Dirk Meissner
Leonid Gokhberg
Alexander Sokolov *Editors*

# Science, Technology and Innovation Policy for the Future

## Potentials and Limits of Foresight Studies

Springer

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Dirk Meissner • Leonid Gokhberg •
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## Potentials and Limits of Foresight Studies

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*Editors*
Dirk Meissner
Leonid Gokhberg
Alexander Sokolov
National Research University -
Higher School of Economics (HSE)
Institute for Statistical Studies and
Economics of Knowledge
Moscow
Russia

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# List of Contributors

**Sanjay Arora** School of Public Policy, Georgia Institute of Technology, Atlanta, USA

**Mario Cervantes** Organization for Economic Cooperation and Development, Paris, France

**Kerstin Cuhls** Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, Germany

**Anastasia Edelkina** National Research University - Higher School of Economics (HSE), Moscow, Russia

**Luke Georghiou** Manchester Institute of Innovation Research, Manchester Business School, University of Manchester, Manchester, UK

**Leonid Gokhberg** National Research University - Higher School of Economics (HSE), Moscow, Russia

**Jennifer Cassingena Harper** Malta Council for Science and Technology, Kalkara, Malta

**Oleg Karasev** National Research University - Higher School of Economics (HSE), Moscow, Russia

**Ekaterina Makarova** National Research University - Higher School of Economics (HSE), Moscow, Russia

**Dirk Meissner** National Research University - Higher School of Economics (HSE), Moscow, Russia

**Ian Miles** National Research University - Higher School of Economics (HSE), Moscow, Russia

Centre for Service Research, University of Manchester, Manchester, UK

**Vitaly Roud** National Research University - Higher School of Economics (HSE), Moscow, Russia

**Ozcan Saritas** Manchester Institute of Innovation Research, Manchester Business School, University of Manchester, Manchester, UK

National Research University - Higher School of Economics (HSE), Moscow, Russia

**Philip Shapira** Manchester Institute of Innovation Research, Manchester Business School, University of Manchester, Manchester, UK

Georgia Institute of Technology, Atlanta, USA

**Alexander Sokolov** National Research University - Higher School of Economics (HSE), Moscow, Russia

**Anna Sokolova** National Research University - Higher School of Economics (HSE), Moscow, Russia

**Konstantin Vishnevskiy** National Research University - Higher School of Economics (HSE), Moscow, Russia

**Jan Youtie** Enterprise Innovation Institute at Georgia Institute of Technology, Atlanta, USA

# About the Authors

**Sanjay. Arora** is a doctoral student at the School of Public Policy at Georgia Institute of Technology with research interests in innovation, strategic management, entrepreneurship, and science and technology policy. Sanjay has worked for JSTOR, the not-for-profit digital scholarly archive, as Data Manager and more recently for IBM Global Business Services as a Public Sector Consultant. He holds a BA in Information Systems from Wayne State University and a master's in Information Systems Management from Carnegie Mellon University. Email: sanjayk.arora@gatech.edu

**Mario Cervantes** Senior Economist, Science and Technology Policy Division, Directorate for Science, Technology and Industry, Organisation for Economic Co-operation and Development (OECD), Paris

Mario Cervantes is senior economist/principal administrator at OECD's Science and Technology Policy Division. In particular, he is responsible for the Working Party on Innovation and Technology Policy (TIP). With more than 15 years of experience in innovation policy, Mr. Cervantes has written on a range of topics from industry–science relations, human resources in S&T, technology incubators, university patenting and licensing, open innovation and globalisation and, more recently, on innovation for social challenges. Current activities include the study of the changing nature of innovation and the policy implications as well as work on demand-side policies for innovation.

A graduate of Columbia University (MA international economics), the University of California at Santa Barbara (BA economics and political science) and the Institut d'Etudes Politiques de Paris (Sciences Po), Mr. Cervantes has also studied at the Berkman Center, Harvard Law School, where he obtained a certificate in internet law, and was a Sloan Fellow in public policy at Princeton's Woodrow Wilson School of Public and International Affairs. Prior to joining OECD, Mr. Cervantes worked as a researcher at the Columbia Institute for Tele-Information (CITI) at the Graduate School of Business, Columbia University, New York.

**Kerstin Cuhls** is Researcher at the Fraunhofer Institute for Systems and Innovation Research (FhG ISI) in Karlsruhe, Germany. From 2011 to 2012, she was representative Professor of Japanology (History and Social Sciences) at the Center for East Asian Studies, University of Heidelberg, Germany.

From 2007 until 2009, Dr. Cuhls was Project Manager of the BMBF Foresight Process. She already coordinated the German foresight studies Delphi '93, Mini-Delphi 1995 and Delphi '98 and monitored the BMBF Futur Process, inter alia, as "scientific secretariat" for both evaluations by an international committee. Kerstin teaches in various seminars on priority setting, foresight and Delphi methods (UNIDO, ESTO/EU and others) and works in different regional, national and international foresight projects as well as studies the comparison between Japanese and European innovation policies. She is involved in several Advisory Boards (institutions and journals).

**Anastasia Edelkina** is Junior Research Fellow at the Institute for Statistical Studies and Economics of Knowledge, National Research University – Higher School of Economics (HSE) in Moscow. She holds a Master of Arts in Economics of International Trade and European Integration from the University of Antwerp and a Master of Science in Economics (International Relations) and a Bachelor of Science in Economics from Moscow State University. Anastasia participated in several Foresight studies; her research interests cover also innovation policy, open innovation and the structuring and management of Foresight networks among others.

**Leonid Gokhberg** is First Vice-Rector of the National Research University - Higher School of Economics (HSE) – one of the most prestigious research universities in Russia. He is also Director of HSE Institute for Statistical Studies and Economics of Knowledge (ISSEK). He authored over 350 publications in Russian and international peer-reviewed journals on S&T and innovation. Dr. Gokhberg has coordinated dozens of international projects, inter alia, on S&T and innovation policies, nanotechnology and roadmaps, funded by Russian governmental agencies as well as by intergovernmental organizations. He has served as a consultant of OECD, Eurostat, UNESCO and other international and national agencies. He is also member of OECD and Eurostat expert groups and task forces on indicators for S&T, nanotechnology, information society and education. Dr. Gokhberg is Editor-in-Chief of the Russian scientific journal *Foresight*. He holds PhD and Dr. of Sc. degrees in Economics. In 2012, the President of Russia awarded Prof. Gokhberg the title "Honored Master of Sciences".

**Luke Georghiou** is Vice-President for Research and Innovation at the University of Manchester and Professor of Science and Technology Policy and Management in the Manchester Institute of Innovation Research at Manchester Business School. He is responsible for the University's research strategy and its implementation and for business engagement and commercialization activities. He has been on the staff of its precursor institute, PREST, since 1977 and was its Executive Director from 1990 to 2004. He has chaired several international panels examining research and innovation issues, including the ERA Rationales group which first put Grand Challenges on the European Agenda. He was rapporteur and panellist in the Aho Group, which set a new direction for European innovation policy with its report to European leaders "Creating an Innovative Europe". He serves on the editorial boards of several ISI journals and has published extensively in leading outlets, including *Science* and *Nature*. He continues to be active in research and policy advice to governments and businesses. In 2011, he was elected to the Academia Europaea.

**Jennifer Cassingena Harper** has been engaged with the Malta Council for Science and Technology since 1989 in various capacities. Until 2011, she was the Director of Policy, Strategy, FP7 and International Relations with core responsibility for the National Research and Innovation Strategy and Foresight and links with the European Union. She currently retains a part-time consultancy role with the Council.

Dr. Harper is active at European and international levels as advisor, reviewer, speaker and expert group member. She has been a member of a number of EU DG Research High Level Expert Groups as chair and rapporteur, including the Expert Group evaluating ERAWATCH (2012), the Impact Assessment on the Environment (2011), the JRC IPTS FTA Committee, the DG Regio Cities Foresight (2010), the Lisbon 3% Objective (2009), RD4SD (2009), ERA Rationales Group

(2007), EU SCAR Foresight HLG (2006), the EU HLG on Key Technologies (2005) and the Impact Assessment Review of EUREKA (2005–2006).

Jennifer lectures in Foresight within the University of Malta's Master's Programme in Innovation and Creativity. Her research interests include International Level Foresight and STI Policy with particular emphasis on transition economies.

She has published a number of articles and papers and co-edited recently *The Handbook on Technology Foresight* (Elgar 2009).

In Malta, she is a member of the National Commission for Higher Education, the National Data Protection Tribunal and Young Enterprise Malta Board of Directors.

Email: jennifer.harper@gov.mt

**Oleg Karasev** is Deputy Director of the Foresight Centre at the Institute for Statistical Studies and Economics of Knowledge, National Research University – Higher School of Economics (HSE), Moscow. He holds a PhD in Economics. Oleg has extensive experience in macroeconomic forecasting, Foresight, development of corporate innovation strategies and innovation policy. He elaborated the concept, methodology and instruments for different Foresight studies including roadmapping, forming of S&T and innovation priorities using Delphi survey and critical technologies. Oleg managed and participated in many Foresight studies at national and regional levels, projects on development of innovation strategies for leading Russian corporations and studies of future innovation markets. During the last 15 years, he has been involved in many teaching programmes at major Russian universities in the area of Economics.

Email: okarasev@hse.ru

**Ekaterina Makarova** is Research Assistant at the National Research University - Higher School of Economics (HSE) Institute for Statistical Studies and Economics of Knowledge. She graduated from the Orel State University with a degree in crisis-management. She is a PhD student in the Department of World Economy and International Affairs at HSE. The areas of her professional interests include Foresight, project management, environmental economics and crisis-management. She was involved in projects aimed at the development of Foresight evaluation methodology.

**Dirk Meissner** is Deputy Head of the Laboratory for Science and Technology Studies at Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE). Dr. Meissner has 15 years of experience in research and teaching technology and innovation management and policy. He has a strong background in science, technology and innovation for policy making and industrial management with a special focus on Foresight and roadmapping; science, technology and innovation policies; funding of research; and priority setting. Prior to joining the HSE, Dirk was responsible for technology and innovation policy at the presidential office of the Swiss Science and Technology Council. He also has long experience in top-level consulting to key decision makers in industry; headed the business unit industry studies and research with T.A. Cook Consultants, which he successfully established; and was management consultant for technology and innovation management with Arthur D. Little. Dirk was and is member of international working groups on technology and innovation policy. He represented Switzerland and, currently, the Russian Federation at the OECD Working Party on Technology and Innovation Policy.
Email: dmeissner@hse.ru

**Ian Miles** graduated in Psychology from the University of Manchester in 1969 and received a higher Doctorate in Social Science from the same University in 2011.

He is Head of the Laboratory of Economics of Innovation at Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE), Moscow, and Professor of Technological Innovation and Social Change at Manchester Institute of Innovation Research (MIoIR), Manchester Business School. He previously worked at the Science Policy Research Unit, University of Sussex, which he left (as Senior Research Fellow) in 1990 to move to Manchester. His research includes studies of service innovation and knowledge-intensive business services, Foresight and futures studies, information technology innovation and social indicators. Numerous publications and presentations are available online (including Scribd and Slideshare) as well as via traditional publication outlets.

Ian's publications include 12 authored books, 12 edited books, almost 100 journal articles and over 200 reports and book chapters, with many other publications.

Email: imiles@dom01.mbs.ac.uk

**Vitaly Roud** holds an MA in Economics specialized in empirical theory of industrial organization from New Economic School, Moscow, and an MSc in Applied Mathematics (optimal control, Lomonosov Moscow State University). Currently, he is researcher and scientific coordinator at the Institute for Statistical Studies and Economics of Knowledge of the National Research University Higher School of Economics and at the Institute for Statistical Studies and Economics of Knowledge. Vitaly has participated in a number of research and policy advice projects initiated by the Russian government and enterprises including several Foresight initiatives and the latest Strategy of Socio-economic Development of Russian Federation until 2020. His academic interests include empirical studies of innovation, evidence-based innovation policy, methodology of innovation surveys, STI statistical indicators and STI policy design and evaluation.

**Dr. Ozcan Saritas** is Research Professor at the Institute for Statistical Studies and Economics of Knowledge, National Research University, Higher School of Economics, Moscow; a Senior Research Fellow at the Manchester Institute of Innovation Research (MIoIR), Manchester Business School; and the editor of Foresight: the journal of future studies, strategic thinking and policy. Ozcan's research focuses on innovation research with particular emphasis on socio-economic and technological Foresight. With a PhD from the "Foresight and Prospective Studies Programme" of the University of Manchester, Ozcan has introduced novel concepts like "Systemic Foresight Methodology (SFM)", which has been applied successfully to address long-term issues and Grand Challenges involved in Sustainable Development, Renewable Energies, ICTs, Nanotechnologies, Higher Education and Developmental Studies. For more information on Ozcan's research and publications, please refer to his personal website: www.systemicforesight.com.

**Philip Shapira** is Professor of Innovation, Management and Policy at the Manchester Institute of Innovation Research, Manchester Business School, University of Manchester, UK, and Professor of Public Policy at Georgia Institute of Technology, Atlanta, USA. His research focuses on science, technology and innovation management and policy, industry analysis, regional innovation and policy evaluation. He is an editor of *The Theory and Practice of Innovation Policy: An International Research Handbook* (Edward Elgar, 2010). Email: pshapira@mbs.ac.uk

**Alexander Sokolov** is Deputy Director of Institute for Statistical Studies and Economics of Knowledge and Director of National Research University - Higher School of Economics (HSE) International Foresight Centre, National Research University - Higher School of Economics (HSE). His main professional interests are related to Foresight as well as S&T and innovation priorities, indicators and policies. Alexander is tenure professor at HSE; he teaches Foresight for undergraduate and postgraduate students.

Alexander authored over 120 publications in Russia and internationally. He managed many Foresight projects, including Russian S&T Foresight: 2030; Foresight for Russian ICT sector (2012); Innovation Priorities for the Sector of Natural Resources (2008–2010); Russian S&T Delphi Study: 2025 (2007–2008); Russian Critical Technologies (2009), etc.

He is member of several high-level working groups at OECD and other international organizations and serves on advisory boards of several international conferences and journals.

Email: sokolov@hse.ru

**Anna Sokolova** is senior research fellow at the Institute for Statistical Studies and Economics of Knowledge National Research University - Higher School of Economics (HSE) and associate professor at the National Research University - Higher School of Economics (HSE) Economics Faculty. She obtained her master's degree from the Moscow Institute of Physics and Technology and has a PhD in political sciences. Her scientific interests are connected with S&T Foresight methods, scenario planning and social choice theory. She is actively involved into the development of methodology and implementation of various Foresight projects ("Foresight and Roadmaps for Nanotechnology", "Monitoring of Global Technology Trends", "Russian S&T Foresight: 2030", etc.). Her responsibilities also include scientific coordination of the International Research Laboratory for Science and Technology Studies within ISSEK.

**Konstantin Vishnevskiy** holds a master's degree with specialization in government policy and regulation with honours from the Faculty of Economics, Lomonosov Moscow State University. He is Research Fellow at Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE) (Moscow, Russia). Konstantin was engaged in a number of Foresight and roadmapping studies and in the development of corporate innovation strategies.

Konstantin authors about 30 scientific publications on Foresight, roadmapping, macroeconomic regulation and government policy, and business innovation strategies. He participated in many conferences and workshops in Russia and worldwide.

Email: kvishnevsky@hse.ru

**Jan Youtie** is Director of Policy Research Services at the Enterprise Innovation Institute at Georgia Institute of Technology (Georgia Tech) and Adjunct Professor in Georgia Tech's School of Public Policy. Her research focuses on technology-based economic development, knowledge measurement, science and technology assessment and evaluation, and manufacturing modernization. She is Director of the Programme on Science, Technology and Innovation Policy at Georgia Tech. She holds a PhD in Political Science from Emory University.

Email: jan.youtie@innovate.gatech.edu

# Chapter 1
# The Meaning of Foresight for Science, Technology and Innovation Policy

**Dirk Meissner, Leonid Gokhberg, and Alexander Sokolov**

Science, technology and innovation (STI) policies are topics that has been much written about in the last decades. However until today no common understanding has been articulated on what these policy fields are and how they are correlated in daily practice of policy making. The book thus pursuits a completely new approach, which goes much beyond existing practices. For the first time the concept of evidence based science, technology and innovation policy making is elaborated and put into context with Foresight studies. Foresight studies are commonly understood as a measure supporting governments, public agencies and companies in designing future oriented strategies. The editorial book brings together contributions from leading international scientists, representatives of national governments and international organisations like the Organisation for Economic Co-operation and Development.

The book gives practical guidance for policy makers, analysts and researchers on how to leverage the use of Foresight studies, which are common practice in many countries for future STI policy. The book outlines approaches and experiences of integrating such Foresight studies in the elaboration and implementation of STI policies at different levels. It delivers insights into practical approaches of developing policy measures oriented towards future societal and technological challenges based on evidence drawn from experiences available worldwide. The book is a valuable resource for policy makers, researchers, analysts and Foresight practitioners. It gives real checklists and guidelines for making more value of Foresight studies and leveraging the potential impact of STI policies.

The book consists of four major sections. The first section introduces new or improved methodologies which are used in Foresight studies, the second section looks at new and emerging markets followed by a section on country experiences and national Foresight studies. The book is complemented by a section on the

D. Meissner (✉) • L. Gokhberg • A. Sokolov
National Research University, Moscow, Russia
e-mail: dmeissner@hse.ru; sokolov@hse.ru

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potentials and role of Foresight studies as tools for innovation policy and on the future potentials of Foresight studies for STI policy.

In the following section (**Section I**) new instruments and concepts for Foresight studies are introduced.

*Anna Sokolova and Ekaterina Makarova* develop an evaluation model to ensure the comparability of the different Foresight studies. Their analysis shows that Foresight studies can have a clear effect on the process of defining research, technology and innovation policies.

*Dirk Meissner* finds that conducting national Foresight studies has become common in many countries. However the impact of such studies on the performance of the national innovation system remains unclear. In the short term, it can be concluded that national Foresight studies contribute significantly to the design and – in some countries – reshaping of the innovation system structure and framework conditions. A direct quantitative measurement of the impact and thus the value of Foresight studies can not yet be done in a statistically reliable fashion. However the changes these studies have caused within the national innovation systems may have an indirect impact on the future national innovation performance.

*Dirk Meissner introduces* indicators applicable for Foresight studies. Due to the nature and characteristics of Foresight studies, there is no 'one indicator that fits all' – different types of Foresight studies have different motivations, and objectives. These features determine the approach and the selection of methodology within the Foresight framework. Given different possible methodologies and techniques available, outcomes, and hence the indicators, vary significantly, and can be qualitative or quantitative in nature. Even quantitative indicators offer sufficient space for interpretation, and, in the course of Foresight studies, these indicators are usually based on quantitative near-time data, which are extrapolated forward to future values. However, such extrapolation requires assumptions that are either drawn from the analysis of statistical trends, by individual assumptions, or both. Eventually, the resulting data are not quantitative but semi-quantitative, with a respectable degree of uncertainty resulting from the inclusion of semi-objective data, and information. Other indicators are needed when evaluating Foresight studies. Again, the evaluation of Foresight studies has many different objectives, goals and motivations and therefore there are a number of different evaluation techniques and indicators that can, and should, be used. In conclusion, indicators developed and used in the course of Foresight studies serve different purposes; thus, indicators are usually tailor-made for each Foresight study and are not necessarily fully comparable between different studies. However, these indicators might eventually be used as input for other Foresight studies.

*Ian Miles* argues that Foresight activities take many forms; they can be internal to organizations or performed, to various degrees, by external contractors. They may engage many members of the client organization, many participants from outside the client, and – related loosely to this – be more designed to shape the organization itself or to influence actors in a wider environment. They may be more focused on producing formal reports and recommendations, or on establishing networks or cognitive alignment among stakeholders. The achievements of the activity may be more or less in line with those set out in the original objectives (which themselves may have been more or less explicated by the client).

Given such a variety of experiences, some aspects of which can be illustrated using available data sets on Foresight practices, it is only to be expected that assessment of the impacts of Foresight is challenging. But the situation is further complicated by the fact that Foresight activities are services provided by practitioners to clients. Services are known to involve greater or lesser degrees of coproduction, in which service users also contribute inputs to service production (and also often to design and delivery) and that these inputs are critical to the final product, its quality and its influences. Indeed "impact" is a problematic term, since the client is unlikely to be a passive of service inputs. Other stakeholders, too, may be important contributors to the process, rather than recipients of formal products.

It is also important to recognize that services are extended over time, and that the interactive impacts are not confined to just one moment. There is exchange of information and knowledge, in different fora and formats, across the various stages of the Foresight activity. These also fit into the various decision-making and other processes underway in the client and stakeholder contexts. While Foresight activity may be intended to feed into an early stage in a policy cycle, often there are multiple policies, and heritage policies, to be interacted with, as well. The influences can thus be multiple – from different stages of Foresight, into and from different points in various policy cycles and related processes.

Using the methods of service system analysis, this essay will set out ways, in which we can think about these issues, and use these ideas to frame better approaches to design and evaluation of Foresight activities.

*Ozcan Saritas* introduces the Systemic Foresight Methodology (SFM). Based on the ideas of systems thinking, the SFM aims at proposing a conceptual framework for designing and implementing Foresight activities. The framework recognises the complexities involved both in real world systems and in idea creation, which emerge due to multifaceted interplays between the Social, Technological, Economic, Ecological, Political and Value (STEEPV) systems. Conducting Foresight systemically involves a set of 'systemic' thought experiments, which is about how systems (e.g. human and social systems, industrial/sectoral systems, and innovation systems) are understood, modelled and intervened for a successful change programme.

**Section II** discusses the new innovative markets, which have been detected and described using Foresight instruments. *Oleg Karasev and Anastasia Edelkina* argue that Foresight studies aimed at identifying promising STI development areas have become a major component of government policy-making during the last decades. Such studies enable policy makers to create a basis for government S&T programmes, specific support initiatives and other complementary policy tools. Among the emerging technologies, which are the objects of Foresight studies and targeted by relevant S&T policies, nanotechnology plays a particular role. In leading countries, e.g. the USA, the EU, Japan and others, the nanoindustry development is considered as a national S&T priority. Different policy instruments should be used to support each nanoindustry segment, depending on its specific conditions and characteristics (e.g. existing S&T results, production and market potential, etc.). The successful development of any nanoindustry will largely depend on the extent, to which interests of the key stakeholders in this process – the government, business and research communities – are matched.

*Oleg Karasev and Konstantin Vishnevskiy* study the challenge of clean water supply as one of the major challenges societies around the world are facing. Thus far water treatment for general public and industrial purposes and wastewater treatment remains an insufficiently resolved technological challenge. These challenges increasingly raise the awareness of a wide range of technology specialists and policy-makers. The article focuses on elaboration of a new approach to roadmapping for the sphere of emerging technologies, including nanotechnologies providing special routes R&D-technologies-products-markets for the given field. The integrated roadmap determines a set of strategic goals for markets of nanotechnologies, develops measures to achieve them taking into account alternative ways, to fix up the points of efforts' application and to make a choice of the most effective alternative way. Roadmap is also aimed at implementation of coordination mechanism of stakeholders' actions for achievement of strategic goals.

*Philip Shapira, Jan Youtie and Sanja y K. Arora* discuss the commercialization of graphene, a novel nanomaterial consisting of a single layer of carbon atoms, has attracted significant attention due to its distinctive properties and potential benefits for diverse applications. Electronics has been suggested as the leading application for graphene. There are also potential applications in energy (e.g., solar cells, batteries) and composite materials. The commercialization of scientific discoveries such as graphene is inherently uncertain, with the lag time between the scientific development of a new technology and its adoption by corporate actors revealing the extent to which firms are able to absorb knowledge and readily implement products based on the new technology.

From this perspective, the paper tests for the existence of three different commercialization patterns: (1) a linear process where commercialization follows scientific discovery; (2) the double-boom phenomenon where corporate (patenting) activity is first concentrated in technological improvements and then followed by a period of technology productization; and (3) a concurrent model where scientific discovery occurs in parallel with commercialization.

