and examples of such objectives include the following:

- Demonstrate how water reclamation can supplement available water supply,
- Determine how water reclamation can affect downstream collection and treatment systems,
- Develop legislative, economic and planning procedures to implement water reuse,
- Examine all available technology for reuse and assess public acceptance, aesthetics and cost-benefit ratios.

The role of industry in water reuse is as follows:

- Examine all plant practices to obtain optimum water reuse and recycling,
- Consider the use of available water of secondary quality (sewage plant effluents, brackish water, sea water, etc.) for suitable plant purposes,
- Examine chemical and processes contributions to pollution and determine if changes in either will help abate pollution,
- Consider product recovery from waste materials,
- Be aware of the new developments in processes to control pollution,
- Make all plant personnel water and pollution conscious.

2. Quality Monitoring Technologies

2.1. Water Quality Monitoring Systems

Increasing environmental concerns and regulations have given water monitoring systems a new role. Particularly in Europe, the Water Framework Directive (WFD) requires that Member States should monitor water status within river basin districts. It also states, that the adoption of technical elements, technical development, and the standardization of monitoring, sampling and analytical methods will be necessary.

Water quality monitoring systems for river basins should include both groundwater and surface water as well as the pollution sources impacting them. A monitoring system should be based on a three-tiered structure, which can be local or regional, and comprising Levels 0, 1 and 2, as follows.

Level 0: The Monitoring Level. This is the systems link to the actual water being monitored. The monitoring should be based on both automatic and manual data acquisition, and the data should be transmitted to Level 1

Level 1- The Data Handling Level. This level is for storage, data control, modelling, data reduction, and other processing and data management. Data could also be transmitted from this level back to Level 0 to allow automatic control or to coordinate manual sampling and analysis work at different laboratories.

Level 2 - The Management Level. This is where the long term management of the system's geographical area takes place. This management should be based on all the available data and tools provided from Level 1.

By its nature the structure of the monitoring system is decentralized, because the technology now offers network based tools. This means that actual physical storage of data and the location of different software could be visible to users in different geographical locations. The result is a high degree of flexibility in the construction and operation of such a 3-level structure.

There are three different types of stations to be monitored at the monitoring Level 0. These are: A - meteorology, B - water, and C - sediment. The monitoring at these different stations should be based on one or more of the following methods:

- Method 1 – physical/chemical parameters (automatic measurements);
- Method 2 – chemical parameters (laboratory analyses on samples);
- Method 3 – biological monitoring (field studies or laboratory work on samples).

These methods are highly dependent on the use of technology and its availability. Whereas the technology used in the Methods 2 and 3 above is based on well proven laboratory equipment, the technology used in Method 1 has been developed over the past one to two decades and is still under development.

The selection of methods at various monitoring stations depends on the nature of the river basin in question. Therefore, different combinations of stations and methods can be used. As an example, automatic rainfall intensity recorders can be established with on-line data input to a hydraulic model. Atmospheric deposition of nutrients and acid, windspeed/direction and temperature can be measured because they are important parameters for interpreting data from lakes.

Besides the hydrological measurements, chemical parameters such as nutrients, organic matter, etc. can be measured, in order to calculate a mass balance for primarily nitrogen, phosphorus and organic matter. This mass balance will give an understanding of the transport mechanism in the system and make it possible to evaluate eutrophication in rivers and lakes.

Moreover, it is important to set up a measuring programme for point sources such as cities and industries (organic matter, nutrients, toxic substances, etc.), non-point sources (rural areas - fertilizer, manure, pesticides, etc) and water abstraction sites. Furthermore, investigation of sediment parameters is important because of the accumulation of sediment. For example, information of the particle size distribution should give an estimate of the sediment transport in a river system, and the distribution of nutrients in sediments is used in eutrophication forecasts in lakes.

Biological monitoring will provide information on the actual ecological state of the system and will be used to evaluate the effect on the ecosystem with changes in water flow and water quality by correlating the on-line measurements and analyses to the biological monitoring. Biological monitoring is important in relation to the evaluation of the potential for algae blooms in lakes, macrophyte distribution and the quality of the fish population in both rivers and lakes. With a detailed knowledge of the dynamics of the ecosystem, some restoration may be possible using techniques such as biomanipulation.

At the data handling Level 1, the operation (system administration and maintenance) of different system software and data storage/data reduction will be carried out together with the set up, calibration and updating of the different mathematical models. Furthermore, different data presentation, calculation and statistical software packages will be employed including updating user interfaces, database links etc. In other words, this level will provide updated tools for the next level (Level 2) and be in control of day-today operations.

The monitoring programme at Level 0 will generate data from both automatic measurements and laboratory analyses. All the data arriving at the data handling level will have passed a quality check and as such would be ready for storage in databases. These data form the dynamic part of the information. In addition, the more static information, such as topographic data, siting of sources, and emission standards, are stored and ready for use.

The data make it possible to understand the hydrodynamics of a river basin through setting up a hydrological model. This model can be used to forecast water flows in different parts of the river basin, and could be run "continuously" using data from meteorological forecasts (weather radar observation if possible) and automatic recording of precipitation and water levels, in order to forecast flooding problems.

Furthermore, the data can be used for ecological purposes such as the modelling of oxygen concentrations in rivers downstream from a point source that introduces wastewater. Other examples include modelling the transport and/or spreading of toxic substances in rivers, or modelling eutrophication in lakes and reservoirs.

Ecological models are designed to describe biological processes and may be used to analyse factors that affect the water quality. The output from these models can be used to evaluate the effect of wastewater treatment for obtaining acceptable water quality in accordance with environmental legislation and to set up a river management programme.