In **Section III** country Foresight study experiences are introduced. *Alexander Sokolov* presents a description of major Foresight activities in the field of science, technology and innovation in Russia, including identification of National S&T priorities and Critical technologies as well as three cycles of the National S&T Foresight that have been performed during the last decade vis-à-vis developing S&T and innovation policies. The development of more complex and elaborated policy instruments requires a better grounded long-term vision of key trends in S&T, society and economy. The evolution of Foresight in Russia on the way from an information source for S&T and innovation policy towards a full-scale policy instrument addressing key issues of S&T and innovation is discussed.

*Kerstin Cuhls* gives a comprehensive overview of the German experience with Foresight studies. Since the beginning of the 1990s, Foresight processes have been part of the instruments in the German Federal Ministry of Education and Research

(BMBF) to look into the longer term future and gain insights and recommendations for research and innovation policies. Whereas the first projects aimed at providing information about future topics, the latest Foresight processes were directed to the BMBF and (indirectly) its portfolio. This chapter tries to trace some of the effects of these Foresight processes and discusses why it is so difficult to really have an impact on policy making. The latest "BMBF Foresight Process" illustrates these attempts and shows a tendency towards systemic integration of Foresight results and even provides topics or Future themes for transformation processes.

*Jennifer Cassingena Harper's* chapter focuses on the experience generated over the last decade in Foresight activity at European level with a view to identifying policy impacts, both formal and informal. European Foresight activity operates at different levels but is primarily implemented through expert groups addressing particular themes and projects implemented by European consortia selected through an open call under the EU Framework Programme for Research and Technological Innovation. The paper identifies the different types of policy impacts generated through these activities based on the design, process and content as well as other factors such as stakeholder consultation and engagement. The potential and early impacts will also be addressed as some of the projects are quite recent and the impacts need more time to materialise. Policy impacts can range from networks generated, change in perspectives and mindsets leading to new policy approaches and a roadmap for action, which leads to the adoption of concrete policy measures. The chapter analyses how the changing rationales for European Foresight have lead to the raising of the level of ambition in terms of the expected results and policy impacts.

**Section IV** discusses the potentials of Foresight Studies as an instrument for innovation policy. *Luke Georghiou* in his chapter on Challenges for Science and Innovation Policy finds that the content of research and innovation initiatives is increasingly being discussed in terms of thematic content on the one hand, through engagement with Grand or societal challenges, and in terms of clusters of key or critical technologies on the other.

In parallel, the processes of innovation have been changing. A broader-based view of innovation has been emerging, which recognizes the critical importance of the research and innovation ecology, in other words the network of relationships between innovation actors and the environment, which structures those relationships. The ability to use knowledge developed elsewhere or to be a knowledge supplier as captured in the terminology of 'open innovation' has started to transform business models and processes. Finally, it is also increasingly recognised that there is no single innovation model that fits the requirements of all fields of innovation. Greater diversity in research and innovation patterns can be observed, as reflected in the greater attention paid to sectoral and thematic specificities of innovation.

Caught in between changes in societal demands on innovation and changes in research and innovation practices, a substantial reappraisal of innovation policy has been taking place in Europe in the past 5 years. Initially the drive for this was the realisation that efforts to underpin the technological base, though vital, were insufficient in terms of providing the environment in which innovative firms would flourish and grow. In the meantime, the economic crisis and other pressing challenges have reinforced the urgency to act. It is generally accepted that governments have to take the lead in addressing societal challenges. The chapter asks whether governance structures and processes are ready to cope with this new perspective on innovation policy. This is mainly caused by the multi-level and fragmented governance in public procurement, but also by regulations and sector policies that are often not in concordance with the requirements of stimulating innovation.

*Dirk Meissner, Vitaly Roud and Mario Cervantes* argue that the contribution of innovation for growing societal welfare is without any doubt an important one. Innovation by itself is a phenomenon known to humankind over centuries. Although much work has been done to understand the process of how innovation is generated the ultimate motivation for people to search for innovation has been neglected in a broader context. Quite recently the term 'innovation policy' became a fashionable expression often used by politicians and administrative bodies to interfere in some way into the sole process. It's certainly wise to design the framework conditions in a society – thus in an economy – which are conducive innovation but as long as designing framework conditions aim at the generation of innovation only and not considering the underlying motivation of society to develop and accept innovation such efforts are very likely to remain at the invention stage where ordinary taxpayers will ask for justification of such activities. Still it seems sufficient to use the terms "innovation" and "innovation policy" to generate awareness and acceptance. In consequence such thinking is likely to lead to promising announcements by whoever to whomever. Their contribution develops a new principle approach towards the governance of innovation on the national level considering the interrelationship between policies at federal and regional levels but also the role and importance of international policy aspects.

*Leonid Gokhberg* discusses indicators for STI policy and Foresight studies. He argues that the current STI indicators system is well suited to describe the configuration of STI systems ex post but need to be broadened by the innovation dimension beyond research and development. Also Foresight is considered as a future oriented instrument, which takes advantage of different STI indicators. Given this background he finds that Foresight studies have a major impact on STI policy and significant contributions to the design and implementation of STI governance schemes.

In the concluding chapter *Leonid Gokhberg and Alexander Sokolov* discuss the potentials to adapt policy to future thinking and derive conclusions. They find that Foresight studies show an ever increasing potential to serve as a general basis for S&T strategy building at different levels. The outcomes of Foresight studies' evaluations contain valuable learnings and information, which should be included in the design of further Foresight activities. Hence a systemic approach towards the preparation and design of Foresight becomes ever more needed in order to ease the preceding phase and to limit the repetition of failures and mistakes done in the preparation and design of Foresight studies. The preparation of such tender process and the subsequent assessments and selection of tenders are a complex process, which is critical already for the quality and validity of the subsequent Foresight study. Hence guidelines for the design and preparation, e.g. the tendering procedure, are valuable instruments for prospective Foresight studies. Foresight not only should take into account potential technological or societal developments but also aim at assessing the need for and the design of potential STI policy measures. Here a new field for forward-looking activities is likely to arise in the near future.

# Part I
# Instruments and Tools for Foresight Studies

# Chapter 2
# Integrated Framework for Evaluation of National Foresight Studies

**Anna Sokolova and Ekaterina Makarova**

## 2.1 Introduction

The number of Foresight projects has increased significantly over the past few years, growing twofold from 2005 to 2009 (Popper 2009); as a result, the evaluation of such Foresight studies has become increasingly important. The monitoring and identification of probable mistakes occuring through Foresight design and implementation are therefore crucial: strong evaluation procedures are necessary for the success of Foresight, and according to Georghiou there are "three basic tests for Foresight evaluation: accountability, justification and learning" (Georghiou 2003).

Issues concerning the evaluation of Foresight studies have formed a separate field of research. The most widespread problems investigated in this regard are the following: factors of Foresight success, areas of Foresight impact, and evaluation of different aspects of the Foresight process.

Scholars presenting the first research area focus on defining Foresight success and identifying factors that lead to such success. Foresight is considered to be successful if it provides more effective learning and more creativity in developing strategies and initiatives (Bezold 2010). Several factors of Foresight success have been determined: strong interconnections between public, private, and academic sectors; inclusion of different stakeholders; links to the current policy agenda; development of novel methodologies, creativity and lateral thinking; proactive public work; and taking previous experience into account (Calof and Smith 2008; Meissner and Cervantes 2008; Habegger 2010).

The impact of Foresight activities, being the main reason for Foresight intervention, is a principal indicator of evaluation as well. Four types of Foresight impacts – including awareness raising, informing, enabling, and influencing – form a Foresight

A. Sokolova (✉) • E. Makarova
Institute for Statistical Studies and Economics of Knowledge, National Research University – Higher School of Economics (HSE), Myasnitskaya st., 20, 101000 Moscow, Russia
e-mail: avsokolova@hse.ru

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impact schema (Johnston 2012). For the purpose of impact evaluation, researchers have determined several areas of the most considerable Foresight influence. These areas include: knowledge society emergence; science, technology, and innovation (STI) system; business; policy-making, and decision-making processes; and public understanding of science and technology (e.g. Popper et al. 2010; Havas et al. 2010; Rollwagen et al. 2008). Some scholars suggest analysing internal criteria (such as those related to actors, processes, objectives, and inputs/outputs), as well as wider environmental factors, and external factors for the purpose of a qualitative evaluation of Foresight impact (Amanatidou and Guy 2008). In accordance with the close interconnection between STI system and Foresight, the impact of the latter is assessed from the national innovation performance perspective (Meissner and Cervantes 2008).

Issues devoted to the evaluation process include choosing optimal methods and criteria, identifying evaluation topics, and elaborating evaluation algorithm. The following criteria are considered to be the most important: appropriateness, efficiency (input–output, input-effects, and input-impact relations), effectiveness (objectives-output, objectives-results, and objectives-impact relations), sufficiency, value added, usefulness, importance, and relevance (Georghiou et al. 2004a; Georghiou and Keenan 2006; Meissner and Cervantes 2008; Popper et al. 2010; Destatte 2007; Dursun et al. 2011; Rijkens-Klomp and van der Duin 2011). The most "economic" criterion – value for money – is assessed through the evaluation of the funding mechanisms' performance and is characterised mainly in qualitative terms (Popper et al. 2010). The specificity of the "behavioural additionality"[1] criterion is widely investigated by researchers in regard to the evaluation of Foresight impact. Many other criteria can be applied for the evaluation of different aspects of the Foresight process, such as the appropriateness of objectives and the experience of the project team (e.g. Georghiou et al. 2004a; Yoda 2011; Calof 2011).

A review of the literature has revealed that there is no consensus among scholars about Foresight evaluation frameworks. Georghiou and Keenan (2006) argue that an evaluation framework should depend on the rationale for the specific Foresight study (the authors identify three main rationales for Foresight: providing policy advice, building advocacy coalitions, and providing social forums). Other researchers propose that evaluation should be based on normative, strategic, and operational levels of management, as well as three basic elements: people, system, and organization[2] (Alsan and Öner 2004).

Foresight evaluation theory has developed in parallel with the formation of practical Foresight appraisal. The first evaluation initiatives appeared in the late 1990s. Nowadays a great number of Foresight evaluation projects are being implemented. Large-scale national programmes are assessed, as well as separate elements of Foresight studies. Evaluation procedures are conducted through all stages of the Foresight process (ex post, ex ante, mid-term, ongoing evaluation); external and internal experts can be engaged. The chronology and classification

[1] Behavioural additionality is the difference in actors' behaviour resulting from the Foresight intervention (Georghiou et al. 2004b).

[2] It is a framework of the adjusted integrated Foresight management model.

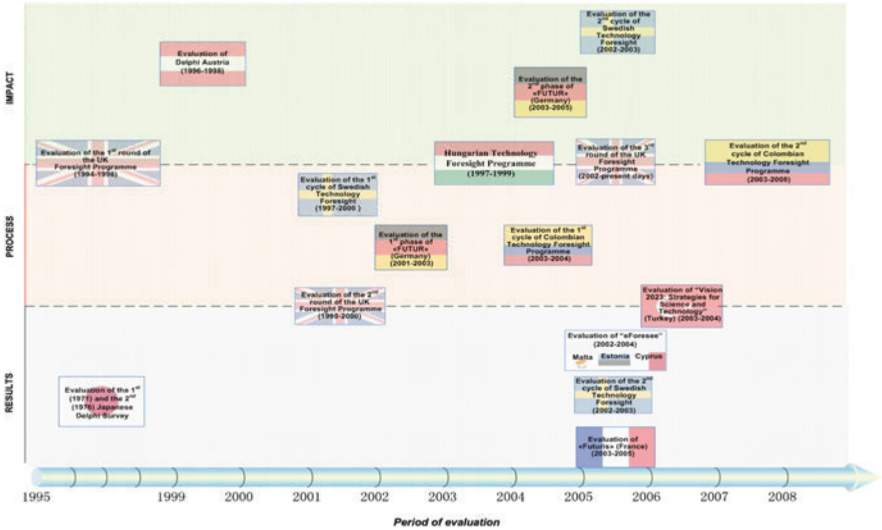


**Fig. 2.1** Foresight evaluation projects: chronology and focus of analysis

according to the focus of analysis of the most remarkable Foresight evaluation projects are presented below (Fig. 2.1).

For the majority of projects presented in Fig. 2.1, the period of time between Foresight implementation and evaluation usually doesn't exceed a year. Moreover, in many cases the evaluation procedures are realised during the Foresight, which allows correct decisions to be made with regard to the following stage (e.g. FUTUR and the first round of the UK Foresight) or project (e.g. Hungarian programme).

International expert panels were formed to conduct evaluation procedures in the majority of the cases. Evaluation projects were sometimes initiated by the responsible ministry or department (e.g. Delphi Austria and the second round of the UK Foresight), as well as by members of the Foresight programme's team (e.g. "eForesee"). The results of evaluation projects have a significant importance for a wide range of stakeholders from different levels of management all over the world. Notwithstanding increasing activity in the sphere of Foresight evaluation, only individual examples of methodology for appraisal have been constructed by scholars and implemented during projects (e.g. Alsan and Öner 2004; Popper et al. 2010; Georghiou et al. 2006). The lack of a commonly applied framework impedes the development of Foresight evaluation theory and decreases the effectiveness of practical procedures. Moreover, it limits the possibilities for spreading the experience of successful evaluation.

The intent of this research therefore is to form a framework for the development of a complex national Foresight evaluation methodology. It includes identifying the key criteria and the main stages of the evaluation process on the basis of analysis and systematisation of accumulated practical and theoretical experience.

## 2.2 Case Studies

Five projects[3] devoted to the evaluation of national Foresight studies were selected for analysis: "FUTUR" (the first phase), the Hungarian Technology Foresight Programme (TEP), the United Kingdom Foresight Programme (the third round), the Vision 2023 Technology Foresight (Turkey) and the Colombian Technology Foresight Programme (the second cycle). Brief characteristics of Foresight programmes and evaluation projects are presented below.

**FUTUR**

"FUTUR" was initiated by the German Federal Ministry of Education and Research[4] (BMBF) in order to identify the future directions of science and technology development, as well as priority areas for R&D funding (Cuhls 2003; Giesecke 2008). As a result of the programme implementation, several Lead Visions were developed. They have included a description of the examined topic[5] and its significance for society and the economy, scenario, as well as lists of future research priorities (BMBF 2002). An evaluation of "FUTUR" was conducted in 2002 in order to answer the following questions:

- Were the project's objectives rational and were they achieved?
- Was the Foresight project as a whole, as well as particular steps, appropriate for achieving the objectives?
- What could be improved?
- Were the methods applied effective and efficient with regard to the objectives? (Cuhls and Georghiou 2004)

This evaluation initiative was quite unique, especially in its methodology, which used hypotheses. For instance, for the purpose of evaluating the methodology, the following hypothesis was formulated: "mass events such as open-space conferences are a suitable method for structuring foresight" (Cuhls and Georghiou 2004). The results of the evaluation procedures concluded that the Programme was successful, but, that it could have been less complicated and more open. This, in turn, would have guaranteed a decrease in costs and a shorter period of realisation. The main elements of the evaluation process are presented in Fig. 2.2.

[3] The main reasons for that choice were the success of the evaluation procedures and the openness of information. The latter is a crucial requirement: evaluation results are sometimes classified. For example, evaluation reports on "FUTUR" and "Vision 2023" were not published, although the sufficient minimum of information was presented in several papers (e.g. Cuhls and Georghiou 2004; Dursun et al. 2011).

[4] Bundesministerium für Bildung und Forschung, BMBF.

[5] For main themes were analysed: Create Open Access to Tomorrow's World of Learning, Living in the Networked World: Individual and Secure, Healthy and Vital throughout Life through Prevention, Understanding Thought Processes (Cuhls and Georghiou 2004).

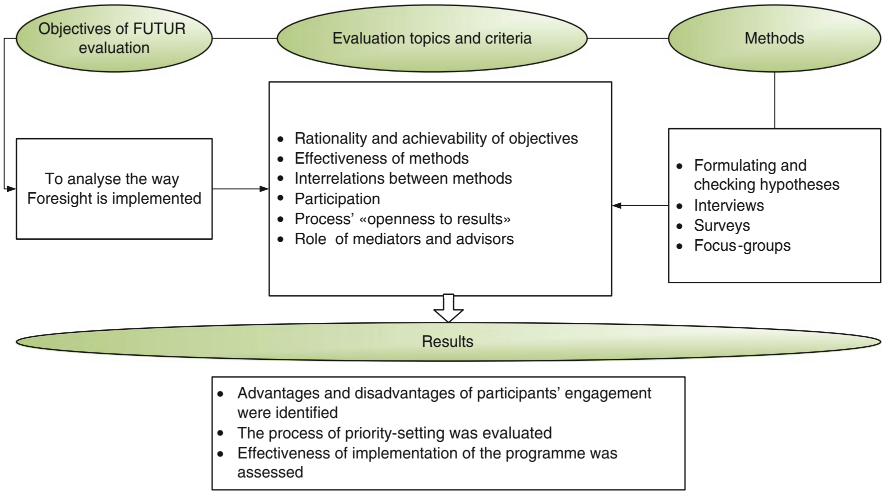


**Fig. 2.2** The main elements of FUTUR evaluation

## 2.2.1 Hungarian Technology Foresight Programme (TEP)

TEP was launched by the Hungarian National Committee for Technological Development. It was the first Foresight programme completed in a Central and Eastern European country. The key objective of the Programme was to identify long-term R&D priorities that would guarantee an effective "catching-up" strategy (Kováts et al. 2000; Rader 2003). According to the findings of TEP, Hungary needs to develop human resources, provide a clean environment, and form an effective national innovation system (Kováts et al. 2000).

TEP became subject to evaluation in 2001–2002. Evaluation procedures were aimed at analysing the level at which the Programme's objectives were achieved and at consulting the decision-making about the future of Foresight in Hungary. Experts' attention was paid to value for money, and obstacles of implementing TEP's recommendations (Georghiou and Keenan 2006). A brief outline of the evaluation framework is illustrated in Fig. 2.3.

## 2.2.2 United Kingdom Foresight Programme

The United Kingdom Foresight Programme was conducted by the Office of Science and Technology (OST). The main distinction of the third cycle of the Programme was the shift from sectoral and thematic panels to a project-oriented structure (Miles 2003). The mission of the projects realised through the Programme were to identify future challenges and opportunities in science and technology in the

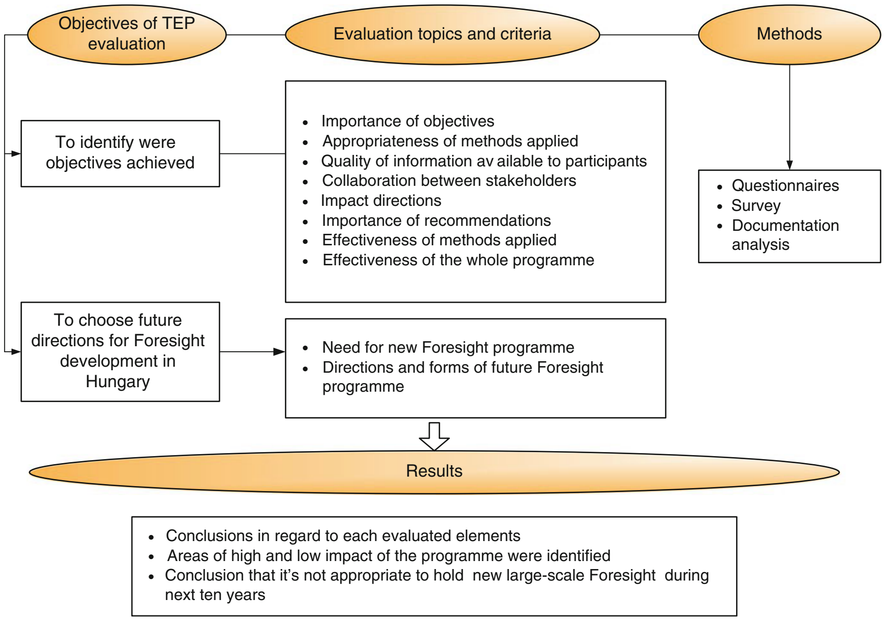


**Fig. 2.3** The main elements of TEP evaluation

United Kingdom, and to find appropriate solutions to topical social problems (Georghiou et al. 2006).

Evaluation procedures play a significant role in the development of the UK Foresight Programme. The changes that took place in the Programme's structure after the second cycle were triggered by the results of its evaluation during the first cycle. Evaluation of the cycle conducted in 2005 included an analysis of the Programme as a whole, as well as several separate projects. The evaluation conclusions were prepared with regard to objectives, process, outputs, impact, and value for money (Fig. 2.4).

### 2.2.3 *Vision 2023: Strategies for Science and Technology*

Vision 2023 was initiated by the Scientific and Technological Council of Turkey (TUBITAK) for the purpose of forming a vision for the development of science and technology in Turkey until 2023 (Saritas et al. 2007). Lists of priority areas of science and technology and of strategic technology fields were identified as a result of this Foresight programme.

A group of experts conducted an evaluation of Vision 2023 in 2006 in order to analyse key elements of the Foresight process (resources allocation, methodology, etc.) and results (expert panel reports and process gain, including broad

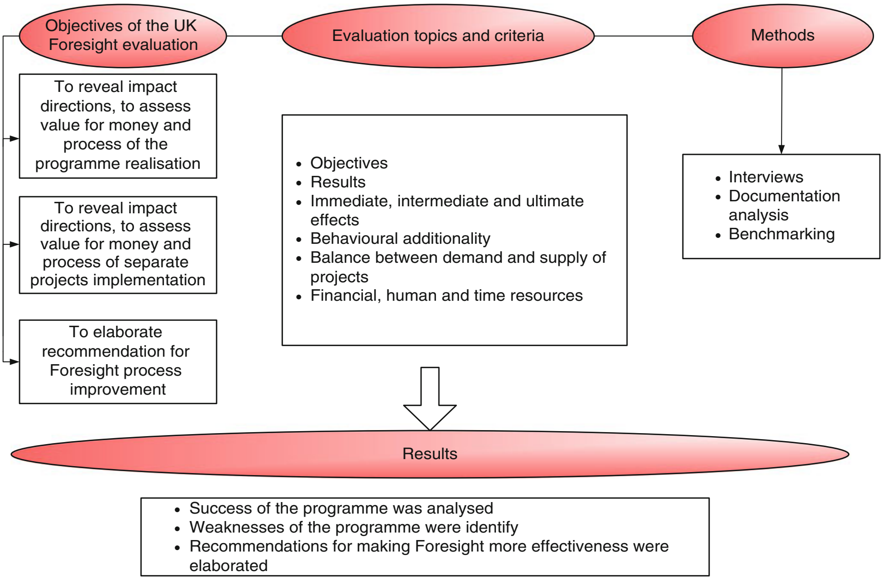


**Fig. 2.4** The main elements of the U.K. Foresight evaluation

participation, coordination, public awareness, social commitment, focusing future, learning of individuals, and experience) (Dursun et al. 2011). Strengths and weaknesses of the Programme were identified as well and the evaluation procedures were conducted through three main steps: system construction, application, and reporting. The framework of the Vision 2023 evaluation is shown in Fig. 2.5.

### *2.2.4 Colombian Technology Foresight Programme*

The Colombian Technology Foresight Programme is one of the most complex Foresight studies in Latin America. The key objective of the Programme was "to steer national skills in technology watch and Foresight towards the development of strategic areas of science, technology, and innovation applied to the knowledge economy" (Popper et al. 2010: xxiii).

The appraisal of the Colombian Technology Foresight Programme is a brilliant example of a so-called "fully-fledged" evaluation (Popper et al. 2010). It presents an analysis of different aspects of the Foresight process and impact (Fig. 2.6), and provides recommendations for aligning the Programme with the implementation environment as well. Moreover, the evaluation procedures "identify new products and services; new policy recommendations and research agendas; new processes and skills; new paradigms and visions; and new players" (Popper et al. 2010: 59).

Although the evaluation projects mentioned above have their own specificity, several common features are revealed through comparative analysis. Evaluations of

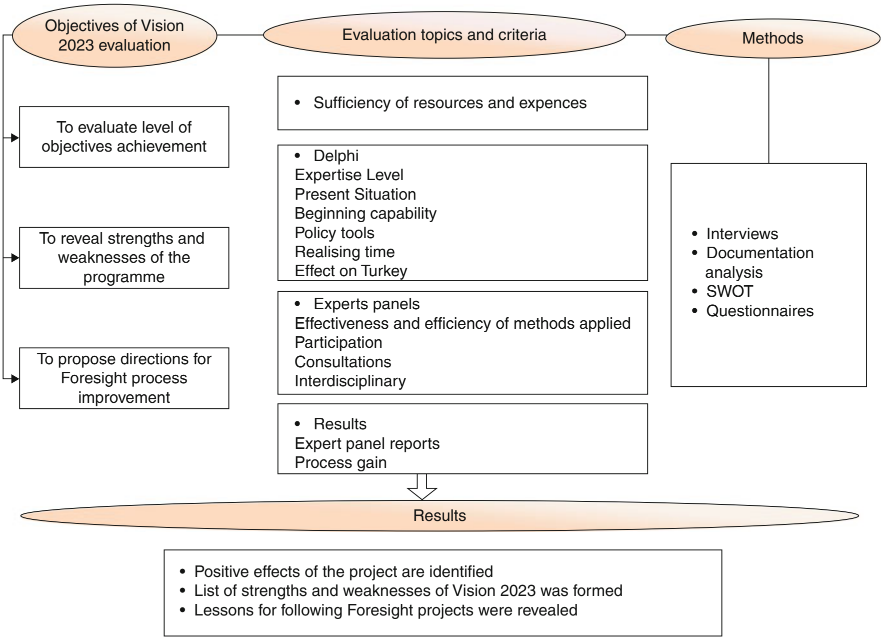


**Fig. 2.5** The main elements of "Vision 2023" evaluation

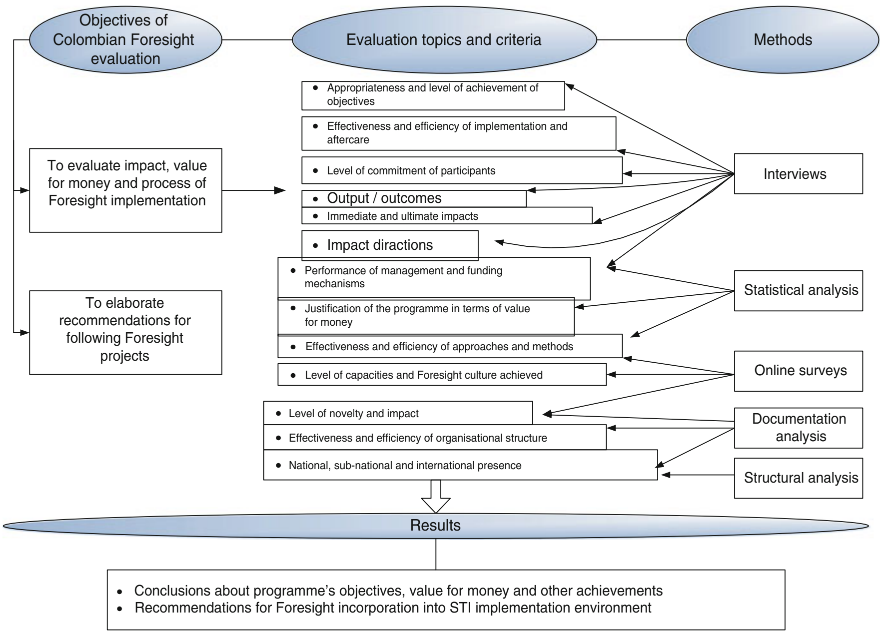


**Fig. 2.6** The main elements of the Colombian Foresight evaluation

Foresight programmes are usually aimed at an analysis of implementation, results, and impact, although sometimes strengths and weaknesses are identified, and lessons for future Foresight studies are drawn. Moreover, specific goals suitable to each evaluation project should be taken into account. Generally, the most widespread evaluation objectives are:

- Analysis of Foresight processes, results, and impact;
- Identification of strengths and weaknesses;
- Elaboration recommendations for Foresight improvement.

The most common used evaluation method was the interview: in all of the evaluation projects reviewed, at least one interview was conducted. Questionnaires and surveys, as well as statistical instruments were regularly used.

Evaluation projects generally produce reports with regard to key evaluation topics, characteristics of advantages and disadvantages of a programme, and lists of lessons and recommendations.

A number of approaches have been developed as a result of Foresight evaluation projects, although several methodological gaps still exist, namely: the absence of measurement standards for particular criteria analysis; insufficient use of quantitative methods; lack of information openness and transparency. These factors impede the effective dissemination of knowledge in the Foresight evaluation field and make the results of evaluation projects difficult to compare. It is therefore crucial to address the weaknesses of the evaluation methodologies mentioned above.

Specific steps for the evaluation process should be developed for each particular project. For instance, the evaluation of the Colombian Technology Foresight Programme includes the following stages: scoping, understanding, evaluating, and learning. The evaluation plan is developed at the first stage, while interviews and data analysis are conducted at the second stage. At the third stage, intermediate results are presented and discussed with experts and benchmarking is conducted. At the final stage, an evaluation report is prepared and validated (Popper et al. 2010). Construction of the evaluation system, application of the system, and reporting are the key stages in the evaluation process for "Vision 2023". The first stage is comprised of identifying objectives and data resources, choosing evaluation tools, and creating an evaluation model. At the next stage, methods are implemented and findings are presented (Dursun et al. 2011).

To sum up the above-mentioned examples of stages in Foresight evaluation processes, four common elements are identified:

- Preparatory stage;
- Identification of evaluation criteria;
- Data collection and analysis;
- Presentation of findings.

At the first stage necessary preparatory procedures (e.g. evaluation objectives, methods and members of project team are identified) are conducted. The activities of the second stage are aimed at identifying indicators for evaluation. Data collection and implementation of the evaluation methods then take place during the third stage. The final step of the evaluation process is the formulation of general conclusions that describe whether the project was a success or not, identify the factors which led to this success or failure, determine the project's strengths and weaknesses, and provide recommendations for follow-up Foresight activities.

## 2.3 Project Management Experience

The field of project management offers substantial experience regarding evaluation procedures. A project can be defined as "a temporary endeavor undertaken to create a unique product, service or result" (PMI 1996: 4) and "a complex series of non-routine tasks directed to meet a specific goal" (Phillips et al. 2002). The results of Foresight studies (policy recommendations, roadmaps, lists of key technologies, etc.) can be justly defined as a "unique product", and Foresight meet the requirements of time limitation ("temporary"), "non-routine", and "specificity". Therefore a Foresight project is, in essence, a standard project with its own specificity. Thus, it is appropriate to implement methods and approaches suitable for project assessment into an evaluation of a Foresight project (Fig. 2.7). In other words, the methodology of Foresight evaluation could be supplemented by some of the approaches and methods used in project evaluation.

Project evaluation was considered to be important mainly for financial decision-makers due to their need to balance investment risk and expected profit maximisation (*financial approach*). Moreover, investors and other project stakeholders were interested in ex-post information on effectiveness and efficiency of resource (time, financial, etc.) allocation.

The evaluation of a project as a series of interlinked activities aimed at the creation of a "unique product or service" may be conducted as well (PMI 1996). According to this definition of a project, economic (resource) aspects should not be the only ones analysed. Objectives, stakeholder behaviour, and organisational structure should also be assessed (*broader approach)*. A variety of methods and evaluation techniques exist for the purpose of assessing a project's performance and expected profitability although most methods are primarily aimed at justifying a project from a financial perspective. Thus, the methods are quantitative, and the evaluation indicators applied are linked with expected profit in one way or another. In some research papers, about twenty-five assessment techniques are described, and these techniques form five groups of evaluation methods (Remer and Nieto 1995a, b): net present value methods, rate of return, ratio method, payback methods, and accounting methods.

A broader project management approach concentrates on evaluating the entire project; not only financial aspects are taken into account. Project objectives, stakeholders, additionality, impact, and effects are analysed together with resources. Various methods and criteria are provided for the evaluation of the project's objectives. According to the SMART-criterion, project objectives should be Specific, Measurable, Achievable, Relevant, and Timed, while the ABCD-rule

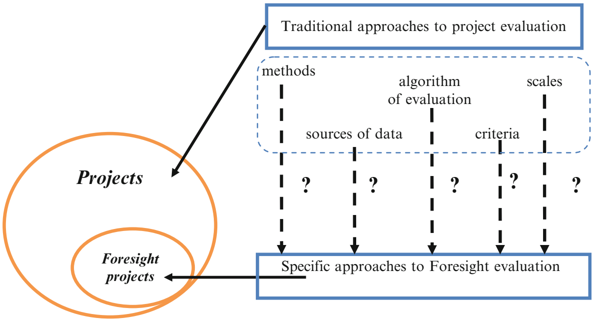


**Fig. 2.7** The place of Foresight in the field of project evaluation

defines a measurable objective as one containing information on the target Audience, Behaviour expected from the latter, Conditions and Degree of accomplishment (e.g. Phillips et al. 2002; HM Treasury 2003; Ricker et al. 1998). Moreover, project objectives have to meet the criteria of appropriateness and relevance. These can be included in the list of common criteria for process evaluation as well as effectiveness, efficiency, credibility, reliability, validity and sustainability (e.g. Zarinpoush 2006; Phillips et al. 2002; Westat 2002). Significant attention is given to the analysis of additionality as an evaluation criterion, which was introduced by Buisseret in 1995. Both input additionality ("the proportion of inputs which would not have been allocated without public support") and output additionality ("the proportion of outputs which would not have been achieved without public support") are used as important criteria in both financial and broader approaches (Georghiou et al. 2004b). Both quantitative and qualitative methods are used extensively in the project management approach, and the following methods are applied most commonly: questionnaires, interviews, observations, documentation analyses, presentations, focus groups, statistical methods for data analysis, portfolio methods, and multi-criteria analysis (e.g. Zarinpoush 2006; Westat 2002; Eilat et al. 2008; Ricker et al. 1998; Bohanec et al. 1995).

Similarities and distinctions between the financial, the broader project management approach, and the Foresight evaluation approach are presented in Table 2.1.

Given the fact that Foresight has several specific characteristics, the process of its evaluation differs considerably from the traditional project evaluation framework. First, the purpose of evaluation is different. Project evaluation concentrates on the efficiency of fund usage or the economic justification of a project (especially for investment projects), and searches for ways to improve the project's design. Meanwhile, Foresight evaluation emphasises the importance of project success, and the influence of results on the future directions of Foresight development. As the purposes of evaluation determine the general design of the process, the evaluation framework is constructed in different ways. Significant attention is paid to pre-evaluation procedures in the broader approach: evaluators conduct in-depth analysis of data sources and methods for data estimation, and also identify barriers for full-fledged evaluation and opportunities for overcoming these obstacles. A preliminary stage takes place in the Foresight evaluation process as well. However, this

**Table 2.1** Comparison of project management and Foresight evaluation approaches

| Criteria for comparison | Traditional project evaluation approaches | | Foresight evaluation approach |
|---|---|---|---|
| | Financial approach | Broader approach | |
| Purposes of evaluation | Evaluation of economic efficiency and effectiveness | Evaluation of the whole project performance; providing recommendations for project development and improvement | Analysis of project's success; evaluation of its impact; development of recommendations for follow-up Foresight projects |
| Common criteria for evaluation | Simple rate of return; payback period; benefit-cost ratio; net present value; effectiveness; efficiency | Effectiveness; efficiency; appropriateness; relevance; eligibility; credibility; reliability; validity; sustainability | Efficiency; effectiveness; appropriateness; relevance |
| Types of methods used | Mainly quantitative methods | Qualitative and quantitative methods | Mainly qualitative methods |
| Methods used | Cost-benefit analysis; cost-effectiveness analysis; payback methods; accounting methods; discounted cash flow analysis; multi-criteria analysis; other statistical analysis | Questionnaires; interviews; observation; documentation analysis; group discussion; presentation; focus group; statistical analysis; multi-criteria analysis | Questionnaire; documentation analysis; interviews; surveys (including online surveys); benchmarking |
| Evaluation results | Economic effectiveness and efficiency of a project are determined | Performance of project is estimated; ways for project improvement are identified | Success of a project is determined; strengths and weaknesses are described; recommendations for continuing or stopping Foresight are developed |

stage comprises only evaluation plan development (as usual, "for internal use only") and the listing of selected evaluation criteria without any specifications. As a result, information on the principles of selection of evaluation criteria and methods is limited. Furthermore, the project management approach highlights the necessity of identifying key evaluation stakeholders, while no attention is given to this issue during analysis of Foresight.

There are several similarities between evaluation criteria applied by the broader approach for project evaluation, and the approach used for Foresight evaluation. The common criteria were taken from the broader approach and then used in Foresight evaluation. However, there is a significant disadvantage: effectiveness and efficiency are assessed mainly with qualitative methods, although originally the criteria should be estimated quantitatively. Analysis of other criteria is implemented according to different scales that are not formalised; for this reason, the results of different Foresight evaluation initiatives become incommensurable.

Issues related to the evaluation process framework are widely studied in the field of project management (e.g. Zarinpoush 2006; IFAD 2009; Grun 2006; CAP 2010). The number and content of stages differ for each evaluation process. Some authors suggest dividing the evaluation process into five stages: establishing the evaluation focus and its expected outcome; choosing alternatives; comparing the actual outcome with the targeted one and with the effects of alternatives; presenting the results and recommendations; disseminating and using the results and recommendations (HM Treasury 2003). Other authors propose the following stages: developing a conceptual model; identifying key evaluation points; developing evaluation questions and identifying measurable outcomes; creating an evaluation design; collecting data; analysing data; and providing information to interested audiences (Westat 2002). The Japan International Cooperation Agency has developed a project evaluation framework that includes three basic stages: evaluating project performance; assessing value judgment; and providing lessons, recommendations, and feedback to the next stages of the project or other projects (JICA 2004). For the purpose of this research, the evaluation stages commonly applied in the project management approach were identified and adjusted (based on HM Treasury 2003; Zarinpoush 2006; IFAD 2009; Grun 2006; CAP 2010; Westat 2002; JICA 2004).

The synthesized process of evaluation is therefore comprised of the following five stages:

- Preparation;
- Modeling;
- Data collection and analysis;
- Economic analysis,
- Presentation and dissemination of findings.

The first stage aims to create the necessary conditions to support the evaluation process and the development of an evaluation plan. Key elements of the evaluation process (actors, indicators, outcomes, methods, budget, etc.) are identified during the second stage. At the next stage, information related to the assessed project is collected and analysed. Methods of economic evaluation are implemented during the fourth stage. As a result of the evaluation, the performance of the entire project is determined, and the directions for project improvement are provided. Finally, these findings are disseminated to the target audience. Thus, the project evaluation approach provides a complex methodology of project analysis from different perspectives.

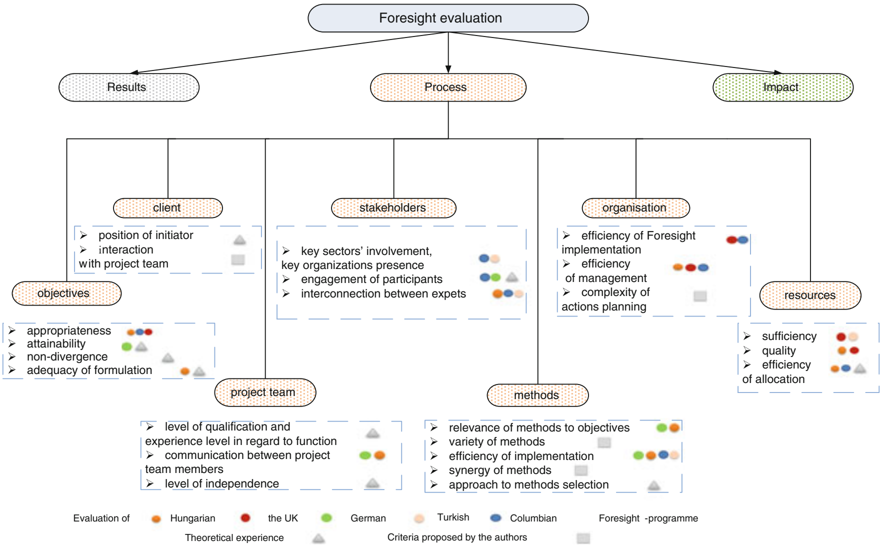


**Fig. 2.8** The main evaluation topics and criteria. (Theoretical experience includes the main findings from Amanatidou and Guy (2008), Destatte (2007), Georghiou and Keenan (2006), Meissner and Cervantes (2008), Rijkens-Klomp and van der Duin (2011))

## 2.4 Findings

### *2.4.1 Evaluation Criteria*

A complex analysis of theoretical issues and practical cases allows for the identification of key elements of the evaluation system: topics, criteria, and methods. The main evaluation topics are objectives, project team, client (initiator), stakeholders, methods, organisation, resources, results and impact. The criteria proposed by the above-mentioned scholars and developed through several practical cases were systematised and distributed in accordance with the topics (Fig. 2.8).

The proposed criteria[6] can be included in evaluation methodology suitable for a variety of Foresight studies. The main criteria for objectives are appropriateness, level of achievement, and adequacy of formulation. Interviews with project team members, experts, and stakeholders, along with a comparative analysis of plans and results allows for thorough assessment of these indicators. The effectiveness of Foresight depends greatly on the professional characteristics of the project's team members. Significant attention should therefore be paid to the qualifications,

[6] There is a wide range of indicators for the last two topics evaluation: specific criteria are developed and applied to meet a particular project's needs (e.g. Johnston 2012; Chan and Daim 2012; Miles 2012; Kappel 2001). In-depth analysis of Foresight results and impact is beyond the bounds of the research: it's an issue for further development.

experience, and level of education of the Foresight team members. Moreover, the identification of the level of independence would be useful during the development of recommendations for the improvement of the Foresight process. Evaluation topics devoted to the analysis of initiator's position[7] and stakeholder behaviour are aimed at providing information about the actors "external" to the Foresight process and their impact on the success or failure of a programme.

A great variety of criteria and indicators has been developed for the purpose of methods evaluation. The relevance of methods can be assessed through the contribution of each method to the achievement of a particular objective. Benchmarking reveals differences between methods applied during a programme and similar Foresight studies throughout the world. A variety of methods is evaluated in accordance to the inclusion instruments from each apex of the Foresight-diamond (Popper 2008).

The effectiveness of the organisational structure and complexity of action planning are analysed throughout all stages of the Foresight process: pre-Foresight, recruitment, generation, action, and renewal (Miles 2002). The inclusion of effectiveness, efficiency, value for money, and value added into the evaluation focus contributes to a more detailed description of a programme, which in turn allows for the increase in quality of the evaluation output.

### *2.4.2 Evaluation Framework*

Certain stages of the project evaluation process – such as designing an evaluation model, and economic analysis – are not usually included in Foresight evaluation. Several differences connected with the applied criteria and methods take place during all stages of evaluation. Some of these differences can be explained by Foresight specificity, while others should be eliminated in order to obtain a higher quality of evaluation procedures. Thus, the framework of a Foresight evaluation process can be improved by supplementing it with several project evaluation elements (Fig. 2.9).

The development of an evaluation model is an indisputable advantage of the traditional approach. Modeling should be added after the preliminary stage of Foresight evaluation as a fundamental element of the evaluation process. The model of an "average" evaluation, detailed above, is based on: identifying the main evaluation steps; choosing the executive member of the evaluation team at each stage; and trying out different evaluation procedures. Therefore, modeling will help to prevent potential mistakes and overcome barriers to evaluation with fewer wasted resources. In addition, it may provide a more quantitative and detailed evaluation process. Several steps are necessary to guarantee the successful

[7] Capability to influence on the situation in national innovation system (Meissner and Cervantes 2008).

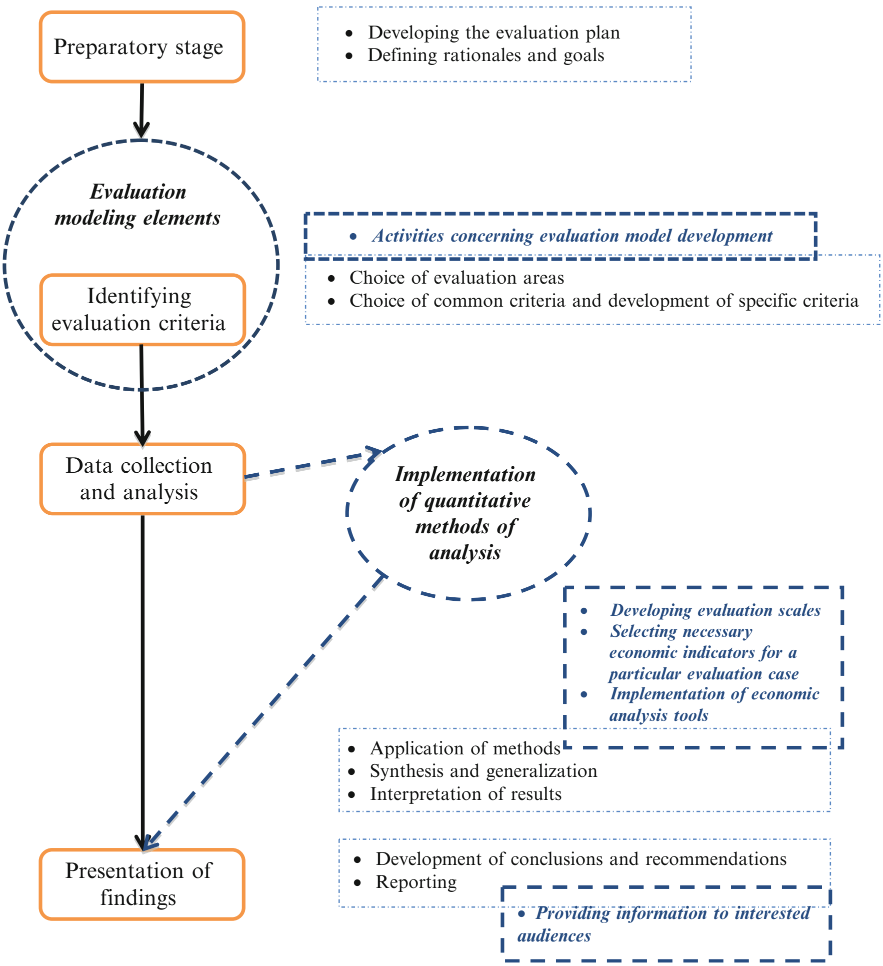


**Fig. 2.9** The supplemented framework of Foresight evaluation

implementation of this recommendation: developing the samples of the evaluation model for projects of the same type (e.g. for national, regional, sectoral, etc.) and with similar purposes; identifying the projects' specific features that can influence the evaluation framework; providing a set of tools for modeling with regards to Foresight peculiarities. The first lesson from project management is to include the modeling stage in Foresight evaluation.

Another proposed change concerns the more extensive implementation of quantitative methods. By incorporating quantitative methods into Foresight evaluation, results from different evaluation projects could be comparable and the level of subjectivity would decrease. For instance, when education and qualification levels are estimated, it is reasonable to use quantitative indicators such as the share of members with a PhD, the number of previous successful Foresight-projects, etc.

It would probably be useful to estimate the extreme endpoints of indicators for different types of projects. The identification of these extremes would be based on international experience and expert opinions. Such methods as ranking, scoring, bibliometrics, statistical, and approximate analysis can be applied. Thereby the extensive use of quantitative methods corresponds to the second lesson learnt from project management.

In order to implement the previous recommendation, it is necessary to take into account the third lesson: development of common benchmarks to evaluate each criterion. The main method for forming benchmarks is expert analysis based on international Foresight evaluation experience. One of the most significant requirements for this is a wide dissemination of information concerning the rules and methods of estimation, and the interpretation of results. The implementation of common evaluation scales will in turn help to reduce the time and resources consumed in the preparatory and modeling stages.