Protection and control of drinking water resources are regarded as high priority tasks at this level, especially the handling of the on-line data from the monitoring stations at the water abstraction sites or upstream from these.

Data may also be used for mass balances, control of point source compliance with emission standards, and for use in Geographical Information Systems (GIS) such as estimating the load from a diffuse source.

The management level is essentially the end-user level, because all work and inputs from the preceding levels provide the necessary background information and tools for managing a river basin. The users at this level can carry out their own analyses using the system or request specific analyses at the data handling level.

The objectives are to prioritize long term environmental action programmes in order to optimize investments, and also to obtain and supervise the planned water quality criteria in different regions of a river basin. By using this information and the tools provided, the identification of "hot spots" such as the major pollution loads from industries, cities or agricultural areas will be possible.

Measures including the implementation of cleaner technology in industry, reuse and/or substitution of materials, upgrading and/or construction of wastewater treatment plants and changes in agricultural practices can be evaluated in advance. Furthermore, the effect of any actions taken can be tracked and, as a result, plans can be modified.

Many years of heavy pollution will affect the quality of the sediments in rivers and lakes and reservoirs. Sediments downstream from point sources may accumulate heavy metals, toxic substances and nutrients, which may be released a long time after the point source has been eliminated or reduced. Restoration plans for the removal or stabilization of heavily polluted sediments can be evaluated in order to select the best remediation technique.

A typical hardware set up for a river basin with automated monitoring stations and laboratory PCs at the monitoring level should be able to transmit data to a LAN (Local Area Network) in a regional database centre at Level 1. The number of regional database centres in a river basin may range from one to several depending on the size of the river basin.

A regional centre may be linked to other regional centres within the same river basin (or to other regional centres in other basins) and to a main data management and processing centre via a WAN (Wide Area Network) for the exchange of data and tools between the regions and for reporting to a managing authority. The management Level 2 will be at the regional centre for some tasks, and for others at the main centre, or it can simply be a PC connected through a dial-up line.

This structure allows for the possibility of having regional computational centres at the different regional authorities within a river basin, and a main data management and processing centre at the river board authorities. Another more simple set up is to have the regional computational centre at the water board and the main centre at a regulatory authority.

The technology needed for monitoring, exclusive of laboratory equipment, can be divided into three groups applicable to the monitoring methods noted above:

- Sensors/automatic analysers for Method 1;
- Other monitoring station hardware;
- Equipment for reporting manual data for Methods 2 and 3.

In addition, weather radar and satellite measurements may be used in some river basins.

Sensor technology is the limiting factor for extending Method 1 and at the same time reducing Methods 2 and 3. However, for some parameters like water level and dissolved oxygen, well proven technology such as pressure transducers and oxygen-electrodes has existed for some years. Other technologies developed mainly for the process industry (for example wastewater treatment plants) have become more reliable, as well as methods developed for research purposes which have reached the scale of automatic field equipment.

Automatic monitoring station hardware is commercially available, and experience shows that rack-based systems with an open structure will, in most cases, be the best choice. However, they must meet the demanding requirements of field equipment, which are: absolutely waterproof, heavy duty design (vandalism), module based for easy repair, low power consumption, local storage capacity, control of water sampling equipment, memory back up, port for local communication and data transmission.

Logically, these microcomputer systems should comply with all the other "normal" demands for hardware and software when used in a data acquisition system. They should be capable of transmitting data to an upper level and receiving commands from that upper level. Furthermore, a monitoring station will in some cases be equipped with an automatic water sampler which should be controlled from the microcomputer with the possibility of using time proportional, flow proportional (if the flow can be estimated locally), or event controlled sampling. The possibility of controlling other equipment from the microcomputer should also be considered.

The data from local laboratories will require manual input. As a consequence, the laboratories will be equipped with a PC-based link to Level 1. This PC should also be equipped with QA-software for the laboratory work. In addition, it will require software for pre-processing of raw data before transmission, a data-management tool for local storage of data (e.g,. a database tool) and of course the capability of requesting data from Level 1 (e.g., for local modelling work). As noted previously, automatic monitoring stations should be able to transmit data and receive "commands", where commands in this case will be a coordinated sampling and analysis programme for all the laboratories.

Level l consists of one or more regional data management and processing centres. As such it does not necessarily have to be one physical unit, but a logical unit comprising a distributed database system. The equipment typically consists of a UNIX-based computer functioning in a LAN with PC's and other input/output devices. The basic software tools consist of a standard relational database system combined with a GIS (Geographical Information System). The user interface for the integrated environment is based on X-Window and Motif (PCs running as X-terminals). Other software products are customized hydrological and ecological model systems for simulation of flows, sediment transport and water quality, models to forecast development in eutrophication, spreadsheets, and statistical tools.

Depending on the organization of the management level, it can operate entirely from a regional/central data management and processing centre or use decentralized PCs at different authorities but connected as X-terminals through dial-up lines to Level l.

2.2. Requirements of Water Monitoring and Automatic Water Quality Monitors

The principal requirements for water monitoring are related to: water type (i.e., surface water and ground water), matrix (i.e., water column, sediment and biota), and determinant type (both quality and quantity parameters). Traditionally, these requirements can also be divided into sampling, analysis and reporting. Sampling strategies may vary according to location and frequency. A number of ways exist to improve the efficiency, and hence cost effectiveness, of water monitoring.

The main features required by an automatic water quality monitor are presented by the European Environmental Agency as follows:

- Appropriate location of sampling point;
- Purpose-designed robust construction, both in terms of the physical protection provided by the instrument housing and the robustness of operational methodology;
- Tolerance of the temperature extremes to be encountered;
- Resistance to the ingress of dust and water;
- Tolerance to electromagnetic fields, electrical transients and power supply disturbance;

- Minimum supervision and maintenance requirements;
- Designed for easy access and fault-finding when maintenance is required;
- Purpose-designed sample transport and conditioning system.