Both quantitative methods and common benchmarks are closely tied to the fourth lesson for the improvement of Foresight evaluation methodology. Such evaluation topics as output and effects are analysed principally from an economic or financial perspective. Effectiveness, efficiency, value for money, and value added are, in essence, financial indicators, therefore an economic approach to evaluation is an essential requirement for getting results. Cost-benefit and cost-effectiveness analysis, discounting, and statistical methods should be applied. Thus, adding elements of economic analysis to the framework of Foresight evaluation may provide a more complex and complete evaluation as well as effective management of follow-up projects. Obviously, methods of economic analysis applied in project management should be adjusted to suit the specificity of Foresight projects. The development of a software solution for evaluation needs based on quantitative methods, common evaluation scales, and elements of economic analysis is a way of increasing the efficiency of the evaluation process. The software would be able to conduct several procedures of data analysis, which in turn would provide evaluators and experts with more structured and formalised information, as well as reduce the time consumed.

Results of Foresight evaluation should be available for interested audiences. The foundation of a specific organisation of Foresight evaluators would guarantee openness and transparency of evaluation results. For example, brief outlines of the final evaluation reports (if full reports are classified) would be placed on the website of the organisation. The European Foresight Platform (EFP) follows this practice when it comes to its Foresight project descriptions. The proposed organisations could likely operate in a framework similar to EFP. Thus, the fifth lesson from project management is to provide more openness and transparency for evaluation results.

## 2.5 Conclusion

Given the variety of applied evaluation approaches and the lack of common methodology, the development of an integrated approach to Foresight evaluation was crucial. Literature concerning various assessment approaches (including the project management approach) was investigated. Several recent and remarkable Foresight evaluation projects were examined as well.

Key evaluation topics were identified (objectives, project team, client, stakeholders, methodology, organisation, resources, results, and impact). The crucial stages of the evaluation process were determined. The proposed stages for Foresight evaluation can be used as a basic framework for assessment procedures and may become a pattern for the following evaluation exercises.

The analysis of the evaluation experience accumulated by project management allows for the identification of several recommendations for the improvement of Foresight evaluation methodology:

- Development of an evaluation model;
- Extensive use of quantitative methods;
- Elaboration of evaluation scales;
- Inclusion of economic indicators in the evaluation;
- Increased transparency of evaluation results.

The proposed topics, criteria, methods, and stages are elements of the complex system of national Foresight evaluation. The system should be further developed, especially with regard to the evaluation of Foresight impact and results. Moreover, separate studies can be devoted to the analysis of a particular evaluation topic. For example, in-depth research should be conducted in order to identify and describe sets of criteria for Foresight methods evaluation.

The proposed evaluation framework may be adopted and modified (some elements can be deleted or replaced, others can be added) to suit the requirements of a particular evaluation process. Generally, the application of the methodology will contribute to making evaluation procedures more standardised, evaluation results less complicated, and outcomes more comparable.

## References

Alsan A, Öner MA (2004) Comparison of national Foresight studies by integrated Foresight management model. Futures 36(8):889–902

Amanatidou E, Guy K (2008) Interpreting Foresight process impacts: steps towards the development of a framework conceptualising the dynamics of 'Foresight systems'. Technol Forecast Soc Change 75(4):539–557

Bezold C (2010) Lessons from using scenarios for strategic Foresight. Technol Forecast Soc Change 77:1513–1518

Bohanec M, Rajkovič V, Semolič B, Pogačnik A (1995) Knowledge-based portfolio analysis for project evaluation. Inf Manage 28:293–302
Calof J (2011) Evaluating future technology assessment – Canadian Case Study. Paper presented at the 4th international Seville conference on future-oriented technology analysis (FTA), Seville, 12–13 May. http://ftp.jrc.es/EURdoc/JRC64647.pdf
Calof J, Smith JE (2008) Critical success factors for government led Foresight. Paper presented at the third international Seville seminar on future oriented technology analysis: impacts and implications for policy and decision-making, Seville, 16–17 October
Chan L, Daim T (2012) Exploring the impact of technology Foresight studies on innovation: case of BRIC countries. Futures 44(6):618–630
Clean Air Partnership (CAP) (2010) Evaluation toolkit: a guide for environmental NGOs. http://www.cleanairpartnership.org/building_evaluation_capacity_private
Cuhls K (2003) From forecasting to Foresight processes—new participative Foresight activities in Germany. J Forecast 22:93–111
Cuhls K, Georghiou L (2004) Evaluating a participative Foresight process: "Futur—the German research dialogue". Res Eval 13(3):143–153
Destatte P (2007) Evaluation of Foresight: how to take long term impacts into consideration? FOR-LEARN Mutual Learning Workshop-Evaluation of Foresight, Brussels
Dursun O, Türe TE, Daim TU (2011) Post-evaluation of Foresight studies: Turkish case. Int J Foresight Innov Policy 7(4):311–337
Eilat H, Golany B, Shtub A (2008) R&D project evaluation: an integrated DEA and balanced scorecard approach. Omega 36:895–912
Georghiou L (2003) Evaluating Foresight and lessons for its future impact. Paper presented at the second international conference on technology Foresight, Tokyo, 27–28 February
Georghiou L, Keenan M (2006) Evaluation of national Foresight activities: assessing rationale, process and impact. Technol Forecast Soc Change 73(7):761–777
Georghiou L, Acheson H, Cassingena Harper J, Clar G, Klusacek K (2004a) Evaluation of the Hungarian Technology Foresight Programme. http://www.nih.gov.hu/english/technology-foresight/evaluation-of-the-080519
Georghiou L, Clarysse B, Steurs G, Bilsen V, Larosse J (2004b) Making the difference: the evaluation of behavioural additionality of R&D subsidies. IWT Studies 48:7–20
Georghiou L, Keenan M, Miles I, Cameron H (2006) An evaluation of the UK Foresight Programme: final report, University of Manchester
German Ministry for Education and Research, BMBF (2002) Futur lead visions complete document, Berlin
Giesecke S (2008) Futur – the German research dialogue. In: Giesecke S, Crehan P, Elkins S (eds) The European Foresight Monitoring Network. Collection of EFMN Briefs – Part 1. Office for Official Publications of the European Communities, Luxembourg. http://ec.europa.eu/research/social-sciences/pdf/efmn-report_en.pdf
Grun RE (2006) Monitoring and evaluating projects: a step-by-step primer on monitoring, Benchmarking and impact evaluation. The World Bank, Washington, DC
Habegger B (2010) Strategic Foresight in public policy: reviewing the experiences of the UK, Singapore, and the Netherlands. Futures 42(1):49–58
Havas A, Schartinger D, Weber A (2010) The impact of Foresight on innovation policy-making: recent experiences and future perspectives. Res Eval 19(2):91–104
IFAD (2009) Evaluation manual: methodology and processes. http://www.ifad.org/evaluation/process_methodology/doc/manual.pdf
JICA (2004) Guideline for project evaluation: practical methods for project evaluation. http://www.jica.go.jp/english/operations/evaluation/tech_and_grant/guides/pdf/guideline01-01.pdf
Johnston R (2012) Developing the capacity to assess the impact of Foresight. Foresight 14 (1):56–68
Kappel TA (2001) Perspectives on roadmaps: how organizations talk about the future. J Product Innov Manage 18:39–50

Kováts et al (2000) The Hungarian Technology Foresight Programme, report by the Steering Group, Budapest
Meissner D, Cervantes M (2008) Results and impact of national Foresight-studies. Paper presented at the third international Seville seminar on future-oriented technology analysis: impacts and implications for policy and decision-making, Seville, 16–17 October
Miles I (with contributions from Mike Keenan) (2003) Ten years of Foresight in the UK. Paper presented at NISTEP's second international conference on technology Foresight, Tokyo
Miles I (2002) Appraisal of alternative methods and procedures for producing regional Foresight, report prepared by CRIC for the European Commission's DG research funded STRATA – ETAN Expert Group Action, Manchester. http://ec.europa.eu/research/social-sciences/pdf/appraisalof-alternative-methods_en.pdf
Miles I (2012) Dynamic Foresight evaluation. Foresight 14(1):69–81
Phillips JJ, Bothell TW, Snead GL (2002) The project management scorecard: measuring the success of project management solutions. Butterworth-Heinemann, New York
Popper R (2008) Foresight methodology. In: Georghiou L, Cassingena J, Keenan M, Miles I, Popper R (eds) The handbook of technology Foresight. Edward Elgar, Cheltenham
Popper R (2009) Mapping Foresight: revealing how Europe and other world regions navigate into the future. Publications Office of the European Union, European Commission, EFMN, Luxembourg
Popper R, Georghiou L, Keenan M, Miles I (2010) Evaluating Foresight: fully-fledged evaluation of Colombian Technology Foresight Programme. Universidad del Valle, Santiago de Cali
Project Management Institute (PMI) (1996) A guide to the project management body of knowledge (PMBOK Guide). Project Management Institute, Newtown Square
Rader M (2003) Hungary – Hungarian Foresight Programme (TEP) 1997/99. FISTERA report WP 1 – review and analysis of national Foresight D1.1 HU – case study
Remer DS, Nieto AP (1995a) A compendium and comparison of 25 project evaluation techniques. Part 1: net present value and rate of return methods. Int J Prod Econ 42(1):79–96
Remer DS, Nieto AP (1995b) A compendium and comparison of 25 project evaluation techniques. Part 2: ratio, payback and accounting Methods. Int J Prod Econ 42(2):101–129
Ricker KT et al (1998) Water quality project evaluation: a handbook for objectives-based evaluation of water quality projects. http://ohioline.osu.edu/b868
Rijkens-Klomp N, Duin van der P (2011) Evaluating local public Foresight studies from a user perspective. Paper presented at the 4th international Seville conference on future-oriented technology analysis (FTA), Seville, 12–13 May. http://ftp.jrc.es/EURdoc/JRC64647.pdf
Rollwagen I, Hofmann J, Schneider S (2008) Improving the business impact of Foresight. Technol Anal Strateg Manage 20(3):337–349
Saritas O, Taymaz E, Tumer T (2007) Vision 2023: Turkey's national technology Foresight program: a contextualist analysis and discussion. Technol Forecast Soc Change 74:1374–1393
Treasury HM (2003) The green book: appraisal and evaluation in central government. TSO, London
Westat JF (2002) The 2002 user-friendly handbook for project evaluation, NSF publication. http://www.nsf.gov/pubs/2002/nsf02057/start.htm
Yoda T (2011) Perceptions of domain experts on impact of Foresight on policy making: the case of Japan. Technol Forecast Soc Change 78(3):431–447
Zarinpoush F (2006) Project evaluation guide for nonprofit organizations: fundamental methods and steps for conducting project evaluation. http://library.imaginecanada.ca/files/nonprofitscan/en/csc/projectguide_final.pdf

# Chapter 3
# Results and Impact of National Foresight-Studies

**Dirk Meissner**

## 3.1 Introduction

Conducting national Foresight has become common in many countries. However the impact of such studies on the performance of the national innovation system remains unclear. A recent study by the author provides a first indication of the impact of national Foresight on the performance of national innovation systems. However the findings so far are preliminary since input data reflect long term developments of national innovation systems. In the short term, it can be concluded that national Foresight studies contribute significantly to the design and in some countries reshape of the innovation system structure and framework conditions. A direct quantitative measurement of the impact and thus the value of Foresight cannot yet be done in a statistically reliable fashion. However the changes these studies have caused within the national innovation systems may have an indirect impact on the future national innovation performance. Most recently national Foresight studies have switched from a rather exclusive focus on technology trend assessments towards more integrated holistic approaches identifying future challenges for society and economy as a whole thus deriving strengths and weaknesses of the national scientific, research and technology base to meet these challenges long term in the most appropriate way (Meissner and Sokolov 2013).

Foresight studies have been intensively discussed in literature in many aspects and forms in the last years. Most discussions center around the design and implementation of Foresight studies but only a few consider the impacts of Foresight studies. Until recently only few approaches have been developed and experiences made in evaluating Foresight. To apply and use evaluation and monitoring tools effectively and efficiently the major characteristics of Foresight need to be known

D. Meissner (✉)
Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE), Myasnitskaya st., 20, 101000 Moscow, Russia
e-mail: dirk.meissner@gmail.com

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and taken into serious consideration. The most frequently applied future-oriented approaches are foresight, technology forecasting and technology assessment (Zweck 2002). Foresight studies can also be grouped into content and process issues. Content issues include the time horizon, the geographical extent and the level of detail, e.g. micro (company), meso (sector), macro (national, global) level of the Foresight project. Process issues are more oriented towards operational issues like participants characteristics (number, nature, disciplinary mix), decision processes (operational, strategic, visionary), study duration, resources available (funding, data, skills), methods used (data needed, analytical outputs), organization (process management), communication flows (internal, external, nature of participation) and representation of findings (technology information products, usability) (TFAMWG 2004; Meissner and Sokolov 2013). More general groupings of Foresight address different aims, territorial needs, outputs and the results attained (Gavigan et al. 2001; Molas-Gallart 2002; Keenan 2003; Cuhls 2003).

It needs to be noted that Foresight does not aim to predict a pre-determined future but through the involvement of players and decisions taken ‘today’ Foresight exercises allow them to actively shape the future although to a modest degree only. Current Foresight exercises are quite often not limited to small expert groups but are participatory involving a wide range of stakeholders thereby opening the minds of stakeholders to new possibilities for the future (Cachia et al. 2007). Foresight studies constitute powerful assistants in planning and managing uncertainty levels. Foresight offers possibilities to identify and take advantage of opportunities; to investigate and understand the nature of risks which are inherent in the innovation process and to develop reaction to mitigate the problems once they start to unfold.

Foresight exercises usually have a longer time horizon (10–50 years or more) and a broader view of environment, organization and strategies commonly resulting in scenarios which in turn usually the stakeholder’s learning, stimulate imagination and enhance aspiration (Bezold 2010; Coates 1985; Godet et al. 2006).

The ultimate goal of national Foresight exercises is to co-ordinate research and innovation agendas across public and private organizations, industrial and service sectors, and academic disciplines by developing new alliances between the producers and the consumers of knowledge. These projects take into account and make visible the processes by which research agendas and priorities are established, the degree and nature of autonomy in the practices of scientists and engineers, the relations of academic disciplines to each other and industrial knowledge, and the ends to which S&T are directed (1999).

Thus a Foresight study is defined as

> A national Foresight study is a participatory process which brings together participants from science, industry, government, administration and other areas of society in order to identify and evaluate long-term developments in science, technology, industry and society.

## 3.2 Model for Assessing the Impact of Foresight Studies

Foresight can take manifold different shapes. Lempert and Popper suggest to group such studies in top-down versus bottom-up, explorative versus normative, quantitative versus qualitative, and expert-based versus assumption-based (Lempert and Popper 2003). Another approach by Popper proposes the "foresight diamond" which builds on the ability to gather and process information, e.g. evidence, expertise, interaction and creativity (Popper 2008). Other approaches towards grouping Foresight are centred around the particular field of the Foresight study (Tran and Daim 2008; Godwin and Wright 2010; Höjer and Mattsson 2000; Bishop et al. 2007; Bradfield et al. 2005; Ringland 1998; Voros 2006) or on the use of methodologies (Popper 2008; Keenan et al. 2007).

Salerno et al. describe the evolution of Foresight during the last years. The 1st generation involved technology experts or professional and futurologists aiming at economic planning. Evaluation indicators used were related to the accuracy of predictions and the diffusion of results. In the 2nd generation representatives from academia and industry were involved to combine market and technological perspectives. In course of the evaluation of these exercises the extent to which priorities have been considered and the networks formed were given much attention. Finally in the 3rd generation increasingly system failures were and are detected thus Foresight bridges the socio-economic gap hence the establishment and existence of broad networks (with social stakeholders) and foresight is being used as evaluation indicator (Salerno et. al. 2008).

Georghiou and Keenan distinguish three classes of evaluation criteria. Firstly they discuss the efficiency of implementation, secondly the impact and effectiveness and thirdly the appropriateness of Foresight. The efficiency of implementation mainly concentrates on the procedural perspective, e.g. organisation and management. Typical indicators developed during the evaluation are the type of people involved, the degree of support to expert panels, the link to decision-makers but also the appropriateness and efficiency of methods used. Impact and Effectiveness indicators reflect the immediate outputs and outcomes. According to Georghiou and Keenan outputs measure only activity, e.g. they count quantitative data like numbers participation in meetings or surveys, reports disseminated, meetings held, website hits and so on but there is no real assessment of the short and long term impact of those. Moreover these indictors have a potential inherent to lead to misinterpretation and misunderstanding as they do not express novelty, size, significance and sustainability. The appropriateness indicators reflect a scenario type style of evaluation centered around the 'what if…' questions, e.g. highlighting alternative scenarios (Georghiou and Keenan 2006).

The evaluation of Foresight also needs to take into account the dynamics of the project, e.g. conducted in real-time or immediately after to ensure that the findings are not distorted by hindsight or obscured by loss of data (Georghiou and Keenan 2006). According to Saritas and Oner there is a lack in translating future requirements into R&D projects and initiatives. In course of most Foresight exercises topic statements are formulated and assessed using different instruments which place more emphasis on action rather than theoretical understanding of the underlying science of matters (Saritas and Oner 2004). Hence evaluation indicators need to be developed which take account of this lack (OECD 1999; OECD 2007). An integrated foresight management model has been developed by Alsan and Oner which is essentially composed of the integrated management model (IMM) of Ulrich (Ulrich 1984) and Bleicher (Bleicher 1991) and the Knowledge–People–-System–Organisation (KPSO) framework of Oner and Basoglu (Alsan and Oner 2004).

The meaning of national Foresight studies goes far beyond studies to explore trends in specifically defined scientific and technology fields, as often carried out at regional level. These studies undoubtedly play a role in the context of national Foresight nevertheless they have to be expanded to include other general aspects particularly with regard to societal development (TEKES 2006; Department of Enterprise, Trade and Employment Ireland 2006). Looking into the future is a complex process of analysing uncertainties. On the one hand a wide variety of subjects have to be considered and on the other hand various stakeholders have to be involved in the implementation of Foresight studies (Conway and Chris 2004).

In result an impact assessment should aim at:

- Examining the impact and suitability of various instruments and methods on the effectiveness and efficiency of Foresight
- Analysis of the objectives, effects and methods used in Foresight and evaluate the experience of Foresight procedures and
- Evaluation of the impact of Foresight on the national innovation policy concerned.

To ensure comparability of the different Foresight studies an evaluation and assessment model is needed which ensures comparability of the different Foresight studies and their specific characteristics all national Foresight studies were assessed according to value added of Foresight/implementation, meaning/position of initiators/motivation of Foresight, stakeholder involvement, assigned resources, experience level, instruments applied, context of the Foresight and the degree of independence of the responsible institution.

Table 3.1 shows a model with criteria for assessing national Foresight and related scales as well as criteria weights assigned used for calculation. The criteria are weighted equally; e.g. 1/8 (0.125); sub criteria were weighted equally; e.g. each sub criteria makes 50 % of criteria value. The criteria were rated on a scale as shown in the table, thus the Foresight studies could achieve a maximum of 5 points for each criteria, which after weighting was normalized to a maximum value of 1. Thus the calculated values for each Foresight study hence country express the ratio of achieved values vs. the maximum total value of 1 possible.

The assessment is based on information publicly available, additional personal interviews with responsible Foresight managers, written survey and evaluation reports of national Foresight. From this variety of information valid conclusions can be drawn to the performance and the impact these studies achieved. Countries

**Table 3.1** Assessment criteria national Foresight studies

| | | Value | | |
|---|---|---|---|---|
| Criteria | Sub criteria | 1 | 3 | 5 |
| Value added of | | the Foresight/ implementation | Value added | No value added |
| | Partially involved in policy definition | Systematic integration in policy definition | | |
| Sustainability of Foresight | Unique | Sporadic | Continuous | |
| Meaning/ position of initiators/ Foresight motivation | Position of initiator | Neglectable in NIS | Medium powerful national position | Powerful national position |
| | Motivation for Foresight | No real internal motivation rather initiated externally | Following fashion trend | Need for systematic analysis of NIS and future options |
| Stakeholder involvement | | One sided domination | Pro forma involvement | Equal rights participation |
| Resources assigned | | Bureaucratic approach, staff member qualification unclear | No explicit resources | Transparent resources; well qualified staff |
| Experience level | | No experience; first time | First time exercise but international experiences used | Continuously conducted; international experiences used systematically |
| Instruments applied | | Unstructured use of instruments | Instruments used selectively | Mix of different instruments |
| Foresight context | | No clear context | Technology related | Technology and society related |
| Degree of dependency of responsible institutions | | Strongly dependent from individual interests | Slight dependence from individual interests | Independent |

with longer Foresight experience exhibit usually a well documented and Foresight specific Internet appearance and make the basic data and results accessible however as Foresight practitioners rarely formulate experiences explicitly and success factors and obstacles are usually specific to countries, these factors have to be seized to a large extent in personal meetings or surveys.

Such assessment model is one precondition to measure or at least estimate the impact of Foresight studies on the national innovation performance.

## 3.3 Impact of National Foresight Studies

### *3.3.1 Impact on National Innovation Policy*

In particular comprehensive Foresight studies produce results, which concern different facets of society. These are relevant for political developments in the broad social context. It is valid to note however that straight political influencing is likely to direct the Foresight study results into a politically correct fashion. Such behavior can be observed in countries especially which for first time accomplished Foresight. With studies focused on certain ranges the effects are likewise only reduced measurable over sector-specific policies. Foresight studies are often characterized by little intrinsic value, a small or missing involvement of political decision makers and a perception of the Foresight study as informative frameworks only. These results confirm the findings by Johnston 2002.

In generally Foresight studies provide the following outputs:

- Scenarios;
- Technology Roadmaps and forecast;
- Trend analyses;
- Key technologies lists;
- Research and other priorities as well as
- Recommendations for action for the policy.

Trend analyses, recommendations for policy action as well as research and other priorities are the most common results of Foresight studies, while scenarios, key technologies and technology roadmaps are outputs in clearly fewer countries.

Nevertheless it is to be observed that listing of key technologies in the countries, in which these are prepared, have strong influence on political decisions. Political decision makers make use of key technology lists in almost half of the Foresight studies which identify such. This is then supplemental to more broadly seized recommendations for action to the policy as well as national research and other priorities. While key technologies lists at mostly are considered in the political decision making, political recommendations for action and determined research priorities stand in a positive correlation to the effectiveness of a Foresight study.

It’s common practice in Foresight to develop visions for industrial sectors and enterprises, science and technology as well as the education policy. These are particularly relevant and important inputs for innovation, technology and science policy. Other policy areas, which avail themselves of the results of Foresight, are settled in the specialized political ranges of the environment, agriculture, energy as well as tourism policy. In the context of innovation and science policy the results of the Foresight became in many instances one important basis for decision making about the establishment or the reorientation of existing research infrastructures. Likewise the results were used in the context of the technology policy as inputs for the research strategies of different institutions and promotion agencies.

The most frequent users of the Foresight are national governments. Regional governments and administrative authorities however hardly use these results. Research funding agencies attach a high meaning to the results. Further it is to be observed that such results are irrelevant for universities also, while public research organizations use these relatively often. For the effectiveness and efficiency of Foresight in particular the use of the results by the national government proved as influential.

On enterprise level national Foresight studies are used for networking and seen as possibility to influence the long-term national innovation policy. For enterprises Foresight studies on national level have less meaning, since they cover a broader horizon than in the direct interest of enterprise.

### *3.3.2 Impact of Foresight Studies on National Innovation Performance*

Foresight studies have a lasting positive impact on the innovation performance of countries. In most countries this is due to the cooperation of the initiators on highest level with the participants of a country taking part directly in the early stages of the study. Within a Foresight process a top down beginning is often extended in addition by a bottom up approach. The necessary acceptance of the expected results is thus tried to be assured from the beginning.

Foresight studies improve communication and co-operation between participants of different sectors and disciplines. Interdisciplinary thinking is strengthened. Besides common indicative visions of the future new targeted innovation policy measures can be developed from a solid base. Such harmonization of participants within the national innovation system is essential for the exhaustion of the new (technological) potentials and in particular for states with fragmented innovation systems. Foresight studies contribute by the inclusion of the public also to strengthen the technology and innovation acceptance among stakeholders and society. It is to be considered however that national Foresight studies are also a political process during which perhaps old requirements for possession in question is placed thus this implies a certain distance to political institution (Cuhls 2000a, b).

Besides it is to be added that Foresight is to be understood as a continuous process from the initial goal definition to implementation. However it turns out essential that implementation is considered in the early planning stage of a Foresight study already. A Foresight study is not finished with results presentation rather it begins again and again. Foresight studies rarely function well with the first time application since a long learning process is necessary.

As already pointed out a Foresight study can affect the innovation performance of a country through different channels. That said does not provide an answer to the principle decision whether a sole Foresight study is valuable to a country but rather that a national Foresight study conducted in a certain shape as described earlier is likely to be one driver to strengthen the innovation performance of a country. Thus in the present globalization context in the industrial nations the view became generally accepted that an explicit and coherent innovation and technological policy are essential for the economic and social development. Foresight affects these policy strategy decisions over their priority-setting function (King and Thomas 2007; van der Meulen 1999). They create in addition, crucial networks and interactions between participants in the national innovation system and contribute in such a way to the acceptance of new developments and to the exhaustion of the technological potentials (Martin 1995). This explains the clearly positive correlation between Foresight studies and the innovative strength of countries measured by the global to innovation indicator as described by Hollanders and Arundel (Hollanders and Arundel 2006).

Besides also company innovation management benefits, if customers, society – and thus the demand side – are included early with exactly defined needs and the existing context (e.g. ethical doubts, environmental problems) are along-considered (Reger 2001). In addition with both processes good communication, commitment and persuasive power are required. The fact that a positive correlation between Foresight studies and the innovation performance exists can be attributed also to the fact that the success factors already existed in the national innovation system. A successful Foresight affects itself in such a case not over improved process components of innovations, but over long-term priority-setting in science and technology, network formation and involving of multiple stakeholders.

## 3.4 Conclusions

The investigation altogether showed that no uniform understanding of Foresight studies predominates. The predominating opinion over Foresight studies is to be called diffuse. The correlation analysis showed that countries, which would continuously conduct Foresight studies and integrate the results systematically in policy making and the development of supporting measures and programs perform clearly better in the national innovative performance than other countries. As a result, it can be established that there is no generally accepted understanding of Foresight studies. It is noticeable that a large number of Foresight studies are used to recognise trends in science and technology. In most Foresight studies, social aspects are not or are only superficially taken into account.

In retrospect, the Foresight studies are considered as something positive in most countries. Three-quarters of the countries consider the Foresight studies to be an effective and efficient instrument to support innovation, technology and research (scientific) policy. Almost all countries are consequently planning Foresight over the next few years.

The analysis of evaluation studies on national Foresight shows that Foresight studies have a significant impact on the structure of innovation, technology and science policy. The results of Foresight are frequently used to establish development priorities and design development programmes. There is a surprisingly clear correlation between Foresight studies and the innovation performance of countries which may be used as an indication that Foresight studies in the long run have an impact on the countries performance. So far it can be assumed and understood that Foresight studies do have a supportive function and role on the innovation culture and awareness for innovation in a country since.

The results of Foresight are often used as input for the design of technology and innovation strategies in countries. However since there is no common understanding of the terms and concepts of innovation and technology strategy such needs to be interpreted with care. Thus far no reliable conclusion can be drawn on the real impact of Foresight on these policy fields. However an impact assessment of Foresight on these policy fields always needs a qualitative in depth research through interviews which is complementary to quantitative, e.g. the survey assessment. It can be assumed that in many cases the results of Foresight have the role of a stimulus for the design and implementation of policies. In addition it needs to be kept in mind that technology and innovation policy measures are of long lasting nature hence Foresight can be supportive detecting future fields which require policy action but not change the policy mix in a short time. Also Foresight can be used as one element of a basis which serves to set priorities for future policy measures. Usually such measures aim at direct support of priority fields but do not reflect underlying framework conditions. Moreover it can be attributed also to the fact that the success factors already existed in the national innovation system. A successful Foresight affects itself in such a case not over improved process components of innovations, but over long-term priority-setting in science and technology, network formation and involving of multiple stakeholders

The benefit of Foresight is demonstrated by the improved coordination of science and industry with positive effects for knowledge and technology transfer, the improved coordination and cooperation of administrative and political institutions and participants as well as the motivation of individual institutions in the university environment to develop strategies and clear profiles which take into account and partly integrate the results of Foresight studies. SWOT analyses of the research infrastructure are often carried out within the scope of Foresight studies, as a result of which measures are ultimately taken to improve the research infrastructure of a country and in part the whole innovation system.

As a result, it can be demonstrated that, in general, Foresight studies suffer from a negative image. Countries which have rarely or only half-heartedly professionally carried out these studies could not achieve the required results. By contrast, countries that adopted a consistent and coherent approach to initiating, planning and carrying out Foresight as well as to subsequent implementation experienced a high degree of acceptance of Foresight results. This acceptance is crucial for successful implementation of identified measures and enables countries to secure lasting scientific, technological and innovative growth.

The eventual, long-term benefit of Foresight cannot yet be validly proven scientifically. Experience in most countries has shown a positive effect on research (science), technology and innovation in the countries concerned. At the same time, incorrect estimates have resulted from Foresight studies and this would be an argument against establishing such Foresight study processes to begin with. A key factor seems to be that all actors in a national innovation system need to believe in the process and be in favour of it. Depending on the various interests at stake, there is also the possibility that, as the process unfolds, existing "ownership" will be called into question and some institutions or individuals will feel as if their turf is being encroached upon. Such a process should therefore be understood and perceived as a means to spur governments to prepare society for the future in a targeted manner. It is equally important that a wide range of stakeholders be involved in the process and that the public be made aware from the very outset of action taken to implement Foresight study results.

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## References

Academy of Finland, TEKES (2006) FinnSight 2015. The outlook for science, technology and society. http://www.tekes.fi/julkaisut/Finnsight_2015_EN.pdf

Alsan A, Oner MA (2004) Comparison of national Foresight studies by integrated Foresight management model. Futures 36:889–902

Bezold C (2010) Lessons from using scenarios for strategic Foresight. Technol Forecast Soc Change 77:1513–1518

Bishop P, Hines A, Collins T (2007) The current state of scenario development: an overview of techniques. Foresight 9(1):5–25

Bleicher K (1991) Das Konzept integriertes Management. Campus, Frankfurt/New York

Bradfield R, Wright G, Burt G, Cairns G, Van Der Heijden K (2005) The origins and evolution of scenario techniques in long range business planning. Futures 37(8):795–812

Cachia R, Compañó R, Da Costa O (2007) Grasping the potential of online social networks for Foresight. Technol Forecast Soc Change 74:1179–1203

Coates JF (1985) Foresight in federal government policy making. Futures Res Q 1:29–53

Conway M, Chris S (2004) Creating and sustaining social Foresight in Australia. Australian Foresight Institute, Monograph Series 2004, Swinburne University of Technology

Cuhls K (2000a) Was kommt nach Delphi'98? Zukünfte 9(33):24–26

Cuhls K (2000b) Wie kann ein Foresight-Prozess in Deutschland organisiert werden? Gutachten. Friedrich-Ebert-Stiftung, Bonn

Cuhls K (2003) From forecasting to Foresight processes – new participative Foresight activities in Germany. J Forecast 22:93–111

Department of Enterprise, Trade and Employment Ireland (2006) Strategy for science, technology and innovation 2006–2013. http://www.entemp.ie/science/technology/sciencestrategy.htm

Gavigan J, Scapolo F, Keenan M, Miles I, Farhi F, Lecoq D, Capriati M, Di Bartolomeo T (2001) FOREN (Foresight for Regional Development Network) a practical guide to regional Foresight, Report

Georghiou L, Keenan M (2006) Evaluation of national Foresight activities: assessing rationale, process and impact. Technol Forecast Soc Change 73:761–777

Godet M, Durance P, Gerber A (2006) Strategic Foresight: problems and methods. LIPSOR working paper Nr. 20, Paris

Godwin P, Wright G (2010) The limits of forecasting methods in anticipating rare events. Technol Forecast Soc Change 77(3):355–368

Höjer M, Mattsson LG (2000) Determinism and backcasting in future studies. Futures 32 (7):613–634

Hollanders H, Arundel A (2006) Global Innovation Scoreboard, (GIS) Report

Johnston R (2002) The state and contribution of international Foresight: new challenges. The role of Foresight in the selection of research policy priorities, Seville

Keenan M (2003) Identifying emerging generic technologies at the national level: the UK experience. J Forecast 22:129–160

Keenan M, Popper R, RIF (Research Infrastructures Foresight) (2007) Practical guide for integrating Foresight in research infrastructures policy formulation. European Commission, Brussels

King DA, Thomas SM (2007) Taking science out of the box: Foresight recast. Science 316:1701–1702

Lempert RJ, Popper SC (2003) Bankes, shaping the next one hundred years: new methods for quantitative long-term policy analysis. The RAND Pardee Center, Santa Monica

Martin BR (1995) Foresight in science and technology. Technol Anal Strateg Manage 7 (2):139–168

Meissner D, Sokolov A (2013) Foresight and science, technology and innovation indicators. In: Gault F (ed) Handbook of innovation indicators and measurement. Elgar, Cheltenham/Northampton, Ch. 16

OECD (1999) Technology Foresight and sustainable development. In: Proceedings of the Budapest workshop, Organisation for Economic Co-operation and Development, Paris, 11 Dec 1998

OECD (2007) International futures programme. Organisation for Economic Co-operation and Development, Paris

Popper R (2008) Foresight methodology. In: Georghiou L, Cassingena J, Keenan M, Miles I, Popper R (eds) The handbook of technology Foresight. Edward Elgar, Aldershot

Reger G (2001) Technology Foresight in companies: from an indicator to a network and process perspective. Technol Anal Strateg Manage 13(4):533–553

Ringland G (1998) Scenario planning: managing for the future. Wiley, Chichester/New York

Salerno M, Landoni P, Verganti R (2008) Designing Foresight studies for Nanoscience and Nanotechnology (NST) future developments. Technol Forecast Soc Change 75:1202–1223

Saritas O, Oner MA (2004) Systemic analysis of UK Foresight results -Joint application of integrated management model and roadmapping. Technol Forecast Soc Change 71:27–65

TFAMWG (Technology Futures Analysis Methods Working Group) (2004) Technology futures analysis: toward integration of the field and new methods. Technol Forecast Soc Change 71:287–303

Tran T, Daim T (2008) A taxonomic review of methods and tools applied in technology assessment. Technol Forecast Soc Change 75(9):1396–1405

Ulrich H (1984) Management. Verlag Paul Haupt, Bern/Stuttgart

Van der Meulen B (1999) The impact of Foresight on environmental science and technology policy in the Netherlands. Futures 31(1):7–23

Voros J (2006) Introducing a classification framework for prospective methods. Foresight 8 (2):43–56

Zweck A (2002) Three perspectives for one future in economy and society. Futures Res Q 18 (1):22–33

# Chapter 4
# Instruments to measure Foresight

Dirk Meissner

## 4.1 Features and Characteristics of Foresight

Foresight studies have demonstrated a positive and lasting impact on the capacity of many countries for innovation. In most countries, this lasting impact is due to the interaction of the initiators of Foresight at the highest level, with actors directly involved in innovation. Within a Foresight process, a top-down approach is complemented by a bottom-up approach. Still as long as the Foresight practitioners and initiators ensure that the top-down and bottom up approach are not conflicting in its aims and directions the necessary acceptance of the results is ensured from the outset. In a wider sense, Foresight is a combination of a wide range of approaches and methodologies that aim to improve future-oriented decision making by the early detection and assessment of emerging trends and drivers of change (Roveda and Vecchiato 2008; Georghiou 2001; Martin 1995). Thus, Foresight studies exist in a variety of shapes, at the national (Grupp and Linstone 1999; Gavigan and Scapolo 1999), and regional level, in the public sector, and the private sector (Schwartz 1991; Ruff 2004; Burmsteir and Neef 2005). However, Foresight studies are always different; there is no typical Foresight study. This holds especially true for public Foresight studies, which aim at national or regional levels and thus require a careful selection and tailoring of methodologies and processes if they hope to bring about notable benefits to national actors, and especially to local firms (Roveda and Vecchiato 2008). The management of Foresight requires an ambitious and sophisticated model, which includes features of an integrated and holistic approach. Such an integrated model is considered a core competence (Major et al. 2001; Alsan and Oner 2004).

D. Meissner (✉)
Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE), Myasnitskaya st., 20, 101000 Moscow, Russia
e-mail: dirk.meissner@gmail.com

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The Foresight results from one country are only partially transferable to another, because each country has specific strengths and weaknesses. Conducting a country's own Foresight is worthwhile also because the resulting processes and discussions are at least as important as the direct output. Foresight studies intend to improve communication and cooperation between actors from different sectors of industry and society; thus interdisciplinary thinking will be strengthened. In addition, a vision of the future that provides for new innovations and educational measures will be developed. It should be noted here that Foresight is also a political process, in the old property claims made under the circumstances in question. In addition, it should be added that Foresight should be seen as a continuous process that extends from the initial target definition through to implementation. The implementation of preparatory decisions must be made following the conclusions reached through Foresight. Foresight is a process that is meant to be repeated anew, following the implementation of its conclusions. Moreover, the learning process involved in Foresight is substantial, and is necessary in order for Foresight studies to be effective, and deliver solid, high-quality results. On the one hand, this substantial learning process is necessary to balance conflictual factors, while on the other hand, it is needed because the stakeholders involved often lack a systematic understanding of Foresight studies.

Foresight can impact the innovativeness of a country through different channels. In the present context of globalization in the developed countries, the view prevails that an explicit and coherent innovation and technology policy/plan/strategy/system is essential to economic and social development. Foresight studies affect the priorities and decisions of these countries. But they also create significant networks and interactions between actors in the national innovation system and thus contribute to the acceptance of new developments and exploitation of technological potential.

Eventually, initiators and stakeholders of Foresight studies have ambitions to seek numerous benefits from such studies, such as dealing with problems at their early stages, believing that problems are easier to solve; improving the perception of opportunities and options; clarifying vision- or mission-focused objectives; and monitoring the future to check approve ad or adjust existing strategies (Bezold 2010). Given such ambitions, Foresight studies generally raise expectations among stakeholders. However, in most cases the framework conditions, and also the organizations initiating the study, are not fully prepared for, nor do they anticipate, the outcomes of Foresight studies. The outcomes are generally considered challenging with major impacts on organizations and systems if implemented properly. Hence, these studies eventually present a substantial risk of failure in meeting the aims and expectations of the initiators and stakeholders in the long run. The analysis of trends is an important issue for businesses, the science community, and also policy makers; however, such analysis is only useful and valuable when coherence between the trends analysed, and the strategic orientation of the actors, is guaranteed (Huss 1987).

An individual's psychological features strongly shape how she or he views Foresight (Bezold 2010). Three basic features are assumed to determine an individual's attitude towards perceiving future events and developments. These

**Table 4.1** Behavioural features

| Feature | Determination | |
|---|---|---|
| Perception | Concrete/specific (Sensing) – S | Intuition – N |
| Judgement | Objectively (thinking) – T | Subjectively by feeling – F |
| Focus energy | More by the external world of people, experience, and activity (extroversion) – E | Internal world of ideas, memories, and emotions (introversion) – I |

Source: Adapted from Bezold (2010)

are the individual's style of future perception, the basis for judging potential developments, and the sources of energy used for the previous two (Table 4.1).

It turns out that that Foresight practitioners often follow an "STE" approach by systematically designing, and structuring Foresight studies so that they are heavily dependent on the attitudes, experiences, and knowledge of external actors, e.g. stakeholders. In turn, external experts and knowledge holders are frequently applying the "NFE" or "NFI" modus operandi, which is strongly based on their personal perception, and trust in the Foresight practitioners to convert the opinions and assessments of numerous knowledge holders into an aggregated summary for deriving conclusions.

Eventually, organizations that are either directly involved in the Foresight studies, or are affected by the outcomes of Foresight studies, find themselves confronted with a compromise between short term manufacturing and production, and long-term adaptation conflicts. The challenge for any organization is "to step outside itself and examine its own adaptive capacity in order to recognize when brittleness is on the rise as the organization struggles to meet faster, better, cheaper pressures" (Woods 2009). Consequently, Foresight in a broader sense needs to take into account the organizational behaviour of institutions, which in turn strongly impacts the interactions and linkages between the different organizations in the overarching innovation system.

Foresight studies have broadened their scope from pure technology forecasting to a wider social process (Georghiou et al. 2010; Saritas and Nugroho 2012). This is mainly due to experiences from the corporate sector, the recognition of the benefits of stakeholder and end-user involvement in the overarching process, as well as consideration of a broad range of policy fields (De Moor et al. 2010). Consequently, Foresight practitioners put great emphasis on understanding the behaviour of individuals in the course of Foresight (Saritas and Nugroho 2012). The outcomes of Foresight are well-suited to act as inputs, and foundations, for technology roadmaps because they focus on alternative futures, and determine the likelihood of the appearance and the application of technologies in light of varying social, economic, and environmental framework conditions (Saritas and Aylen 2010). In this manner, Foresight studies do contribute to the growth of the knowledge base, which in turn is necessary to any understanding, or definition of innovation (Metcalfe and De Liso 1998). Thus as a matter of fact, Foresight and technology roadmaps are closely connected, since Foresight studies usually result in scenarios that are the basis for technology roadmaps (Erdmann and Behrendt 2006;

Lizaso and Reger 2004; Drew 2006). Eventually, as technology-impact assessments are included in the development of concrete scenarios, a wide range of technological trajectories with differing long-term consequences are integrated into the framework as part of Foresight studies (Berkhout and Green 2002).

Thus, the core issues of Foresight are related to the changeability, and adaptability of organizations; the ability of organizations to adapt to changing environments whose impact has been long underestimated; the ability to detect and quantify actual sources of resilience; the development, and implementation of systems that detect and manage such reliance; and finally the ability to establish and maintain change management processes, which are the result of learning processes as well as the actual Foresight process (Woods 2009).

Foresight studies are typically implemented in two ways: either as policy outcomes for national science and technology, or social programs, depending on the objective functions set for the program; and/or as concrete outcomes for companies in all sectors in the form of market trends, products, processes, and underpinning science and technology to facilitate the development of a company's business (Saritas and Oner 2004).

Different types of knowledge are reflected in different modes of learning and innovation which impact Foresight studies in a way that these studies are strongly based on the knowledge and assessments of individual experts. In this respect, technology should be "understood as involving both a body of practice, manifest in the artefacts and techniques that are produced and used, and a body of understanding, which supports, surrounds and rationalises the former" (Nelson 2004, p. 457). Eventually the most powerful technologies combine knowledge derived from different fields of science (Jensen et al. 2007).

## 4.2 Foresight Methodologies

With the increasing use and application of Foresight studies for different purposes, a broad range of methodologies have been developed or adapted. These methods are used to varying extents at various stages of Foresight moreover, these methodologies are used in different shapes and combinations – in most cases a bundle of different methodologies is used instead of selected a single one. The choice depends on the specific objectives, context, target audience, resources, and the existing innovation culture. Furthermore, some methods are only suitable for specific phases of a Foresight study. The Foresight methods are explained according to their use in the course of Foresight studies. It is thus shown in which phase the instruments are designed.

Foresight studies can employ various methodologies, depending on their goals. Critical technology lists are useful in the transfer of technologies, generally in the intermediate stages of their life cycle, from one sector to another. For the detection of more radical innovation, and technologies, other methodologies like scenarios are more appropriate. However, these alternative methods are definitely more complex, expensive, and time-consuming, requiring a wider, and more active, participation of many stakeholders. Still, the advantage is that these approaches consider an organic, and comprehensive analysis of the long-term evolution of the economic, social, and cultural framework, especially in light of global competition (Roveda and Vecchiato 2008).

A common starting point for the majority of Foresight is desk research. Information obtained through literature, and Internet research is used to gain an overview of existing work, analyse international experiences, and design a national context for the best possible Foresight. While prior research is incorporated into feasibility studies, and design proposals, the results of this research may feed back and generate more inputs over the course of the literature and media analysis. Surveys are a very efficient and effective tool, and are used in various forms in virtually all Foresight studies. As such, they provide an important foundation for the preparation of future scenarios, and can be combined with almost any Foresight methods. Brainstorming is also a widespread methodology, but is not often considered as a stand-alone method; rather, it is used in conjunction with other methods, such as the scenario building workshops. The main objective of these techniques is to collect the ideas of the participants in a structured fashion, and to promote creative thinking.

SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis' identifies and structures internal and external factors that influence a country (or a region or company) and are likely to have a future impact. Often, the results of SWOT analysis will take into account the needs and requirements of different stakeholders, and develop lists of strengths and weaknesses, as well as risks and opportunities. SWOT analysis focuses on information that allows for optimized adaptation of resources and capabilities to the environment, thereby improving competitiveness. Brainstorming techniques can be used to complement SWOT analysis. Based on the knowledge gained, future actions will be aligned so that the strengths are consistent with opportunities, risks can be avoided, and weaknesses overcome. SWOT analysis can therefore provide a good starting point for a focused analysis of Delphi or scenarios. To carry out a SWOT analysis, experts with sector-specific or country-specific knowledge, as well as stakeholders from different sectors, are involved at multiple levels. The advantages of this approach are its simplicity (requiring no technical skills) and its flexibility in application, as well as its systematical processing of information. It should be noted, however, that due to many factors, the resulting lists are not always clear, nor are the items prioritized.

The STEEPV (Social, Technological, Economic, Environmental, Political, and Values) method is a technique of structured brainstorming that focuses on initial assessments of key issues. Accordingly, the topics that STEEPV stands for will be the topics discussed in panels, workshops, or via online platforms along these six thematic priorities. Since individual issues can't be assigned exclusively to one category (social, technological, economic, environmental, or political), the category with the highest relevance to an issue is selected. The STEEPV method is suitable as input for the SWOT analysis, which is more target oriented. The structured consideration of future trends and factors in addition to the agenda-setting is suitable for panels and for the Foresight study as a whole, as well as for the development of scenarios.

For the identification of factors, and perspectives based on a precise question, a combination of desk research, workshops, and expert interviews are most important, as well as an analysis of their interaction, and mutual influence. The most important and uncertain factors can then be used when influencing the development of scenarios. It is also important in the development of prospects that no trend analysis is performed based on historical data; instead, potential new factors should be involved in the development of prospects. The morphological box/analysis and relevance tree methods were derived from strategic planning. In these methods, actions and technologies are identified on the basis of future needs and goals with the involvement of relevant stakeholders. The goal is to break up a vast subject into increasingly smaller subtopics, and identify possible paths of development with the involvement of the cost, duration, and probability. The interactions of the various elements are simultaneously considered by means of a detailed illustration. Similarly, the morphological box is designed using a multi-dimensional matrix from the (normative) organization, and stepwise refinement of information, and proposes ways to solve problems, and stimulate new ways of thinking. The starting points for this method are potential or occuring structural problems, which can be solved by means of graphic dimensions and related hypotheses.

The method of critical technologies has been developed in connection with early detection technology to prioritize short-term research and development policy objectives. The long term is also assessed in Foresight studies by a series of standardized criteria in specific technologies for their future importance. For the assessment of funding and action, experts use technology benchmarking with other countries. The goal of international comparison is to identify weaknesses, and assess possible future developments in the country of study. Discursive methods are particularly effective in looking at the technological development in social and economic factors further.