The basic measuring techniques, generally for on-line use, are as follows:

- Physical techniques:
  Colour, turbidity, suspended solids, conductivity, pressure, depth, level, density, temperature, flow rate, volumetric flow;
- Electrochemical techniques:
  pH, ammonia, nitrate, bromide, calcium, carbon dioxide, chloride, chlorine, metals. cyanide, fluoride, redox, dissolved oxygen;
- Colorimetric techniques:
  Ammonia, nitrate, nitrite, phosphate, chloride, fluoride, sulphate, metals, manganese, phenols;
- Other techniques:
  High and low temperature methods for organic carbon measurement, respiratory for BOD and toxicity, gas chromatography and HPLC for phenols and organics.

2.3. Sensors

It is evident that an advanced water monitoring system requires sensors for continuous on-line information. A water sensor is an instrument that is capable of obtaining information on the quantity or quality of water resources. In general, sensors are the weakest links in the chain of real time monitoring process: presently sensor technology lags far behind computer technology.

The selection of sensors depends on several factors as follows: type of sensor, range, accuracy, drift from calibration, speed of response, and cost. Cost is very often the deciding factor, since some sensors are still quite expensive. The sensors require competent installation and regular maintenance, therefore their location is important from the viewpoint of their maintenance. In theory, the optimal on-line water sensor should have a continuous output and be operated without continuous human attention, even if periodic interventions are necessary. Another important factor is that the sensors must last a long time; if not maintenance costs become very high and real-time monitoring can not be done.

With technical and technological progress, continuous water monitoring systems will clearly be needed and used in the future. Today, however, effective water quality monitoring is still limited, mainly by the lack of suitable, reliable and inexpensive sensors. An important reason is that they have to be located and operate in difficult environmental conditions. Furthermore, most sensors can not operate for long periods without extensive maintenance.

Some sensors are used with great success for measuring such parameters as water temperature, pH, dissolved oxygen, conductivity and turbidity. These particular probes are already so highly developed technically that with regular maintenance and calibration, reliable measurements are possible. Today sensors also exist for ammonia, nitrite/nitrate, and phosphorus, and it is expected that these will be more commonly used in the near future.

However, there is a lack of reliable on-line sensors for a large number of very useful water parameters. It is anticipated that with advances in automatic instrumentation, the number of continuously measured parameters will increase, together with improvements in the measuring accuracy and detection limits. Water quality parameters measured by existing monitoring stations vary with the purpose of the monitoring and are mainly limited by cost considerations.

2.4. Existing On-Line Water Measurements

Flow rate, level and temperature are of fundamental importance for continuous water monitoring. The present sensors for the physical properties of water are for turbidity, conductivity and redox potential (the oxidation-reduction potential). One of the most frequent measurements in automatic monitoring is for pH.

Dissolved oxygen (DO) determination is a key on-line measurement in water quality monitoring. Usually membrane electrodes for DO measurement also have a sensor for measuring temperature. Organic content, based on such parameters as BOD (biochemical oxygen demand), COD (chemical oxygen demand) and TOC (total organic carbon), is still quite difficult to measure automatically. Therefore, a considerable amount of development work is being conducted using on-line techniques to replace the above parameters and involves determining particular wavelengths that correlate well with BOD, COD and TOC values, however fouling of sensors has been observed.

In order to overcome the above difficulties, there has been a move towards the development of biosensors. Also, a sample handing system called flow injection analysis (FIA), which employs photometric, fluorescence and electrochemical detectors, has been used in water quality monitoring. It should be noted that most of the existing chemical and biological sensors when used for continuous measurement have automatic sample conditioning.

There is progress being made in the continuous measurement of nutrients (N and P). The use of on-line nutrient sensors, actually measuring ammonium (NH4), nitrate (NO3) and phosphate (PO4) is increasing and a large number of new nutrient sensor prototypes is appearing. Determination of nitrate is quite difficult, presently electrode sensors and sensors based on photometry and colorimetry are used. Phosphate sensors are normally more complex then nitrate sensors, and more based on photometric principles.

In addition, a number of specific probes exist. For example, the determination of anionic surfactants with specific electrodes is a well-known measurement method.

2.5. New Developments in Monitoring Technologies

The capability for on-line water measurements is rapidly changing, since new sensors are being developed. The advent of inexpensive, mass produced, micro-electro-mechanical systems (MEMS) devices opened-up new possibilities for chemical detection. Microcantilever chemical sensors are presently being developed at the Oak Ridge National Laboratory, U.S.A. These microcantilevers respond to chemical stimuli by undergoing changes in bending and resonance frequency. They can be employed as chemical sensors based on adsorption-induced stress, photo-induced stress, and thermally-induced stress. Most recently, research Oak Ridge National Laboratory, U.S.A has shown that chemical processes can be designed into the microfluidic circuit of a microchip. Lab-on-a-chip technologies, pioneered at this laboratory, are microdevices designed to carry out procedures that would normally be conducted in a laboratory to provide chemical information. These technologies attempt to emulate the laboratory procedures that would be performed on a sample, but within a microfabricated structure.

The basic microchip operation is somewhat analogous to the operation of microelectronic devices but information is carried in fluids rather than electrons. These microchips consist of a microfabricated channel network that includes fluidic elements that allow the execution of basic chemical analysis processes that are included in an analytical procedure. Electric voltage is applied to the ports, or fluid reservoirs, of the microchips to manipulate fluidic materials throughout the microchannel network. By moving sample or reagents to given parts of the network an analytical procedure is accomplished. The microchips are fabricated using methods similar to those used to make printed circuit boards. Different chips that are designed to accomplish different measurement goals will all fit into a common controller device. Currently, as many as 49 chips are being fabricated on a single wafer of glass at a cost of a few dollars each. Eventually the microchips will be mass produced and will be inexpensive. Once commercial applications start, chips will likely be made from plastics and cost pennies each to fabricate. The retail cost of a ready-to-use commercial microchip will range from one to tens of dollars.

This approach allows new and improved analytical procedures on advanced microchip designs, as well as new microchips designed to detect new targets or suites of targets, to be deployed on existing hardware. A broad array of materials has been handled on these structures. Basic operations relating to the identification of materials used in nuclear, chemical, and biological weapons have been demonstrated. However, microchip technologies can also be used as a robust approach to chemical detection and *monitoring for in-situ remote monitoring and field applications.* For in-situ measurements the microchip is placed in contact with the fluid stream. Liquid is drawn into the analysis chip by electrokinetic forces and analysed according to the fluidic circuit design included on the chip. In field monitoring a sample is collected and placed onto a chip for analysis and results are generally available within a minute.

A sensor system based upon polarization ratio analysis (PRA) has been developed in Japan for monitoring oil-on-water. In this method, a laser beam composed of P-polarized light (longitudinal vibration) and S-polarized light (transverse vibration) obliquely irradiates the surface of water containing floating slicks. The sensor is based on an optical system, a signal processing block, a housing and floats. The signal processing block calculates the polarization ratio showing a difference between water and oil.

A new chemical sensor with an organic film on a quartz crystal microbalance (QCM) has also been developed in Japan for oil contamination. The organic film is a hydrocarbon polymer with a high affinity for the organic compounds in petroleum products (gasoline, kerosene, diesel and fuel oils). The chemical sensor is part of a water monitoring system for oil contamination. The monitoring system consists of the following parts, a sampler, a purger, a humidity control and a sensor. Oil in contaminated water whose threshold odour number (TON) is less than three can be detected. The detection time is less than 5 minutes depending on the type of oil. Also, the test results have indicated that one sensor device could work longer than half a year.

A water monitoring system that uses an electronic nose consisting of quartz crystal microbalances (QCMs) as a sensor probe to detect odorous materials in water has been developed in Japan. These QCMs operate at 9 MHz, and are 8.5 mm in diameter and 0.1 mm thick. QCM sensors coated with photo-assisted plasma-organic films made of polyethylene can detect semivolatile petroleum hydrocarbons without water vapour at a low level. A monitoring system for detecting odorous materials in water uses an electronic nose consisting of quartz crystal microbalances.

A toxicity monitor using nitrifying bacteria biosensors and applied to the toxic monitoring of purified water and river water was developed in Japan. The biosensor consists of a dissolved oxygen electrode and an immobilized microbial membrane containing pure cultured nitrifying bacteria (Nitrosomonas europaea). When a chemical is present that inhibits the oxidation of ammonia, the assimilation is reduced and the sensor current increases. This toxicity monitor using a nitrifying bacteria biosensor for continuous monitoring is an example of preliminary development.

A team from Sweden/Norway/Germany has developed an amperometric biosensor and a chemiluminiscence-based method for rapid detection of fecal contamination in water. A cellobiose dehydrogenase (CDH)-based biosensor was used for Escherichia coli (E. coli) detection. A second biosensor was based on the immobilization of the enzyme glucose dehydrogenase (GDH) in a polymetric matrix on the surface of a platinumbased, screen-printed electrode. It was considered as an alternative for rapid detection of E. coli with low bacterial numbers.

Colifast is a biotechnology company based in Oslo, Norway specializing in early warning solutions for microbial pollution. An automated Colifast At-line Monitor (CALM) can measure the level of E.coli based on the hydrolysis of 4-methyllumbelliferyl--D-glucuronide in the Colifast E coli medium. The monitor collects and analyses a sample by a five-vial Most Probable Number (MPN) technique, and it can be a tool for frequent monitoring of E.coli in water. The results are based on the number of positive vials after 12 hours. A mA signal correlating to the number of possible vials is then sent from the monitor to the main computer.

This patented technology is based on the fact that all bacteria posses characteristic and specific enzymes. Selected fluorogenic substances, along with a variety of compounds, are added to detect target microorganisms. When the bacterial enzyme hydrolyses the selective substrate, a fluorogenic compound is released and measured as fluorescence. Tests for the determination of total and thermo tolerant coliforms, E. coli, and Pseudomonas aeruginosa are also available. The instrumental platforms consist of a semi-automated laboratory comprising the Colifast analyser and the Colifast At-line Monitor.

In Japan, a method of measuring water level by processing the image of a slant plate was recently applied to the practical water level measurement of a reservoir. The image of the slant plate that is formed around the water surface boundary is optically analysed. This equipment consists of a number of sections such as, subject, image input, image processing, general data processing, data management and display. The measurement equipment is a vertical staff gauge and slant plate.

3. Conclusions

Water reuse plays an essential role in integrated water management. In particular, reclaimed water should be used by industry. Many industries treat and recycle their own wastewater either to conserve water or to meet stringent regulatory standards for effluent discharges. The important reasons for water reuse are both the alleviation of water shortages and also the prevention of pollution.

Industrial reuse represents a significant potential market for reclaimed water in many countries. Reclaimed water for industrial reuse may originate from in-plant recycling of industrial wastewater and/or municipal water reclamation facilities. Recycling within an industrial plant is usually an integral part of industrial processes and must be developed on a case-by-case basis. An economic analysis of water reuse options is a very useful tool.