Delphi surveys are multi-stage surveys that are characterised by standardized questionnaires, and. several rounds of questioning. The purpose of this type of survey is a consensual evaluation of formulated hypotheses. The topics to be evaluated are compiled by various means, including desk research, brainstorming, workshops, and SWOT analysis. Based on the results of the first questionnaire, a second one is prepared, whith the aim of identifying common opinions, and subsequent re-assessment, and re-organisation of the expert statements, and discussions. By gathering opinions from a number of experts, this procedure can then make assessments on the possibilities, opportunities, and constraints of different topics with a long-term focus. From the results, starting points for further discussion or action can be developed. In addition, this phase of multi-stage surveys is often followed by a scenario process, which develops the acquired information to form future pictures. In some cases, the method is supplemented by a workshop or interim evaluation of the results.

Delphi studies have been conducted in Japan in connection with Foresight since the 1970s, and began to spread to Europe in the 1990s. They are gaining in popularity, especially because of the possibility of electronic surveys. One of the biggest challenges, however, remains the identification of relevant experts. Often, the return drops considerably in the second round, so a strong commitment is needed from the experts. It should also be noted that this method is based on results and has no measurable effect on communication and network building. For the benefit of Foresight, Delphi studies can therefore be combined with other methods, or simply replaced by them. Delphi surveys are mainly used for setting priorities in technological areas. For more complex issues, other methods are more suitable. Finally, it should be noted that Delphi studies promise a high accuracy of results; however, they are time- and labour-intensive, and costly. Instead of two-round expert surveys, forward-looking surveys that take into account society, politics, economics and/or science, may be performed using polling techniques that record the needs and perceived challenges of a wide audience. Such a survey is to be combined with other Foresight methods, in order to facilitate the desired dialogue between actors, and stimulate forward-looking discussion. Group workshops, facilitated by a moderator, for the collection of information and experience are suitable in different phases of a Foresight study. The interaction of the participants can either focus on topic areas, identified strategies, or results.

Often, in the early stages of Foresight, brainstorming techniques and SWOT analyses are used to structure the discussion, and panels consisting of around 10–20 experts are used to compile relevant expertise on a particular subject area. The interdisciplinary nature of this discourse lays the foundation for wider discussions. Here, the panels take different organizational forms. Expert panels are a valuable complement to other methods because they generate inputs, outputs, and direct the use of other methods. According to their use in the course of the Foresight study, the panels generate knowledge and opinions, develop scenarios, prioritize, and make recommendations. Also, specific tasks such as enriching memories of Delphi-statements, can be perceived by expert panels. In addition, the experts involved are used in part as ambassadors of the Foresight study to support the results in the eyes of the public, and to promote follow-up actions. If respected experts can be attracted, the prestige and authority of the Foresight study are increased. Accordingly, the choice of experts must be made transparently, and according to the function of the panel. In contrast to the expert panels, mixed panels of experts, stakeholders, and interested parties are also used. Through the exchange of ideas and opinions of different parties, an overall, broader perspective can be developed, which takes into account specific technical and social knowledge, and related interests. On such a panel, around 20 people are involved, most of whom were chosen based on recommendations and personal reputation. The scenario technique is carried out to assess how the identified factors (which were often identified using Delphi, SWOT and STEEPV techniques) could affect current, and in particular, future developments. Scenarios are particularly suitable in cases where a large number of factors have to be considered, and a significant degree of uncertainty persists. The scenarios therefore aim to assess a range of possible developments, and public reactions. Usually three to five different future scenarios are used to test the robustness of the recommendations. This stimulates strategic and creative thinking, and promotes communication among stakeholders, leading to more robust strategies.

In most Foresight studies, workshops and conferences are common methodological approaches. However, Foresight studies globally show a large variance in complementary methodologies, including impact matrices, multi-criteria analyses, scenario writing, backcasting, expert panels, background studies, and working groups. The differences in approaches reflect the meticulous balance that has to be found between the expertise of scientists and engineers, the interaction between researchers and users (industry, government, society), and the creativity of visions of the future (van der Meulen 1999).

## 4.3 Foresight Indicators

Meanwhile, it is common practice to evaluate the Foresight study itself. Such Foresight study evaluations are commonly done using different indicators, such as leading, lagging, and real time indicators, as well as input-, output-, and process-related indicators. However, despite the fact that these evaluation approaches have been developed quite thoroughly, evaluations of the longevity of the impact of Foresight studies are still lacking. Moreover, it has been shown that the effects of Foresight studies can hardly contribute to the long-term performance of a country in any respect. First, indicators are needed to evaluate the contributions of Foresight studies to the development, and the eventual impact of today's strategic decisions. Foresight studies typically cover a long time frame – 10 years or more – during which strategic policy decisions are usually revised several times, making it impossible to measure the impact of previous strategic decisions. Second, neither the direct nor the indirect impact of science and innovation on the economic performance and societal welfare of a country, region, or the world can be measured reliably. Although economic theory thus far recognises the contribution of technological progress to economic welfare and growth, there is no reliable quantitative measure for the contribution of technological progress, and thus innovation. Moreover, innovation per se is more than technology; it includes soft skills, which are not generally encompassed in the definition of technology.

Typically, such evaluations are based on indicators of the potential value, and contribution of Foresight studies. However, such contributions are measured by the achievements of specific goals, rather than the overall global context of the Foresight study (for example, relevant institutions, and linkages between institutions). One special feature of Foresight studies is the resulting impact through learning, understood here as the awareness of potential future developments; for example, broadening the horizons of institutions and actors, and helping them learn to design future-oriented policy and strategy in all fields related to innovation (van der Steen and van der Duin 2012). Hence indicators used for the evaluation of Foresight studies need to reflect the learning effects of Foresight studies. Moreover, softer impacts of Foresight studies such as the creation of trust between stakeholders form an essential part of the outcome, although these effects might be counterproductive as well. As most evaluations of Foresight studies are ex post evaluations, the broad spectrum of learning effects is barely considered; thus, misleading interpretations producing unfavourable consequences are highly likely to occur. In this light, evaluations of Foresight studies should also be used to contribute to learning the effects of the purpose, potentials, and limitations of Foresight studies; thus, the expectations, ambitions, and goals of stakeholders need appropriate reflection. A possible way to evaluate the output of Foresight studies is the analysis of the resulting scenarios' internal coherence, or the verification of the consistence of the developed vision (Boaventura and Fischmann 2008). The challenge, however, lies in determining the relationship of a company's or country's strategic STI direction (vision and products) to trends and megatrends in science and in the industry to which the organisation belongs (Battistella and Toni 2011).

From a learning perspective, it becomes evident that the established Foresight evaluation models need to be complemented by indicators that evaluate the learning potential, and, later on, its success. In other words, the related indicators have to reflect the Foresight study process, the impact achieved, etc., but also take advantage of the respective learning and improvement achieved at different levels. Such a requirement is especially challenging since it does not only affect the correlation between selected indicators, but also the causality dimension (van der Steen and van der Duin 2012). The established dimensions of Foresight study evaluation, namely quality, impact, and success, thus have to be complemented by the dimension of learning. Moreover, the Foresight evaluation process should be adjusted to these new requirements: it should be modified from the rather static approach towards a dynamic one that involves several learning and feedback loops; towards an interactive, exchange-oriented process. An evaluation process designed as an interactive process also has the potential to improve the trust and confidence of the stakeholders and participants in the Foresight process. As such it will render the decision-makers more inclined to implement the recommendations of the Foresight studies. This approach also enables Foresight practitioners to build a stronger bridge with the decision-makers, who are confronted with the challenges of operational daily management, and whose decisions are being more strongly determined by future considerations.

One of the main objectives of Foresight studies is to detect trends in science and technology. Detection and monitoring of such trends is often done using patent and/or bibliometric indicators (Gokhberg et al. 2013; Moed et al. 2004). These indicators are suitable for comparisons between different scientific and technological fields, countries, and organisations, and allow for studies of the life cycle of science and technology. Traditionally, it is assumed that publication statistics mirror basic research trends, whereas patent statistics reflect applied research trends

(Blind 2004); however, a look at both patenting, and publications reveals a slightly different picture. First, patent statistics are strongly influenced by the strategic and also cultural features of patent applicants and patent holders. Second, the role of patents is not limited to the protection of a market with active use of the underlying technology, but also serves the purpose of hampering the use of competing or substituting technologies for selected applications. Third, patent strategies – especially by large companies who hold the majority of patents – generally aim at filing a larger number of patents in order to protect narrowly defined applications, rather than smaller numbers of patents, which in turn protect a broad range of applications of a certain technology. Consequently, a patent statistics analysis might identify trends that do not necessarily allow for solid and reliable detection of the application of technology; even in the case of the use of property rights for fighting substitution technologies, these indicators evaluate the strength of technologies and the likelihood of substitution. Finally, the analysis of patent statistics is limited by the fact that completely new science and technology fields are usually the subject of patentability at the point when these fields first emerge, and well before they are included in the patent classifications (Blind 2004). However, longevity studies of patent statistics by technology field, or industrial classification enable the identification of technology fields with dynamic features (Schmoch et al. 2003).

Complementary, or even substitutive, indicators can be traced from technical standards released by standard-setting bodies (Blind 2004). The time lag between patent filing and actual commercialisation is considerable, especially for emerging technologies (Blind 2003). Hence, there is considerable risk at the early stages of technology development in emerging and enabling general purpose technology (EEGPT) fields, which in turn is expressed in rather modest patent activities. Furthermore, standards are not being negotiated and set at the very early stages of technology development, and are lagging behind patent applications, even though there is a need for regulation, and standardisation (Blind 2004).

Regulatory action becomes relevant for allowing emerging technologies to grow and establish in the early phases of the technology life cycle. The challenge lies in detecting the concentration of actors holding a critical mass of legal rights, which has the potential to limit, or even stop the development and application of technologies. Such detection can be done by using concentration indices of patents; for example, the share of single patent holders in the overall number of patents for a selected technology field (Blind 2004). Thus Foresight studies, especially broad, national ones, should not only focus on detecting emerging technologies, but should be complemented by a concentration index of technology owners and patent holders. The calculation of such an index is possible using a timeline of patent applications for a given technology, and the respective concentration index over a longer time period. The volatile development expressed by such a concentration index first gives insight into a emerging echnology, and application power of individual actors in the long-term. Eventually, such an indicator provides early detection of the mid- to long-term evolution of new industries around emerging technologies.

**Table 4.2** Indicators for measurement of the attractiveness and feasibility of technologies

| Attractiveness | Feasibility |
|---|---|
| The potential capability of a technology to give rise to relevant product and process innovations | The level of knowledge regarding a technology in academic, and public, research centres, and in local industrial systems |
| The pervasiveness of a technology | The availability of this knowledge in academic, and public, research centres |
| The potential capability of a technology to give rise to new firms | The number of researchers able to transfer a technology to local firms |

The value of Foresight studies lies in its usefulness as a tool for strategic decision making; for example, in raising the awareness of decision makers of potential disturbances that might arise from the evolution of external conditions. Still, Foresight analysis of such trends does not stand alone; rather, it should be integrated into an overall national, regional, or institutional strategy "so that instead of remaining a mere exercise, it becomes actionable" (Battistella and De Toni 2011). Given this background, the outcomes of Foresight studies help decision makers and knowledge holders to understand whether the vision, and measures, of their country or institution are aligned with foreseeable, or possible, trends; additionally, they outline the major weaknesses of existing thinking, and measures, thereby establishing a culture of being "ready in advance" (Battistella and De Toni 2011). Indicators that are suitable for assessing technologies and knowledge are the attractiveness of technologies for a region/cluster, and the feasibility of development of these technologies in that region (Roveda nad Vecchiato 2008). Indicators which are suitable for assessing the feasibility and attractiveness of technologies, technology fields respectively as illustrated in Table 4.2.

Foresight studies typically result in different scenarios that mirror potential future developments. Moreover, such scenarios are quite frequently used as the basis for decisions about concrete measures. Thus, there is reason to introduce and apply an indicator that expresses the degree of materialization of the measures proposed, and implied, by different scenarios; for example, in an ex post assessment of a Foresight study, the indicator "share of realised measures" or "share of partially realised measures" is adequate to assessing the awareness, and plausibility of scenarios developed. These are then expressed in concrete measures. The "joint realisation rate" is the percentage of measures that are derived from Foresight outcomes for a special topic. The share of "not realised" measures indicates how many topics have not been put into practice to date, thus raising concerns about the plausibility of scenarios. In addition, the "expected realisation rate" indicator reflects potential development, and measures based on scenario analysis (Brandes 2009).

Table 4.3 outlines major indicators associated with methodologies applicable in the respective phases of a Foresight study.

**Table 4.3** Indicators for Foresight methodologies

| Phase Foresight process | Methodology | Objective | Indicators | Data requirements | Strengths | Limitations |
|---|---|---|---|---|---|---|
| Pre-Foresight/ scoping | Workshop | Identification of main research directions | Broad lists of technology and science fields | Objectivity required | Broad coverage of multiple topics/ subjects | Potential threat that Lobby groups might influence the agenda |
| | Key technologies | Revelation of the most significant technology directions in the subject field | Keyword counts | Broad keyword for technologies needed | Broad analysis | Vague analysis |
| Desk research | Literature review | Collection of initial information for the description of prospective markets, products, technologies, scientific and technological resolutions | Keyword counts | Quantitative data<br>Objective data solidly researched | Broad overview of topics/technologies | Difficulties determining the appropriate keyword<br>Secondary data – collection procedure of primary data often remains unclear |
| | Bibliometrics | Reveal of recent trends of advanced products, demands and technologies in the subject field | Publication counts | | | |
| | | Elaboration of preliminary list of experts (domestic and foreign) for expert group's creation | Citation counts | | | |
| | Patent analysis | Reveal of recent trends of advanced products, | IPC class dynamic | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | demands and technologies in the subject field | | | | |
| | | Elaboration of preliminary list of experts (domestic and foreign) for expert group's creation | | | | |
| | Benchmarking | Elaboration of a list of perspective products, technologies and R&D | | | | |
| | Scanning | Estimation of external environment for subject field | | | | |
| Expert procedures | Interviews | Adjustment in of a list of the most prospective products, technologies and R&D | Qualitative assessments<br>Ratings<br>Rankings | | | |
| | Expert panels | Creation of chains R&D–technology–products–markets, Discussion and assessment of future market dynamics, factors influencing market development in a long term prospects | | | | |
| | Delphi | Identification of major trends, possible applications etc. | Quantitative | Micro data of the respondent and the organisation | Detect insights of specific needs for future regulation | High cost and time-consuming |

(continued)

**Table 4.3** (continued)

| Phase Foresight process | Methodology | Objective | Indicators | Data requirements | Strengths | Limitations |
|---|---|---|---|---|---|---|
| | | | Qualitative | Assessment of future relevance of regulation, but also actual relevance of existing regulation | Findings from the surveyed sample can be generalized to the universe | Processing and analysis of data requires large human resources<br>Identification of adequate samples Some types of information are difficult to obtain (answers to counterfactual questions or earlier situations)<br>Long time series generally not available |
| | Surveys | | Qualitative | Qualitative and semiquantitative data from Delphi surveys | Consensus-building to reduce uncertainty about regulatory priorities and impacts | Impossibility to detect major technological breakthroughs and their regulatory requirements |
| | | | Semiquantitative | | | In case of conflicting interests, missing-consensus about priorities<br>Identification of experts<br>Uncertainty increases with complexity of the context (technology, markets) and future time horizon |

| | | | | | | |
|---|---|---|---|---|---|---|
| Creative analysis | Wild cards and weak signals (WiWe) | Determination of potential application fields | Weak signals | Structured data set | Open for new unexpected developments and trends | Indicative data but not scientifically founded |
| | | Identification of new substantial market and market segments | Qualitative assessments without direct reference to special technologies | Semantic analysis of trends | | |
| | Backcasting | Creation of an idea about expected state of a subject field | | | | |
| | SWOT-analysis | Determination of strong and weak sides, assessment of opportunities and threats | | | Structured analysis of risk and benefits | Mainly qualitative indicators with reasonable room for interpretation |
| | Cross-impact analysis (CIA) | Analysis of innovation chains: R&D–technology–products assessment of interactions between products and technologies characteristics and also preferable consumer features in different segments of the market | | | | |
| | Brainstorming | Determination of links between different elements of roadmap | | | | |

(continued)

**Table 4.3** (continued)

| Phase Foresight process | Methodology | Objective | Indicators | Data requirements | Strengths | Limitations |
|---|---|---|---|---|---|---|
| | Stakeholders analysis | Estimation of roadmap beneficiaries and ways of effective use of roadmap for them | | | | |
| Interactive discussion | Scenario workshops | Development of alternative paths of subject area development | Quantitative data for market descriptions | Real time data with projected future developments | Different future scenarios developed | Uncertainty of future data |
| | | | Qualitative data for technology assessment | Primary data complemented with secondary historic data | Awareness raised for different combinations of possible futures | Societal and other weak data are hard to predict correctly |
| | Workshops | Public discussion of a roadmap. Bring the information about the main results to the notice of a broad spectrum of stakeholders | | | | |
| | | Indicators | Quantitative also providing qualitative information | Adequate science and technology indicators combined with qualitative data | Systematic approach | Only quantitative data is not sufficient to detect emerging fields of regulation |
| | | | | | Comparison across technologies, countries and over time | Little information about possible types of regulation |
| | | | | | Detailed analysis allows the identification of specific regulation-relevant content and even stakeholders | Influence of non-technology-related factors cannot be considered |

Source: Adapted from Blind (2004)

## 4.4 Conclusions

Foresight is a powerful tool that is frequently applied in response to major challenges facing science, technology, and innovation policy. Such challenges include the failure of industry to exploit scientific discoveries, and the need to concentrate budgetary resources on research areas (Hanney et al. 2001). With the use of Foresight policy makers give a clear indication to the science, technology, and innovation community that policy making in a broader sense is considering a bottom-up approach rather than a purely top-down one.

Foresight in a broader sense goes beyond simple predictions by including competitive intelligence approaches at different levels; in this manner, it becomes anticipatory intelligence, based on a wide diversity of viewpoints, and knowledge sources (Malanowski and Zweck 2007). These sources in turn serve as a base for future-oriented decision making. Essentially, Foresight is "an instrument of strategic policy intelligence which seeks to generate an enhanced understanding of possible scientific and technological developments and their impact on economy and society" (Salo and Cuhls 2003). Foresight therefore considers the role and impact of technology in the framework of the economy, and society as a whole, thus linking science and technology to wealth creation, and improvements in living standards (Martin, Johnston 1999).

Foresight studies at the national level need to consider not only the future prospects of technology fields, and the competences already available in existing clusters within a country in order to leverage the economic, and social potential of these technology fields. It is also crucial to consider the existing infrastructure in order to achieve a successful and sustainable implementation of study results. Hence, "what really matters is the need to convince these firms that the new technology will not force them to give up the position they have in the local socio-economic system and to which they are used; what really matters is to convince these firms of the possibility of fully grasping the new technology, and therefore of shaping it, so being able to still play a relevant role in the continuous knowledge creation process, which underlies the future evolution of the technology" (Roveda and Vecchiato 2008). Thus, future technology and knowledge fields detected by Foresight studies need to be converted into understandable and usable language in order to be accepted and absorbed by local industrial clusters. Roveda and Vecciato correctly assert that for product creation, and generation within a regional cluster, it is not only organizational skills, and processes that are important, "but also its history, culture, social values: definitely, a combination of resources and circumstances that, altogether, are something of unique and completely different from the one of any other place. Therefore, if external scientific and technological experts want to give an effective contribution to local firms, they must be able to become themselves a part of the district, by speaking an understandable language and by adapting their approach to problem setting and solving to the usual way of thinking and doing of local entrepreneurs" (Roveda and Vecchiato 2008). The "knowledge creating company" proposed by Nonaka and Takeuchi as early as the mid-nineties stresses the importance of overlapping information, resources, and business activities within companies, and regional agglomerations of companies. In addition, the inclusion of companies alone is no guarantee that Foresight studies can, and will have a measurable and sustainable impact. Moreover, it is essential to involve company representatives from different hierarchical levels – senior management, middle management, and frontline employees – in the Foresight studies, since they all have different perceptions of the capabilities of the companies, the interfaces within, and between the companies, and of the external infrastructure of comapanies (Nonaka and Takeuchi 1995). Hence, within corporations there are different types of knowledge generated, and used in daily operations, which do not necessarily fit into long-term, focused Foresight studies. It turns out that the scope of Foresight studies is even broader encompassing different types of knowledge.

In addition, communication between different actors and hierarchical levels strongly influences the way information is perceived. Beyond the formal output of Foresight studies, follow-up activities are needed.

Due to the nature and characteristics of Foresight studies, there is no "one indicator that fits all" – different types of Foresight studies have different motivations, and objectives. These features determine the approach of any given Foresight study, and the selection of methodology within the Foresight framework. Given the different possible methodologies and techniques available, outcomes, and hence the indicators, vary significantly, and can be qualitative or quantitative in nature. Even quantitative indicators offer sufficient space for interpretation, and in the course of Foresight studies, these indicators are usually based on quantitative near-time data, which are extrapolated forward to future values. However, such extrapolation requires assumptions that are either drawn from the analysis of statistical trends, by individual assumptions, or both. Eventually, the resulting data are not quantitative but semi-quantitative, with a respectable degree of uncertainty resulting from the inclusion of semi-objective data, and information. Other indicators are needed when evaluating Foresight studies. Again, the evaluation of Foresight studies has many different objectives, goals and motivations and therefore there are a number of different evaluation techniques and indicators that can, and should, be used.

In conclusion, indicators developed, and used in the course of Foresight studies serve different purposes; thus, indicators are tailor-made for each Foresight study, which in turn are not necessarily fully comparable between different Foresight studies. However, these indicators might eventually be used as input for other Foresight studies.

## References

Alsan A, Oner AM (2004) Comparison of national Foresight studies by integrated Foresight management model. Futures 36:889–902

Battistella C, De Toni AF (2011) A methodology of technological Foresight: a proposal and field study. Technol Forecast Soc Change 78:1029–1048

Berkhout F, Green K (2002) Managing innovation for sustainability: the challenge of integration and scale. Int J Innov Manage 6(3):227–232

Bezold C (2010) Lessons from using scenarios for strategic Foresight. Technol Forecast Soc Change 77:1513–1518

Blind K (2003) Patent pools – a solution to patent conflicts in standardisation and an instrument of technology transfer. In: Jakobs K, Krechmer K, Gyedi T (eds) Proceedings of the 3rd IEEE conference on standardisation and innovation in information technology, Delft, pp 27–35

Blind K (2004) The economics of standards – theory, evidence, policy. Edward Elgar, Cheltenham

Boaventura JMG, Fischmann AA (2008) Is your vision consistent? A method for checking, based on scenario concepts. Futures 40:597–612

Brandes F (2009) The UK technology Foresight programme: an assessment of expert estimates. Technol Forecast Soc Change 76:869–879

Burmsteir K, Neef A (2005) In the long run. Oekom, Munich

De Moor K, Saritas O, Schuurman D (2010) Future-oriented user involvement in living labs drawing on innovation Foresight. In: Huizingh KRE, Conn S, Torkkeli M, Bitran I (eds) The XXI ISPIM conference on dynamics of innovation, proceedings of the XXI ISPIM conference (CD-ROM), Bilbao, 6–9 June 2010, p 11

Drew SAW (2006) Building technology Foresight: using scenarios to embrace innovation. Eur J Innov Manage 9(3):241–257

Erdmann L, Behrendt S (2006) From technology-driven roadmapping towards sustainability-oriented roadmapping: development and application of an integrated method. Second international Seville seminar on future-oriented technology analysis, Seville, 28–29 Sept 2006. At http://forera.jrc.ec.europa.eu/documents/papers/FTA%20Seville%20Seminar%20-%20submitted%20paper.pdf. Last visited 5 Nov 2009

Gokhberg L, Fursov K, Miles I, Perani G (2013) Developing and using indicators of emerging and enabling technologies. In: Fred G (ed) Handbook of innovation indicators and measurement. Elgar, Cheltenham/Northampton, Ch. 15

Gavigan JP, Scapolo F (1999) A comparison of national Foresight exercises. Foresight 1 (6):495–517

Georghiou L (2001) Third generation Foresight – integrating the socio-economic dimension. In: Proceedings of the international conference on technology Foresight – the approach to and potential for new technology Foresight, NISTEP Tokyo, Japan

Georghiou L, Keenan M, Miles I (2010) Assessing the impact of the UK's evolving national Foresight programme. Int J Foresight Innov Policy 6(1–3):131–150

Grupp H, Linstone HA (1999) Foresight activities around the globe: resurrection and new paradigms. Technol Forecast Soc Change 60:85–94

Hanney S, Henkel M, von Walden Laing D (2001) Making and implementing Foresight policy to engage the academic community: health and life scientists' involvement in, and response to, development of the UK's technology Foresight programme. Res Policy 30:1203–1219

Huss I (1987) Scenario planning: what style should you use? Long Range Plann 20:21–29

Jensen MB, Johnson B, Lorenz E, Lundvall BA (2007) Forms of knowledge and modes of innovation. Res Policy 36:680–693

Lizaso F, Reger G (2004) Linking roadmapping and scenarios as an approach for strategic technology planning. Int J Technol Intell Plann 1(1):68–86

Major E, Asch D, Cordey-Hayes M (2001) Foresight as a core competence. Futures 33:91–107

Malanowski N, Zweck A (2007) Bridging the gap between Foresight and market research: integrating methods to assess the economic potential of nanotechnology. Technol Forecast Soc Change 74:1805–1822

Martin B (1995) Foresight in science and technology. Technol Anal Strateg Manage 7(2)

Martin B, Johnston R (1999) Technology Foresight for wiring up the national innovation system. Experiences in Britain, Australia, and New Zealand. Technol Forecast Soc Change 60 (2):37–54

Metcalfe JS, De Liso N (1998) Innovation, capabilities and knowledge: the epistemic connection. In: Coombs R, Green K, Richards A, Walsh V (eds) Technological change and organization. Edward Elgar, Cheltenham

Moed HF, Glänzel W, Schmoch U (eds) (2004) Handbook of quantitative science and technology research. Kluwer, Dordrecht

Nelson RR (2004) The market economy and the scientific commons. Res Policy 33:455–471

Nonaka I, Takeuchi H (1995) The knowledge-creating company: how Japanese companies create the dynamics of innovation. Oxford University Press, New York

Roveda C, Vecchiato R (2008) Foresight and innovation in the context of industrial clusters: the case of some Italian districts. Technol Forecast Soc Change 75:817–833

Ruff F (2004) Society and technology Foresight in the context of a multinational company. EU–US Seminar: New Technology Foresight, Forecasting & Assessment Methods, Seville

Salo A, Cuhls K (2003) Technology Foresight: past and future. J Forecast 22(2/3):79–82

Saritas O, Aylen J (2010) Using scenarios for roadmapping: the case of clean production. Technol Forecast Soc Change 77:1061–1075

Saritas O, Nugroho Y (2012) Mapping issues and envisaging futures: an evolutionary scenario approach. Technol Forecast Soc Change 79:509–529

Saritas O, Oner AO (2004) Systemic analysis of UK Foresight results – joint application of integrated management model and roadmapping. Technol Forecast Soc Change 71:27–65

Schmoch U, Laville F, Patel P, Frietsch R (2003) Linking technology areas to industrial sectors. Final report to the European Commission, DG Research, Karlsruhe

Schwartz P (1991) The art of the long view: planning for the future in an uncertain world. Doubleday Currency, New York

van der Meulen B (1999) The impact of Foresight on environmental science and technology policy in the Netherlands. Futures 31:7–23

van der Steen M, van der Duin P (2012) Learning ahead of time: how evaluation of Foresight may add to increased trust, organizational learning and future oriented policy and strategy. Futures 44:487–493

Woods DD (2009) Escaping failures of Foresight. Safety Sci 47:498–501

# Chapter 5
# Interactive Impacts – Foresight as a Product, Service and Coproduction Process

**Ian Miles**

## 5.1 Introduction

It is commonplace to note that Foresight programmes are as much about the *processes* of these programmes as they are about the *products*. Indeed, it is so regularly stated that repeating distinction between the product outputs and process benefits of exercises would be banal – were it not for the fact that it often needs to be restated. The repetition is not so much a matter of authors continually rediscovering the familiar, as a case of needing to insist upon the oft-forgotten. Many "users" coming to Foresight for the first time seem to be unaware that they are not simply commissioning a report from technical consultants or external authorities. They are in fact commissioning a service; recognising this helps account for some of the main challenges of Foresight practice – and efforts to evaluate it. Some "suppliers" also seem to be unaware that Foresight is not just a matter of supplying users with a set of forecasts or scenarios. They are providing a service, which can include learning about Foresight practice as well as enhancing understanding of the issues being addressed.

A report is certainly one of the classic **product outputs** of a Foresight exercise, and is one that is produced as a matter of course in most such exercises. Product outputs will mainly involve tangible artefacts like interim, final and summary reports, and websites. Their content may remain accessible for long periods of

I. Miles (✉)
Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE), Moscow, Russia

Manchester Institute of Innovation Research, University of Manchester, Manchester, UK

Manchester Business School, Booth Street West, Manchester M15 6PB, UK
e-mail: ian.miles.manchester@gmail.com

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time; it may be disseminated in part or whole far from the point of origin. Activities like conferences and training programmes may also be regarded as products, since they are relatively visible and often reported or recorded themselves in various ways. Product outputs are also often fairly straightforward sources of metrics, some of their features are easy to count up (for example, the number of reports produced or downloaded, the number of people trained or attending events).

While it is often stated that service industries and activities are largely in the business of producing intangible outputs for their users, it is also common for services to involve tangible products. Management consultants' clients are provided with reports, patients leave their dentists with new fillings in their teeth, money can be delivered by a cash machine, and so on.

**Process benefits** will include things like deepening knowledge – including know-who (better understanding of where expertise resides and what stakeholder interests are, for example) – and building networks. These are frequent consequences of the activities of the Foresight exercise, even when these activities are notionally devoted to creating formal products. Though they may be hard to measure, many commentators argue that process benefits can be of equal importance as the formal products of the exercises, or may even be more important. (Of course, measuring importance involves thinking about what sorts of influence, on what sorts of stakeholder, we are concerned with.). An example of how process benefits may be achieved from activities notionally devoted to products is the creation of interpersonal links among participants in a scenario workshop, the recognition of possible convergence and divergence of interests, etc. The impact that these formal outputs achieve – which is where their value rally resides – is often very much a function of the achievement of process benefits. Having key stakeholders engaged in the exercise means that they are aware of the products, they understand the thinking that lies behind them, and then can translate the information into the language of their own organisations, and so on.

Service activities very often involve their users in the service processes, with the customer or client of the service organisation typically engaging with the service organisation and its staff, and/or sometimes with its equipment and information resources. Thus the clients of management consultancy are likely to have had to open up company affairs to the service suppliers, dental patients have had to open their mouths – and typically also interact with receptionists, nurses as well as with the actual dentist (and the equipment wielded!), and even the user of a cash machine will normally have had to enter security codes, and so on. The quality of the service experience and outcome is highly affected by the user inputs, which is part of the reason for commentators talking of the "coproduction" of services jointly by users and suppliers. This is liable to be very much the case in Foresight work too; so let us examine in more detail how service research may inform the approach we take to Foresight.

## 5.2 What Are Services?

A great deal of attention has been paid to services and service activities in recent years. Many economists and statisticians propose what we have labelled an "assimilation" perspective – that service and manufacturing activities are inherently highly similar, and can be assessed well using tools developed originally for analysis of manufacturing. But it has been common for service management and marketing researchers to propose "demarcation" perspectives – arguing that completely new approaches need to be developed to allow us to grasp the new phenomena of the service economy.[1] We have argued for a "synthesis", where it is recognised that many things thought peculiar to services apply in some respect to manufacturing as well. This requires paying attention to things that are brought to the fore in studies of services, even if they are not necessarily exclusive to services.

We will need to examine some of the main features that characterise service activities – and to explore how different sorts of service vary one from another – in order to gain insights from the view of Foresight as a service. At the end of this account, it should be clear that understanding the role of Foresight as a service is important for thinking about the ways in which the quality of Foresight activities and processes can be enhanced.

The term "services" is apt to cause confusion, since as a noun it can refer to industries and to the products of these industries. This is in contrast to the clear distinction between manufacturing industries and the goods (or manufactures) that they produce. In this chapter we will use the term to refer to service products, and when we are talking of industries and firms we will make this clear. Even the notion of services as products is seen as too limited by some commentators, who stress that what we (often) see is a relationship between the nominal supplier and user, and who may come up with formulations such as "the process is the product". In this chapter, we recognise that the product of a service activity can extend far beyond the formal (more or less tangible, in the case of Foresight) output.

To further complicate matters, "service" is not necessarily the singular of "services" – the latter refers as much to a range of different activities conducted by service industries (and others), while "service", the noun, can be one of these activities (a service), but can also refer to the relationship between the provider and the user (to be of service). The verb to "service" refers to the maintenance of things, usually, or the insemination of livestock; while to "serve" may refer to a relationship again (the work of servants – private and public servants – and subjects), as well as to the activities of *some* other service workers (serving customers in retail services, for example). These semantic points are inherently interesting for what they reveal about attitudes and changing historical roles, but they are also necessary to avoid confusion in the following discussion, and when readers seek to follow up points made here. (For example, one very popular idea recently, especially in the marketing literature, is that of service-dominant logic. To simplify the approach somewhat for the purposes of brevity, it portrays all economic activity as essentially about supplying services, whether these are the products provided by service firms, or the self-services that consumers can generate from the goods provided by manufacturers – see Vargo and Lusch 2006).

Service industries are, as a matter of definition, those whose major role is the production of producing services. In mainstream statistical frameworks, these exclude "utilities" (power and water), but include a wide range of activities. Thirteen broad "sections" are now identified in NACE Rev. 2 (NACE = "Nomenclature générale des Activités économiques dans les Communautés Européennes", cf Eurostat 2008): G – Wholesale and retail trade; repair of motor vehicles and motorcycles; H – Transportation and storage; I – Accommodation and food service activities; J – Information and communication; K – Financial and insurance activities; L – Real estate activities; M – Professional, scientific and technical activities; N – Administrative and support service activities; O – Public administration and defence; compulsory social security; P – Education; Q – Human health and social work activities; R – Arts, entertainment and recreation; and S – Other service activities. Section M contains R&D services, consultancy, and a range of related activities typical of Foresight (though we may find training elsewhere).

It should be recognised that organisations in other sectors of the economy may also produce services, most obviously the aftersales service supplied by many manufacturers. There has long been interest in how firms in other sectors are adding services to their portfolios, or even moving from being goods producers to service industries – the so-called "servicisation" or "servitisation" of manufacturing.[2] But most research on services concerns service firms and industries. These service industries have grown to be the dominant sectors of Western economies, though much of our economic theory persists in thinking in frameworks that are derived from the analysis of manufacturing. Thus the services they produce are sometimes treated as if they are simply "intangible products", analogous to goods (which are "tangible products"). The idea then is that services can thus be treated more or less similarly – to goods there are just problems in counting them, covering them with patents, and assessing their quality in advance (since they cannot be picked up and handled before purchase).

There are many efforts to characterise service industries, and the **intangibility** of their products is one of the most commonly cited features, as we have already mentioned. The advice given by consultants verbally may count for more than the documentation that substantiates this in the report they deliver; the dentist provides fillings as a last resort, and is usually more concerned with hygiene and cosmetic treatments; the cash machine is liable to belong to a bank or other financial services company, who provides us with account management and many other services. Some organisations have products that make a tangible difference to their users – we are transported from one location to another by rail services, for example – but do not give us a product we can carry away with us.

Intangibility has important implications. It means that services (service products, that is) are typically difficult to demonstrate in advance, to store, to transport. Service products are often produced and consumed at more or less the same moment and in the same place (**coterminality**). In contrast, goods are typically produced in advance of purchase, they are manufactured in factories that are removed from the consumer, they are transported and stored, and the consumer only gains access to them through retail services. The goods are often retained from a long time by their purchasers – some are "consumables" that are quickly destroyed in the act of consumption (rather than the act of purchase), others are more like capital goods, that can be used time and again to produce the desired results.

We have already noted that service industries can provide tangible products. If it were the case (definitionally or an empirical result) that they never provide do so, then the idea of treating Foresight exercises as services would have to be abandoned at the outset. Indeed, the published and online outputs of Foresight activities may be consumed far away from their point of origin, and stored for use at future times, just like conventional durable goods. (Publishing has traditionally been treated as a manufacturing industry, though in the latest revision of NACE, reported earlier, it is included in a section of Information and Communication Activities). But in many instances, services do provide users with tangible products. Wholesale and retail trade may be discounted – they do not produce the goods they sell. (The cash machine example mentioned above is in many ways analogous to this.) Traders do sometimes process or assemble them: for example, bicycle shops frequently assemble the bikes from a kit; more mundanely, old-fashioned shops and the deli counter in supermarkets will slice off pieces of the food being sold and even prepare sandwiches. Repair and maintenance services are liable to introduce new components into artefacts, or otherwise change their physical configuration, though, and there are many other cases where the service organisation rather actively produces a material good as part of the service. Indeed, as well as being numerous, they are also – like service industries in general -highly diverse. Dentists and consultants have already been mentioned, but consider also such cases as restaurants (they prepare meals as well as serving them); rapid prototyping services (making test versions of devices based on designs produced by their clients); software firms (they may deliver their products encoded onto physical media such as optical disks); and many other knowledge-intensive business services (KIBS) provide reports to their clients. As well as consultants, KIBS include architects (who may provide models as well as designs), auditors, research and testing services, engineering services, legal and marketing services, and more.

Since intangibility makes for difficulties in demonstrability of the service produced by a service firm, information asymmetries are commonplace. The client may find it hard to estimate what value they will acquire from the service, and what inputs they will be expected to provide. They may find it hard to compare the service offerings of different suppliers, unless they are prepared to give them both a try – which is easy enough with relatively cheap services that one uses frequently (such as transport between two points), but is problematic when one is dealing with costly, infrequent or critical services. It is common to talk of how informed clients are needed to make good choices among (and uses of) service firms, and much advice is available for selection of some sorts of business service (e.g. IT systems outsourcing).[3]

Actually, information asymmetries may work both ways – service suppliers may not be fully aware of just what inputs the client is really prepared to make. The involvement of the user in creating the product is a critical issue, and the success of an exercise is very dependent on how the user is engaged. The service supplier has some scope for influencing this,[4] but much depends upon the willingness of the user to be involved, in one way or another. For example, it is much remarked by researchers into service productivity and quality that these features are very heavily, when not completely, dependent on the use of these services. When one acquires a good, then it is possible to say whether it works or not as specified, whether it is fit for purpose, and the like. But when services are involved, then it may be a good deal harder to make this assessment. If one has not been fully forthcoming to the dentist or consultant, it is no wonder that their diagnoses and prescriptions may be imperfect. If one has not arrived at the railway station or theatre on time, then the fact that one has missed the service altogether may be grounds for complaint about schedules – but the failure to derive the desired service is quite likely to be completely in line with the contract involved when the ticket was purchased. If one is too tired to enjoy a concert or a holiday, or too frightened to take a theme park ride or psychiatric consultation, then the service supplier has only a limited part to play in creating the impact of the service. In these, and many other instances, the word "coproduction" becomes applicable. (Thus a challenge for productivity measurement is that the usual denominator for productivity measurement – the labour inputs of the producer – becomes problematic; should we also include the labour inputs from users that have gone into creating the final product?).

We return again to the issue of coproduction in a few moments. The discussion of intangibility also drew attention to the fact that unlike many tangible goods, a service is not typically purchased at one moment of time and then stored for consumption later. The service production and consumption process often intertwine over time, which may be very brief (a telephone call), moderately so (a bus ride, a theatre performance) or protracted (a holiday, hospital stay, University degree course). How we see this is partly a matter of granularity – do we regard each visit to a social networking site or a doctor as involving a separate service (product), or do we see them as elements of a more extended service? There is no one correct answer, since the granularity of our analysis depends upon the purposes we are pursuing. The medical profession is prone to describe the series of encounters we have with them while undergoing a course of treatment, a "pathway", though the term is often used to describe steps within a health organisation (for example, how information on a particular patient is handled internally, from first contact with the patient to the reporting back to them of the outcome of diagnoses or treatments).[5] It is also common for service providers to describe the customer as undertaking a service "journey"[6] – which may last a matter of minutes, or be much more extensive. Often in the course of a service journey the customer encounters the service organisation (possibly different members of staff, and/or different electronic resources) at specific "touchpoints",[7] taking place at various "servicescapes".[8] The design of touchpoints and servicescapes can be important in shaping engagement and the experience of service quality. The client/customer/user of the service traditionally has interactions with the service organisation's "front office" or field staff, on the "front stage"; meanwhile the organisation has support activities taking place in the "back office" or "back stage", that the clients does not encounter. (New Information Technology is often used to open up some elements of these back stage processes, for instance by giving direct access to databases so as to enabling the user to track the process of delivery of a parcel they have sent, for example).[9]

When the services are being supplied to businesses (or to families or communities, indeed), it is quite possible for different sets of people on both supplier and user sides being brought into relationship at different points in time. There may also be service providers from multiple (ostensibly cooperating organisations) involved in the course of the extended service process – think of the various personnel from shops, customs and immigration agencies, security, baggage handling services, and the like, one is liable to encounter at an airport. The consumption of the service may thus be an extended activity, as is suggested by the idea of a journey or a pathway. The design tools and procedures known as "service blueprinting"[10] thus result in diagrams of activities organised over time, as opposed to the more static and physical representations of physical goods.

In the course of this journey, the customer or client of the service organisation typically has to engage in different ways with the service organisation and its staff, and quite possibly not only with materials and facilities provided by that organisation (e.g. hotel rooms, restaurant meals), as mentioned. This usually requires some knowledge of such systems on the part of the client, and service staff are expected to be able to deal with customers who present different levels of experience with services of this sort. But another element in the equation is the presence of other customers in many service settings. The quality of the service experience may be very much a product of the behaviour of other customers. There are extreme cases of this, such as in matchmaking and dating services. But there are many less extreme cases where we regularly find our experience to be highly shaped by the way in which other users are behaving – for instance, cinema, theatre, and restaurant visits, encounters in hospital and other waiting rooms, not to mention actual journeys on public transport and virtual journeys in multiplayer game environments.

The users of services are thus expected to abide by particular norms of behaviour, and may be ejected or refused service when they fail to conform. Beyond this, the service user typically has some role to play in creating the service – services are known as being **customer-intensive**, as featuring high levels of **interactivity**, or, as we have seen, as involving **co-production** with their users.

There are, admittedly, some services that can continue to operate regardless of consumers – late-night buses and television programmes may have no customers. From the supplier perspective the organisations are still producing services, but nobody is actually being transported or watching TV broadcast, and thus no service – other than the promise that service would be available if required – is actually being consumed. This proves the point that, given the diversity of service industries, it is very hard to establish any general accounts that apply to all services!

But more generally, the customer is involved to some extent in coproduction of the service. This may be minimal – by being present and following a few basic rules, or far more intensive. Some service activities demand intensive physical participation (those of sports facilities, for example), others are more socially, aesthetically or intellectually demanding. The client may be expected to describe the problems that the service is intended to be helping with, to cooperate with dentists or masseurs as they apply their treatment, to react to a performance or meal, to select among goods or menus, and so on.

These aspects of services have numerous ramifications. First, there may be change over time in the division of effort across service staff and service users, with the phenomenon of "self-service" being a widespread form of innovation from service organisations (and one that changes the customer role in co-production). Second, this has implications for assessment of service quality and service productivity. A major literature has grown up around the topic of service quality assessment,[11] while service productivity remains a highly disputed area.[12] Third, services are liable to be heterogeneous, with differences across each instance of service production and delivery. This may be a matter of customising a fairly standardised service to specific customer requirements, or a much more substantial generation of something rather new and quite possibly unique. The challenge for service firms is to learn from such experiences, so they can replicate effective practices and successful service elements, thus achieving high quality with less effort. There is some tendency toward the "productisation" of services, with more standardised services supplied to users, or at least, standardised modules combined to suit broad groups of consumer requirements.[13] This way economies of scale and mass customisation can be achieved, which may support the growth of the service firm (or the wider outreach of a public service). On the other hand, many service firms try to avoid supplying basic commodity services, as they see it, and to move up into more value-added and interactive services.

The general picture is for more knowledge-intensive and complex services to be highly customised and even one-off activities. This is not to say that each is produced completely from scratch. The service supplier draws on knowledge of the provision of services to clients in the past, as well as drawing on more generic knowledge that their specific expertise gives them about the problem for which the service in question is intended to be a solution. We can see such service suppliers as drawing intelligence from the client as to its specific contexts and problems, combining this with the knowledge that the KIBS firm already possesses (including knowledge about how to access information from other sources), and learning from the designing and testing of the service solutions.[14]

## 5.3 Foresight as a Service Activity

What can we gain from seeing Foresight as a service activity? Again, a little terminological clarification is in order. Here, we will use "Foresight" to refer to the sorts of exercise that first crystallised in the Technology Foresight Programmes (TFPs) of the 1990s on, inspired by the work of Irvine and Martin (1984), Martin and Irvine (1989). These authors had examined efforts to inform Science, Technology and Innovation (STI) decision-making around the world, and were the main factor in establishing the term "Foresight" to describe such activities. They also contributed the combination of knowledge drawing on both futures and innovation studies to the topic, which helped situate the TFPs as more than just in the business of providing a set of research themes for governments to fund. One key element of this understanding was that the STI system is not a top-down machine operating the linear model of innovation, but an interconnected system in which knowledge is widely dispersed across many areas of expertise (including research funders, policymakers, practitioners, together with innovators, funders of innovation, marketers, trainers and many others). Likewise, it is not a command and control system, but one in which achieving the results from decisions typically requires coordination among multiple players: it is one in which many stakeholders (including different parts of the policy system) have viewpoints and bring to bear influence of various kinds. The more successful TFPs recognised this and adopted what we have dubbed "fully-fledged foresight" (using this terminology when it became the fashion to describe just about any futures activity as "foresight"). In our view,[15] "fully-fledged foresight" is not just three Fs, but can also be described in terms of three Ps; it combines:

- **Prospective analysis** (drawing from futures studies not just forecasting methods, but also the recognition of the importance of relating present choices to long-term prospects and potentials, with due regard to uncertainty, agency, and the value of considering alternative futures);
- **Participatory** orientation (paying due regard to the dispersion of knowledge across many institutions, professions, disciplines; and of agency across multiple stakeholders; ways of mobilising a range of expertise, insights and potential actors are thus required, beyond conventional stakeholder analysis);
- **Practical** relevance (relating the activity closely to actual decisions, as well as to longer-term strategy analysis – many TFPs were designed to inform urgent decisions confronting European countries' STI policy).

Foresight exercises typically go through several stages: it is tempting to think of there being a Foresight journey (or pathway) rather like the service journeys mentioned earlier. But in reality there is liable to be an intertwining of numerous Foresight journeys for different stakeholders, as they are engaged into activities, across these stages, on various occasions and in various ways. Figure 5.1 displays an account of six stages in a typical exercise – this is rather schematic, since in practice the various activities may well overlap, there can be a revisiting of some elements, and the like. The activities involved are all parts of most fully-fledged Foresight exercises, however. The scope of the exercise is established early on (the specific focus of attention, the geographical and time scales that are central), and early on there will be attempts to access key sources of knowledge (typically through horizon-scanning and literature reviews). This material will be analysed to provide insight into major drivers, trends and actors, and the uncertainties associated with them; on the basis of this analysis there will be some construction and appraisal of alternative future prospects and the opportunities and challenges these imply; courses of action that can generate a desirable future are identified and assessed; and ultimately the participants need to communicate the key messages


**Fig. 5.1** The Foresight cycle (Source: Miles (2012a))

that they have gleaned from the process, including the lessons about foresighting, about the strengths and weaknesses of the specific project, and about the future requirements and scope for Foresight.

The analysis of Foresight as a service suggests that we should consider the touchpoints associated with each of these stages. For each of these (and there may be several in the course of any one stage), we will need to consider what expectations are (or should be) as to:

- What roles are to be undertaken in each,
- With what provision of equipment and materials,
- In what servicescapes,
- By whom.