A cost-benefit analysis of alternative water reuse systems should be performed when preliminary tests suggest the potential practicality of this reuse. For the analysis of each solution, cost estimates should be obtained for construction, as well as operation and maintenance costs on an annual basis. The present values of the costs for each solution should be chosen. The economic analysis will indicate which solution has the lowest present value for a cost over a 20-year period, and this lowest cost solution should be chosen. However, it is useful to recalculate the costs for each solution based on different assumptions and to test the sensitivity of the results to possible changes in important factors. This analysis is based upon economic considerations only. However, other factors such as environmental impact, energy consumption, system reliability, and others can influence decision-makers.

An economic analysis was conducted for the industrial reuse of treated municipal wastewater at a plant in Tucson, Arizona. It was shown that existing technology could reuse municipal wastewater at a cost competitive with alternative supplies. The construction cost of a 10 mgd water reclamation plant, including chemical pretreatment and filtration, activated carbon adsorption with a carbon reclamation system, cation and anion exchange, but exclusive of waste disposal facilities, was estimated at US$ 6.2M. A plant of this size was capable of recovering water suitable for significant industrial use at a cost of about US 10 cents per 1000 gallons. Given that primary industrial water costs US 25 cents per 1000 gallons or more, this reused source of water definitely merits consideration under certain conditions.

Wastewater reclamation provides available water resources, and reuse of water for industry is technically and economically feasible and justified. In areas of water shortages there may not be a choice: wastewater will have to be reused particularly for industry but also other purposes. The potential for water reuse in industry is large and the role of industry is as follows:

- Examine all plant practices to obtain optimum water use and recycle with a minimum of waste effluents, and try to become a minimum discharge industry;
- Consider the use of available secondary quality water (sewage plant effluents, brackish water, sea water, etc.) for suitable plant purposes;
- Examine chemicals and processes contributing to pollution and determine if changes in either will help abate pollution;
- Consider product recovery from waste materials;
- Be aware of new developments in pollution control processes;
- Make all plant personnel water and pollution conscious.

The governments' role in legislation has been outlined earlier in this paper using the United States as an example. There should be strong governmental support for the reuse of reclaimed water and water reuse programmes. The objective for such programmes is to support development efforts for reuse applications. Topics for these programmes are as follows:

- Evaluation of national reuse needs and potentials;
- Evaluation of existing and advanced technology and reuse applications;
- Development support of selected reuse applications (for example directed to a specific industry);
- Treatment processes and systems;
- Planning and management aspects of water reuse;
- Health effects and socio-economics aspects.

Governmental agencies together with industry should also support research towards problems associated with water reuse.

International organizations, such as the United Nations Industrial Development Organization (UNIDO) and others, should sponsor international meetings on industrial reuse dedicated to specific industrial applications. A variety of industrial water reuse demonstration projects should also be developed and carried out worldwide in areas of water shortages. Pilot demonstration plants should be developed to study the feasibility of treated water. In addition, industrial water reuse programmes should be coordinated on an international scale. Finally the distribution of information on the possibilities of industrial reuse is also needed.

Intereco s.n.c.

Main field of activity
Water recycling and reuse

Innovative products
Special treatment plants

About
Founded in 1978 in Italy in the first years of operation INTERECO concentrated on heating and air conditioning for civil and industrial plants and on some very sophisticated operations for filtering and recovering air in industrial buildings. As the company has progressed, the manufacture of wastewater treatment plants has become the biggest part of INTERECO's business. INTERECO has become a leader in sludge dewatering plants and equipments. With its items of qualified engineers and technicians and the know-how achieved after long intensive studies and research, INTERECO is also manufacturing hightech complete UF and RO plants, using, thanks to the continuous studies and searches, the most advanced techniques in the field of the membrane filtration. In the latest years INTERECO has improved its added new equipment to the production program and now is able to supply almost all equipment (as scraping bridges, screens, grit and oil traps, sand classifier and others).

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AMG Ltd

Main field of activity
Matching water quality to use requirements

Innovative products
Brand new mixing and aeration device, which prevents thermal stratification of reservoirs called the AQUAERATOR

About
The Invention of the AQUAERATOR was born from a crescendo of 35 years of working within the Water Industry, including aeration using Air Curtains and Helixors. The AQUAERATOR was invented by AMG Ltd and received a substantial EU Grant of nearly 1 Million Euros. The R&D was spilt between HR Wallingford (UK) and the University of Barcelona. The 2 year EU Project (with full scale field trials) was completed in 2003. Since then AMG has installed 3 complete AQUAERATION Systems in drinking water reservoirs and 1 in a recreation lake with a Metropolitan Borough Council. In addition AMG have expanded their Environmental Consultancy Division which enables them to scientifically evaluate the pre and post AQUAERATOR Installation. AMG Ltd are the only Company who have the sole rights to Supply and Install the patented AQUAERATOR, which has proven to be significantly better than our nearest competitor. During the R&D it was concluded that the AQUAERATOR would be suitable for the Fish farming and the Wastewater Treatment Industries.

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Waste water treatment

Innovative products

About
The KÖRTE Environmental Technology joint-stock company is a key player in the Hungarian industrial protection of the environment. The company's roots reach back to 1983 when the CHEMITECH Chemical- Technological economic association was founded as one of the first co-partnership private enterprises. This small venture provided sludge dewatering services from mud to industrial companies with rather undeveloped environmental background of the time, with equipments deployed to trucks. Through meeting customer demands as well as realizing the future perspective of this activity, the scale of services rendered had gradually grown: *the appliance manufacture* had expanded to the development of water and sewage purification technologies which were subsequently supplemented by the production and distribution of chemicals. The mobilized technological systems provided a sound basis for entering the environmental damage prevention market. The 3 Hungarian owners and 70 employees are proud to take part in the conservation of our environment not only as citizens thinking responsibly but also as people practicing their profession. Every day we work on purifying our waters, reducing the amount of waste material, and bringing about procedures that serve for the protection of the state of our more immediate surroundings.

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DATAQUA Elektronikai Kft.

Main field of activity
Water level, temperature and conductivity recording

Innovative products
GSM and INTERNET based monitoring stations with flexible, centralized, extensive data logging networks

About
One of the most important components of our environmental values and natural resources is water. All of our activities have been closely interrelated to the environment, hydrography, and water management measurements. As the founders of the latter DATAQUA Electronics Ltd., in 1992 we started to develop a fully electronized microprocessor controlled water level recorder without any moving parts for recording variations of the karstic water level due to bauxite mining. The recorder collected data in digital form to be directly processed by computers. Our measuring setup and equipment are protected by our Patent No. 209 850. As the result of our developments, beside the field recorders we are also manufacturing various (pressure, temperature and level) transmitters.

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TUZAL Ltd.

Main field of activity
Water recycling and reuse

Innovative products
„EcoDrain" TM equipment containing inputs from„Aikaterisil" TM

About
Our company is active in production of „ECoDrain" TM equipment containing inputs from„Aikaterisil" TM, in storm water direct treatment Consulting and intermediary in field of environmental engineering and technologies, especially water and wastewater cleaning and preparation. We deal with neutralization of wastes and solutions containing heavy metals and oil waste and with neutralization of used reagents and chemical wastes. Liquidation of closed, non-operating industrial plants suffering from chemical pollution and disposal of dangerous, toxic and overdue chemical substances is also part of our business. Our company has the exclusive right for FKJA/LAFT system for neutralization of industrial wastewater, concentrated solutions and solid waste containing heavy metals V, Cd, Zn, Hg, Pb, Cu, Ni, Cr, Al, oils, grease, toxic, hazardous and other dangerous contaminations, especially from metal finishing industry and Exclusive right for ORTWED Process of sludge contained oil derivatives treatment with quick lime (CaO).

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Beijing Hengu UK Ltd

Main field of activity
Water recycling and reuse

Innovative products
Highly effective new cationic floculant range just launched

About
Beijing Hengju manufactures and supplies specialty water treatment chemicals for oilfield, wastewater treatment, potable water, mineral processing, sugar and paper industries. Founded 12 years ago the company has grown rapidly as a result of its involvement in the Chinese oilfield industry where a variety of our products are currently used to improve the efficiency of oil production. In addition to complete range of powder grade polyacrylamides, marketed under the HENGFLOC trade name, our company also supplies polydadmac, polyamine and dicyandiamide type liquid coagulants to cater for all requirements of the industries that we serve. As a result of the investments in new technology our products are capable of competing with other global suppliers and are now being exported around the globe. We are continually looking to further improve and expand our product range and have established a partnership between our research department and Huadong Industrial University to achieve this goal. With this partnership we are able to quickly respond to customer requirement and develop new products and effects to achieve the desired performance in all industries we serve.

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GB Environmental Ltd

Main field of activity
Saving water and increasing industrial water productivity

Innovative products
UV disinfection of water

About
GB Environmental Ltd is a UK based design and manufacturing company, they are specialists in the field of UV. Their range of instrumentation includes many patented technologies employing second generation UV disinfection. This maximizes UV dose whilst minimizing energy consumption. Their high level of technical competence and commitment to research ensures it is at the frontier of UV technology design, providing advanced non-chemical disinfection of water, air and surfaces. GB Environmental provides disinfection solutions for a cross-section of companies and organizations. Their systems are employed protecting against contagious diseases in public sector buildings in both air and water supplies, eliminating microbial contamination in food, drink and pharmaceutical products and are extensively used in the leisure market ensuring that ecological impact is kept to a minimum by reducing chemical usage.

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HydroVRTX BV

Main field of activity
Water recycling and reuse

Innovative products
VRTX Technology

About
The VRTX system is working in a wide range of industries. We provide chemical Free Watertreatment for Cooling Towers and Condesers utilizing VRTX Hydrodinamic Cavitation. The system has been introduced in the European Market in 2003 but has been around in the USA for some time. In Europe more then 40 locations use this system and reduced their cooling water usage with 40 to 60 per cent without use of chemicals. We offer excellent treatment against scaling, corrosion and biological fouling, including protects against legionella. Our system is backed by forty years of research and development; seventeen inter-related patents and up to 15 years of service at several customer sites - continuously running 24/7. Research clearly shows our method of fluid treatment is extremely effective!

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GYULAVÁRI CONSULTING Co. Ltd.

Main field of activity
Saving water and increasing industrial water productivity

Innovative products
Sludge reduction, energyfree biological waste water treatment

About
The production program of our company includes 1. waste-water treatment plants (small, prefabricated,1,0 m3/d- up to 30 m3/d (= 200 P.e.) when the recipient is a stream, or a trench or a local subsurface irrigation), 2. night-soil (sewage water) pre-treatment (energy free, sewage water treatment without energy, pre-treatment and local subsurface irrigation – energy woods (poplar)), 3. industrial waste-water treatment plants: a. in the meat industry - the waste-water treatment with FLEXIPAK® system - for example: Nove-*Zamky in Slovakia, Sopronhorpács in* Hungary, pre-treatment (energy woods (poplar), total waste-water treatment systems (stream, or irrigation), b. special- industrial waste water treatment, or pre-treatment in front of the city canalization - for example: sweet corn conserve industry (100.000 P.e) industrial pre-treatment with FLEXIPAK® System Gyulavári- FEVITA Co. Székesfehérvár- Hungary, 4. pig-manure treatment system (buffer tanks-lagoon with the mixing system of the typ OLOID), 5. special systems, own license technologies, combinations and cooperation - Systems Gyulavari (FLEXIPAK® System Gyulavari, TURBOPAK®, TLS® lamella Systems, BMKO ® lagoon system, DABS Anaerob System - Energy free, EPAS Anaerob-psirophil System).

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ANTARES - AZV, Ltd.

Main field of activity
Water and wastewater treatment, sludge treatment

Innovative products

About
ANTARES - AZV, Ltd. was established in Prerov city, The Czech Republic, in 1991. At the outset of our operation we focused specifically on the design, manufacturing and delivery of filter presses for filtration and sludge dewatering. With an increasing need for our services and expertise the scope of our operation has grown to the present form – the design, development, manufacturing and delivery of complex technological lines and individual equipment especially for the following operations: Industrial and biological WWTP, Chemical, food processing and paper industry, Material surface adjustment, Porcelain, ceramics and glass production, Manufacturing of Machinery, Metallurgy, Power industry, Deactivation of surface materials. Reconstruction and intensification of existing operations with high economic benefits to our clients is an important part of our business. Our strength lies in our high level of flexibility, and the fact that only 30 per cent of our parts and technology are of standard production - the remaining being manufactured according to the client's requirements.

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ProMinent Magyarország Kft.

Main field of activity
Water and wastewater treatment

Innovative products
Chemical transfer pumps, metering pumps, solid metering

About
Process pumps, dosing pumps, complete measurement and control stations, wastewater and drinking water treatment, dosing systems, filters and softeners. Products for disinfection, oxidation and membrane technology.

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SACCO Engineering

Main field of activity
Water recycling and reuse

Innovative products
Membrana systems for water reuse

About
We have been working for many years in the sector of water plants, directly executing the planning, the projects and the construction of what we realize. Thanks to our remarkable experience in the sector, our organization can give a wide and diversified range of answers to the market needs: complete plants, separate machines, restructures, maintenance management, advising and planning services, training courses. Our designing includes interventions in other engineering sectors too. Mainly plants for food processing, chemical, pharmaceutical and textile industry.

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Zenon Systems Kft.

Main field of activity
All of the mentioned

Innovative products
Immersed hollow fibre ultrafiltration membranes

About
ZENON is dealing with industrial and municipal water preparation and waste water treatment based on the advanced membrane products and technologies. Our wide range of filtration products trusted for municipal drinking water and wastewater treatment, industrial process water and wastewater treatment, seawater desalination, wastewater recycle, commercial property development, mobile and emergency response, household water filtration, shipboard water and wastewater treatment, military water and wastewater treatment.

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ORGANICA Zrt.

Main field of activity
Water and wastewater treatment

Innovative products
ORGANICA® TECHNOLOGY being one of the Company's flagship technologies, is the most cutting-edge and cost-effective biological wastewater treatment system currently on the market.

About
For two decades, ORGANICA has been one of the largest and most trusted companies in the Hungarian environmental services industry, widely recognized for its innovative environmental technologies and professional excellence. The core activity of ORGANICA is the treatment of industrial and municipal wastewater. The company provides efficient and cost effective technologies, professional design & build implementation and reliable operating services for the full range of industries. Introducing the technology worldwide, ORGANICA has already granted exclusive License in 13 countries of Central- and Eastern Europe to Veolia, world market leader in water- and wastewater solutions and technologies, and is still looking for further partners of cooperation around the world.

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Ecotecno srl

Main field of activity
Water recycling and reuse

Innovative products

About
Ecotecno is the oldest manufacturer of vacuum evaporation plants exploiting the principle of the heat pump. Our aim is resolving customers' environmental problems, caused by manufacturing activities, by supplying the higher technology, the higher quality for pre- and post-sale service and the experience of a Company present in the market with more than two thousands equipments running for most dissimilar industrial fields. Our staff is always ready to supply all necessary information studying all problems and cases, obtaining so tailored units totally fit for the treatment requested.

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University of Wales, Aberystwyth

Main field of activity
Research and education

Innovative products
Assessment, monitoring and remediation of watercourses and floodplains contaminated by mining activities.
Assessment and monitoring microbial water quality for drinking and bathing quality in urban and rural settings.
Advanced flood risk assessment and modelling.

About
The University of Wales, Aberystwyth (UWA) is represented at the Technology Foresight Summit 2007 by members of the Centre for Catchment and Coastal Research (CCCR), which brings together complementary expertise in terrestrial and marine research and sustainable management in partnership with the University of Wales, Bangor. UWA's catchment-related component of this initiative focuses on the study of river systems and environmental change, including the effects of climate, land-use, extreme hydrological events and pollution. The research group has established itself as one of the leaders in its field, whilst the consulting off-shoots of the group, CREH (Centre for Research into Environment & Health) and Fluvio (River Basin Environmental Consultants), actively integrate this cutting edge research into practical solutions for an array of international clients with diverse environmental and societal management challenges.

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Halma Water Management

Main field of activity
Saving water and increasing industrial water productivity

Innovative products
Permalog acoustic leak noise loggers

About
Halma Water Management is dedicated to providing solutions to the issues faced by our customers in managing leakage in their distribution system. From flow measurement and data logging to establish areas of potential leakage, through localization and pinpointing leaks to sophisticated pressure control designed to maintain optimum performance and longevity of the underground assets. Halma Water Management is committed to providing the best technology and support services in the increasingly challenging field of managing a scarce and invaluable resource - water.

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R.E.M. International mechanics

Main field of activity
Water recycling and reuse

Innovative products
High performance DAF, combined units for wastewater pretreatment

About
R.E.M. is your leading supplier for the water and wastewater industry worldwide providing a full range of equipment for every need. We design and built wastewater treatment equipment with high efficiency process.

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Koch Membrane Systems

Main field of activity
Water recycling and reuse

Innovative products
PURON(R) membrane filters for wastewater treatment in membrane bioreactors (MBR)

About
For nearly 35 years, Koch Membrane Systems (KMS) has been a world-class developer and manufacturer of innovative membrane filtration systems serving a global marketplace. KMS involvement in various water treatment applications includes high purity water, potable water, wastewater, industrial process water, and desalination. KMS covers the complete submicron membrane separation spectrum with microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) products. As a result, KMS delivers an exceptional array of state-of-the-art membranes that include FEGTM PLUS, ULTRA-COR®, SUPER-COR®, and SelRO® tubular membranes; TFC®, ROGA®, SelRO®, and MegaMagnum® spiral membranes plus a broad range of hollow fibre products including TARGA®, TARGA®-10, ROMIPURE®, PMPWTM, PMPWTM-10 cartridges, and the PURON® submerged hollow fibre modules for membrane bioreactors.

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Inwatech

Main field of activity
Industrial and communal wastewater, designing and main contracting

Innovative products
DryVac technology at WWTT in England; WWTT for a diary and meat factory (special separation of treated wastewater and sludges by flotation unit)

About
Inwatech Ltd. is a main contracting, engineering company, supported by a substantial international technological background. Representing global, leading wastewater technologies, we offer complex wastewater solutions at an outstanding professional level for our partners in the industry and for municipalities. The increasing environmental duties and fees force dischargers to make strenuous efforts to treat and discharge wastewater. An economical and sustainable solution may only be obtained through optimization of appropriate treatment level and the right choice of disposal and reuse. Our technologies, services, engineering and main contracting skills expressly serve this purpose. Our wastewater treatment plants, meeting the increasingly special expectations of industrial clients, do not only treat wastewater, but also produce bio energy, facilitate freshwater substitution, or recover and recycle valuable by-products and raw materials.

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SebaKMT

Main field of activity
Saving water and increasing industrial water productivity

Innovative products

About
Worldwide, we are the leading company for the development and manufacture or measurement equipment for diagnosis of the state of a network and for fault location. Our sectors of the market include electricity supply networks as well as communications and pipe networks.

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DRAFT JOINT MINISTERIAL STATEMENT ON "ZERO DISCHARGE"

[*to be discussed and for possible adoption by the Ministers (heads of delegations) participating in Ministerial Round Table on the future of sustainable water availability and quality in the region of Central and Eastern Europe (CEE) and Newly Independent States (NIS) at the Technology Foresight Summit 2007*]

1. We, the Ministers who have issued this statement, recognize the importance of the issues discussed during the Ministerial Round Table at the Technology Foresight Summit 2007 in the context of the unique value of water for people living in the Central and Eastern Europe (CEE) and Newly Independent States (NIS) region, as well as the urgent need to increase water productivity, its optimal use, re-use and recycling. We note that industry, the largest water consumer, has a primary responsibility for the rational use of scarce water resources. We urge the industrial sector to apply adequate technologies to save water in production, reduce water pollution, adopt adequate waste water treatment technologies and optimize water re-use and recycling.

Challenges

2. We recognize, in particular, that economic and social development go hand in hand with responsible industrial growth and competitiveness; that freshwater is a precious resource which supports all terrestrial life; and that industry is a major water user and has a key role to play in its stewardship, yet can cause serious damage through discharging effluents.

3. We further recognize that this stewardship would be best served if all industrial effluents are reused and recycled, thus avoiding any polluted discharges to water bodies ("zero discharge"). Water pollution and shortages are a threat to industry, communities and ecosystems. New industrial technologies for water reuse and recycling, and new business models such as chemical leasing, offer a remarkable opportunity to eliminate industrial waste generation and effluent discharge permanently.

4. We are conscious of the need to reduce industrial freshwater intake from rivers, lakes and aquifers; of the need to increase industrial water productivity in terms of the value added by industrial production, relative to the volume of water used; and of the need to avoid water pollution by industry.

5. We are aware furthermore of the need to encourage the achievement of "zero discharge" at both enterprise and local district level, and the need to provide effective mechanisms for such encouragement, such as information exchange, economic incentives and regulation.

Call for action

National governments

6. We therefore call upon our national Governments to legislate "zero discharge" to watercourses from industry. In addition, we call on the Governments to strengthen the powers of river basin organizations and local authorities to regulate industrial discharges; and assist industrial sectors in finding cost-effective ways to move towards "zero discharge".

Local and regional authorities including river basin organizations

7. We further call upon our local and regional authorities to work together with industrial sectors and individual enterprises to develop and help them meet "zero discharge" commitments as well as encourage local information exchange on water and waste recycling and, where necessary, to create local or district-based facilities for industrial effluent treatment and reuse. We call upon river basin organizations to support and track the achievement of "zero discharge" in their catchment areas, and to record the related benefits of water quality improvement and ecosystem response wherever possible.

Academia, research institutions and industrial enterprises

8. We appeal to academia and research institutions to contribute to the goals of "zero discharge" through capacity-building and development of appropriate technologies. Furthermore, we call upon industrial enterprises to achieve "zero discharge" targets individually or jointly, through district-based effluent recycling facilities, and request river basin organizations.

United Nations Industrial Development Organization

9. Finally, we call upon the United Nations Industrial Development Organization to support the "zero discharge" initiatives and information exchange worldwide, and to monitor the progress of its Member States in setting and achieving "zero discharge" targets.

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