Much of the detailed design of the Foresight exercise takes place during the Scoping stage (at the top of the diagram), and it may even be that the main providers of the Foresight service will only be selected and appointed during this phase, bringing their experience and preferred tools with them. The sponsors of the exercise will need to be able to define enough of the scope of the exercise – the available funds and necessary timescale, the broad objectives and intended audiences, the main issues for analysis, and the like. They will use this information to recruit the service suppliers – or instruct their internal staff, if the exercise is to be run by the sponsoring organisation itself. The well-informed client is likely to be able to specify the requirements for the exercise more effectively than a naïve client, and a reasonably open-minded client is more likely to be able to appreciate suggestions from those bidding to implement the activity than one who is more into subcontracting something that it believes itself to have more or less mastered.

Substantial engagement on the part of the client is usually required for a Foresight service process to operate effectively. Often, the exact nature of the inputs that will be required from the client is highly uncertain at the outset of the service relationship. (In the Foresight field, there may be exceptions when the Foresight practitioners have made numerous contributions to the client, and there has been little staff turnover on both sides).[16] Even if efforts are made to design the coproduction roles at the earliest stages, these will need to be elaborated and quite possibly reinvented in the course of a service relationship – for example, as the context of a Foresight programme is rapidly changing. In discussing relationships between KIBS firms and their clients, Bettencourt et al. (2002) identified six ways in which the client can contribute to the effective coproduction of complex and highly customized services. Their discussion is fairly extensive, but the headlines for these six points are:

- Communication openness (sharing pertinent information with the service provider, honestly and in timely fashion);
- Shared problem solving (taking initiatives to identify and resolve problems, sharing responsibilities);
- Tolerance, accommodation (prepared to be patient, displaying understanding in the event of minor problems);
- Advocacy (promotion of the project within the client organization, by the sponsoring individuals);
- Involvement in project governance (playing a role, for example, in monitoring of progress); and
- Personal dedication (being conscientious and responsive).

The Foresight service supplier has to play a role here, not least in being selective where it comes to clients,, and being prepared to turn down offers of work (when they can afford to) if these do not appear to offer opportunities to undertake the sorts of Foresight they wish to pursue. It can be very unrewarding to work with a nonreceptive client, and the service literature has much discussion about how clients can contribute to poor service quality (and/or limited use of the tangible service products that are eventually delivered).[17] Bettencourt et al. (2002), writing for KIBS, suggest that they should apply criteria to decide whether to work with or to avoid specific clients and commissions. The criteria discussed here include features of the service to be commissioned, such as its urgency and importance to the client, its liability to be a high-profile operation. Features of the client are also important – what is known of the philosophy it pursues, its management style, organisation, and treatment of business partners; and, not least, the extent to which its resources are liable to be dedicated to the project. The Foresight supplier can also be proactive where it comes to client capabilities – Bettencourt et al. talk of service suppliers providing necessary training and education, and more generally “socializing” the client in terms of expectations about roles in, and outcomes of, the process. This can also involve management procedures, organisation of joint planning, mutual evaluation of performance undertaken with the client, rewarding transformational leadership and partnership building, and applications of methods to build trust among people that need to work together (including allowing for important interpersonal links to be created, for example, through matching authority levels in the staff on both sides, providing opportunities for project leaders on both sides to meet informally, etc.). In short, KIBS providers need to develop and apply critical skills to support the development and management of the service relationship with clients. An example in a real-life Foresight exercise[18] is the engagement of members of the client organisation and a number of stakeholder groups in a "design workshop" intended to inform the detailed planning of a subsequent scenario workshop.

When it comes to detailed design of the activities to be undertaken in different stages of the exercise, then the service blueprinting approach could be useful, at least as a guide to what we may need to consider when designing an exercise. We can follow the broad outlines of Bitner's approach here (Bitner et al. 2008), taking as an example a SWOT or scenario building workshop. For reasons that will become clear, this is not intended to suggest that most Foresight activities should be conducted on the basis of such blueprinting. But framing the service activity in question in this way prompts a number of observations that should be useful for informing Foresight practice.

The recommendation made by service blueprinting practitioners is to begin with the **point of view of the service user** – to construct a framework which outlines each of the touchpoints that the user engages in. These might include such elements as initial contact and invitation, provision of background material, arrival at the venue, briefing as to the programme, distinct tasks – such as analysis of drivers/horizon scanning, generation of scenario or SWOT appraisals in break-out groups, summing up and feedback sessions – breaks for drinks and meals, and post-event follow up, etc. This provides us with a sequence of touchpoints, at each of which we need to be clear, and clear in communicating the actions that are expected from the service users. In typical service blueprinting we are talking about consumers, but in the case of Foresight exercises we are typically engaged in coproduction not just with our sponsor, but also with various stakeholders and sources of expertise. These should be considered users for the purpose of blueprinting, except when they are individuals who are enlisted to provide briefings or lectures.

Blueprinting then proceeds by identifying activities in the service organisation, in this case the Foresight practitioner team. The blueprint is constructed in a number of layers – rather resembling a technology roadmap. Two layers build on the service user layer, these are layers dealing with the service staff (Foresight team members) with whom the user contacts. First there is a second layer dealing with their front-stage, visible actions – how they encounter and relate with the user. There is a 'line of interaction' between this layer and the user layer. The second blueprinting task is to describe the actions of the front-line staff. For example, they may be greeting workshop participants, instructing them as to tasks or informing them about facilities, visibly taking notes and providing summaries on flip charts, etc. In the third layer, with a 'line of visibility' separating this from the previous layer, is located the back stage, invisible (to the user) actions of the service providers with whom the users have contact. They may be discussing progress of the workshop among themselves, rescheduling timings, organizing for new supplies of materials required, consulting as to how to deal with problems that have arisen, etc. The third task is to define these "invisible" actions, as far as possible. In practice, while some of the actions will be inevitable and recurrent, others are likely to be less predictable. These unpredictable activities may not be planned, but they need to be planned for, as far as possible. Many arise from the complexity of the interactions with participants in the workshop, and of the Foresight process itself. It is possible that surprising new knowledge is generated or revealed. Participants may challenge particular task features or objectives (social scientists seem rather prone to this!), or express dissatisfaction with the time that has been allocated to tasks. There are also more mundane problems such as fire alarms and equipment failures that may arise. One important lesson drawn from experience of numerous exercises is that it is very helpful to have at least one senior person with oversight of the whole process, who is not so preoccupied with facilitating a particular break-out group of making a particular presentation that they miss problems that are arising; and one technical support staff member is required, who can deal with logistics issues. Service scholars and practitioners have paid much attention to the issue of service recovery,[19] which is what we are discussing here.

Two more layers are typically applied to establish a full service blueprint. The fourth layer involves other back-stage processes, in this case focusing on staff and organisational groups other than the contact employees – thus there is an 'internal line of interaction' between the third and fourth layers. Typically there are numerous activities required in order to develop, implement and deliver a service. The Foresight service provider is liable to have an office staffed by administrators and clerical staff who rarely come into contact with the users; they prepare costings and print or web-publish documentation, organise venues and other logistics, run databases and contact lists, and so on. There may be research staff who undertake literature reviews and horizon scans to feed into the workshop, and so on. The fifth layer involves the servicescape and tangible material that the users engage with in the course of the service (and thus it relates both to the first, third and fourth levels, and quite possibly to the second level too). The tangible material includes such things as briefing documents, handouts from presentations, etc., and extends to such features of the wider servicescape as the IT equipment used and the content it provides, along with the physical surroundings of the venue and such elements as food and drinks provided. These elements can be vital for perceptions of quality, and for achieving sustained engagement with the process.

It is unusual for a service blueprint, as outlined above, to be formally constructed for a component of a Foresight exercise such as a scenario or SWOT workshop. Often the elements of such a blueprint are assembled in a number of locations, but not integrated into a single diagram – and not necessarily even fully within the purview of any single individual. A **programme** for the event is almost always produced, and this is liable to be situated within a longer plan for execution of the whole process (this may be part of the contract for the activity, or of a project management process). The programme is also liable to be the broad framework within which a far more detailed "script" for the activity is prepared, for example as a set of noted to facilitators providing instructions about how to conduct each step of the break-out group and plenary activities, quite possibly with suggestions about how to prompt brainstorming or other responses, how to resolve conflicts, how to reach rapid decisions by voting or other means, and the like. Meanwhile, there will be some other activities that are ongoing functions within the supplier organisation (for example database maintenance), and others that are one-off or occasional functions that are handled by administrative staff (for example, organising the logistics for the venue).

Many service activities have not been designed with the use of blueprinting or other formal methods, and Foresight services are no exception here. Indeed, service design is itself a new and rapidly developing field, which is not familiar to many service practitioners. While some very large organisations, such as health and public services agencies,[20] are utilising a wide range of design approaches, these are still exceptions. Most service design is carried out informally and often without explication, using tacit knowledge and past experience more than specified instruments. Complex, one-off, and/or highly variable services, relying upon much accumulated expertise on the provider side, are particularly unlikely to be subject to such methods. That being said, there are exciting developments in the service design field, involving the use of techniques from creative industries (e.g. storyboarding) and interaction design (e.g. user scenarios – which are not the same as scenarios in Foresight studies).[21] Many of these approaches could be helpful for those planning complex and large-scale Foresight exercises – and one lesson from studies of service innovation is that practitioners often benefit from seeing what providers of other types of service are doing.

One of the complexities of Foresight services, already mentioned several times, is the fuzziness of the term "user", given that a range of stakeholders and sources of intelligence may be engaged alongside members of the sponsoring organisation and main intended audience, in coproduction of the service, in different ways through the different phases of the exercise. It may not be realistic to create a blueprint for the experience of each of these types of participant, though thinking about who these broad types are, and what touchpoints they make contact through, is bound to be an important design step. Even if a fully-elaborated blueprint is currently liable to be a step too far for most Foresight service providers,[22] the general approach outlined above suggests a useful framework for thinking about the activities that comprise such exercises, since it explicates the various elements that need to be drawn together, and how these relate to participants on all sides of the coproduction system.

## 5.4 Learning

This essay has argued that Foresight practice can learn from the substantial literature that has accumulated in recent years about service systems, service design, service innovation, and related topics. It has only been able to highlight a few of the ways in which Foresight can be informed by service research, but hopefully this is enough to encourage readers to pursue the latter body of work further. Furthermore, Foresight is often addressed to topics that are in essence complex service systems. Thus, attention to service research can enhance more than just our understanding of

Foresight practice. Analysis of features of service systems can provide useful inputs – at least general background, and sometimes absolutely critical elements – for understanding social and organisational dimensions of many of the domains with which the exercises are concerned.

As with other complex KIBS-type services, Foresight exercises can be seen as involving mutual learning processes. Perhaps this is the most important insight: that beyond the tangible products, successful Foresight should involve substantial learning on the part of sponsors, stakeholders, and practitioners of Foresight. Of course, this will include learning about the domain that is the object of Foresight, the focus of the exercise. Policymakers, researchers, innovators, and other stakeholders should have a much improved grasp of the (long-term) issues at stake and how these relate to (shorter-term) decisions and strategies. Their knowledge will typically be expanded to give them broader understanding of insights emerging from a wider set of disciplines, professions, and communities of practice than they are normally exposed to. Additionally, they will have acquired "know-who": such as understanding of the capabilities and interests of other participants. On all sides, this learning should also include awareness about Foresight in general: why and when it is necessary, how it can be most appropriately conducted in specific circumstances, and what qualities are required from Foresight providers and their sponsors.

The success and impact of the Foresight activity can be seen as largely a function of this learning on the part of users (sponsors, and other stakeholders whose action may be required for the implications of the exercise to be effectively incorporated into new policies and strategies, and for these to bear fruit). What about learning on the side of the original Foresight practitioners? (We say "original" because hopefully some of the other participants in the exercise will themselves become practitioners, or at least continue to develop their knowledge of Foresight as informed users.). The following sorts of learning should be accomplished in the course of service design and delivery; learning about:

- *The methods that have been implemented, and the methodology behind them.* Some of the methods used may be so frequently used that this learning will be less a matter of improving technique as of understanding how the technique fits into the particular contexts encountered in the exercise. Often this will be the case in small-scale or hasty activity. But frequently there is some need to develop tools to fit the contexts or questions being asked and there is thus scope to reflect upon what has been learned, what methods can be used in future exercises, ways in which methods and their implementation could be improved. Where there is some competition or indeed collaboration among Foresight providers, there is also scope from learning about methods from other practitioners – indeed this may well be one of the most efficient ways of transmission of knowledge about technique.
- Beyond methods as narrowly understood, the practitioners can learn about *the nature of Foresight as a service*, and come to appraise how to enlarge the scope and improve the delivery of the service that is the ultimate goal of exercises of

this sort. In line with the arguments of this essay, they can learn about how to design such activities better to achieve these service objectives, which will mean taking account of the range of types of knowledge we are here listing.

- *The specific domain* being studied. It is likely that literature will have been reviewed, statistics compiled, and at least basic knowledge about the topic accessed and internalised. This may provide a good basis for further studies; it may become known among users as an area of strength of the Foresight practitioners; it may also provide the basis for thinking about future studies that might valuably be conducted, and knowledge of this can be used as a form of marketing, or circulated more widely as an alert about gaps in understanding of long-term issues.
- *The client*, including its organisational features and the ways in which these can be engaged with and how they are liable to shape the outcomes of the exercise. Such knowledge can be generalised to provide lessons about dealing with clients of a particular types (for example – high-tech versus other types of firm, larger and smaller firms, international governmental and nongovernmental organisations, government departments of various competence in different countries). It could be used to establish management routines for interfacing with the specific client types – including ways of detecting at early stages that the level and type of client engagement is not optimal for the exercise.
- *Other parties*, including sources of expertise and major stakeholders. This goes beyond simple checklists of who is who, and who can be relied upon to participate and contribute in an open-minded and serious manner. It will also involve some early appreciation of likely interests of these parties, in the topic of concern and in participating or staying outside of the exercise. This can provide the basis for more subtle approaches to stakeholder identification and recruitment, and to the social engineering required to get expert participants to engage in dialogue rather than reiteration of their standard lectures.

Unfortunately, often practitioners have little time to reflect upon this learning, to share it effectively in their organisation, and to make explicit the background to the sorts of implementation decision that they have had to make in the course of exercises. Service researchers should be encouraged to engage with the Foresight process, and to play a role in capturing this learning so that it does not remain the preserve of a limited number of gurus.

## Notes

1. See Gallouj (1998), Coombs and Miles (2000) and Droege et al. (2009).
2. The term seems to have been introduced by Vandermerwe and Rada (1988), though earlier discussions of the phenomenon can be located. See Baines et al. (2009) for a recent review of the topic.
3. See Gallouj (1997).

4. An interesting study focusing on how service practitioners can select and socialise their clients is provided by Bettencourt et al. (2002). Alvesson et al. (2009) examines implications of the fact that the client is, in reality, often a mix of individuals with their own points of contact and purposes in the service encounter.
5. See for example, http://www.networks.nhs.uk/nhs-networks/health-intelligence-tools/blogs/nhs-patient-pathways/pathway-explained (accessed 23/07/2012).
6. See Ghobadian et al. (1994).
7. See, for example, McKechnie et al. (2011).
8. See Bitner (1992). A wide-ranging guide to current service research is Maglio et al. (2010).
9. See Glushko and Tabas (2009), Glushko (2010).
10. Shostak (1984), Bitner et al. (2008).
11. See the work of Gummesson, and Parasuraman, e.g. Gummesson (1991), Parasuraman et al. (1985).
12. For an account suggesting major problems, see (Grönroosa and Ojasalo 2004).
13. See, for example, Valminen and Toivonen (2012).
14. Miles (2012b), Strambach (2008).
15. Miles (2005, 2010).
16. Since 2003, the UK Foresight Programme, for instance, has been a rolling programme. There is a stream of major projects, each of which typically lasts for about 2 years, with at any one time some projects being fairly new ones, while others are nearing completion or into their follow-up stages. Smaller one-off exercises are also frequently conducted. The policy sponsors of the programme have experience with those they are working with, and the programme managers have longstanding relationships with some (not all) of the external service suppliers they deal with.
17. Miles (2012b) provides a recent review.
18. This example is the study ofg social research implications related to genomics, as described in the special issue of the journal *Foresight* vol 4 no 4 (2002).
19. See for example Hart et al. 1990; Miller et al. (2000). Researchers often make the point that good recovery from a service failure is important for building loyalty to the service provider. The research has tended to focus on rather simple services, where failure and recovery are relatively easy to define – in the case of KIBS and Foresight activities, this may be much less evident. The role of the client in recovery is addressed in some recent literature, however, e.g. Dong et al. (2008).
20. Here it is extremely interesting to see the work of the Design Council on public service design – see http://www.designcouncil.org.uk/briefing02 and many other pages on that website (accessed 23/07/2012).
21. For more on service design, and links to the journal *Touchpoint*, see http://www.service-design-network.org/ (accessed 23/06/2012).
22. Though we might expect to see more limited forecasting activities to be more readily amenable to such approaches.

## References

Alvesson M, Kärreman D, Sturdy A, Handley K (2009) Unpacking the client(s): constructions, positions and client–consultant dynamics. Scand J Manage 25(3):253–263
Baines TS, Lighfoot HW, Benedettini O, Kay JM (2009) The servitization of manufacturing. A review of literature and reflection on future challenges. J Manuf Technol 20(5):547–567
Bettencourt L, Ostrom A, Brown S, Roundtree R (2002) Client co-production in knowledge-intensive business services. Calif Manage Rev 44(4):100–128
Bitner MJ (1992) Servicescapes: the impact of physical surroundings on customers and employees. J Mark 56:57–71
Bitner MJ, Ostrom A, Morgan F (2008) Service blueprinting: a practical technique for service innovation. Calif Manage Rev 50(3):66–94
Coombs R, Miles I (2000) Innovation, measurement and services. In: Metcalfe JS, Miles I (eds) Innovation systems in the service economy. Measurement and case study analysis. Kluwer, Boston, pp 85–103
Dong B, Evans KR, Zou S (2008) The effects of customer participation in co-created service recovery. J Acad Mark Sci 36(1):123–137
Droege H, Hildebrand D, Heras Forcada MA (2009) Innovation in services: present findings, and future pathways. J Serv Manage 20(2):131–155
Eurostat (2008) NACE Rev 2: statistical classification of economic activities in the European Community. European Communities, Luxembourg, ISSN 1977-0375. At: http://circa.europa.eu/irc/dsis/nacecpacon/info/data/en/NACE Rev 2 structure + explanatory notes – EN.pdf. Accessed 23 July 2012
Gallouj C (1997) Asymmetry of information and the service relationship: selection and evaluation of the service provider. Int J Serv Ind Manage 8(1):42–64
Gallouj F (1998) Innovating in reverse: services and the reverse product cycle. Eur J Innov Manage 8(3):123–138
Ghobadian A, Speller S, Jones M (1994) Service quality: concepts and models. Int J Qual Reliab Manage 11(9):43–66
Glushko RJ (2010) Seven contexts for service system design. In: Maglio PP, Kieliszewski C, Spohrer J (eds) Handbook of service science. Springer, New York, pp 219–249
Glushko RJ, Tabas L (2009) Designing service systems by bridging the 'front stage' and 'back stage'. Inf Syst E-Bus Manage 7(4):407–427
Grönroosa C, Ojasalo K (2004) Service productivity: towards a conceptualization of the transformation of inputs into economic results in services. J Bus Res 57:414–423
Gummesson E (1991) Truths and myths in service quality. Int J Serv Ind Manage 2(3):7–16
Hart CWL, Heskett JL, Sasser WE Jr (1990) The profitable art of service recovery. Harv Bus Rev 68(4):148–156
Irvine J, Martin B (1984) Foresight in science. Edward Elgar, Aldershot
Maglio PP, Kieliszewski CA, Spohrer JC (eds) (2010) The handbook of service science. Springer, New York
Martin B, Irvine J (1989) Research Foresight. Edward Elgar, Aldershot
McKechnie DS, Grant J, Golawala FS (2011) Partitioning service encounters into touchpoints to enhance quality. Int J Qual Serv Sci 3(2):146–165
Miles I (2005) UK Foresight: three cycles on a highway. Int J Foresight Innov Policy 2(1):1–34
Miles I (2010) The development of technology Foresight: a review. Technol Forecast Soc Change 77(9):1448–1456
Miles I (2012) Dynamic Foresight evaluation. Foresight 14(1):69–81
Miles I, Miles I (2012) KIBS and knowledge dynamics in client-supplier interaction. In: Di Maria E, Grandinetti R, Di Bernardo B (eds) Exploring knowledge-intensive business service: knowledge management strategies. Palgrave, London, pp 13–34
Miller JL, Craighead CW, Karwan KR (2000) Service recovery: a framework and empirical investigation. J Oper Manage 18:387–400

Parasuraman A, Zeithaml VA, Berry LL (1985) A conceptual model of service quality and its implications for future research. J Mark 49:41–50

Shostack GL (1984) Designing services that deliver. Harv Bus Rev 62:133–139

Strambach S (2008) Knowledge-intensive business services (KIBS) as drivers of multilevel knowledge dynamics. Int J Serv Technol Manage 10(2/3/4):152–174

Valminen K, Toivonen M (2012) Seeking efficiency through productisation: a case study of small KIBS participating in a productisation project. Serv Ind J 32(2):273–289

Vandermerwe S, Rada J (1988) Servitization of business: adding value by adding services. Eur Manage J 6(4):314–324

Vargo S, Lusch RF (2006) Service-dominant logic: what it is, what it is not, what it might be. In: Lusch RF, Vargo S (eds) The service-dominant logic of marketing: dialog, debate, and directions. M.E. Sharpe, Armonk

# Chapter 6
# Systemic Foresight Methodology

**Ozcan Saritas**

## 6.1 Introduction

As an unavoidable human trait of thinking about the future, foresight has been practiced since the existence of the first human being on earth. The use of individual foresight in a collective and participative way, however, is a rather new phenomenon, which led to today's formal, institutionalized Foresight. More recently Foresight has been a widely acclaimed activity associated with policy making by government, industry and other organisations to shape the society's future. As the complexity of societies has increased, the scope of Foresight activities has widened to cover a wide variety of issues. This has been mainly due to the increasing importance of technological and organisational innovation; the development of service economies; and other developments such as rapid globalisation, and changing nature of demographical structures, cultural practices, environmental affairs and social services.

Foresight practice has evolved in time to address the expectations of various stakeholders and challenges of their times. For instance, the Foresight practice in the 50s and 60s was mainly characterised by the forecasting of the future technologies mainly for defence purposes as required by the conditions of the cold war in the post-WW2 period. The nature of the situations has changed in time and so as the Foresight practice. This paper mainly considers the complexities

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O. Saritas (✉)
Manchester Institute of Innovation Research (MIOIR), University of Manchester, Oxford Road M13 9PL, Manchester, UK

Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE), Moscow, Russia
e-mail: Ozcan.Saritas@manchester.ac.uk

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and uncertainties of the current world and discusses how Foresight practice can be more responsive to tackle with today's more 'systemic' situations involved in human and social systems, which are 'open' in nature and require more customised methodological approaches. This paper introduces the Systemic Foresight Methodology (SFM) as a way to cope with the complexities of the human and social systems and to develop a more tailored Foresight methodology with the integration of qualitative and quantitative Foresight tools in line the nature of situations. The need for systems thinking and adapting Foresight into its context have been highlighted (see Aaltonen and Sanders 2006; Salo et al. 2004; Forlearn[1]). Besides acknowledging these necessities with systems theory and practical evidence, the SFM sets out to create systemic concepts and methodological frameworks that are useable for future-oriented idea creation in complex human and social systems. It considers the Foresight activity as a 'systemic inquiry' where the actual design of the system can only be partially specified in advance of system operation. This is because, when human and social systems are dealt with, the most thoughtful and carefully designed systems may have unintended consequences. System behaviour and informal structure emerge only through system operation regardless of the detail or diligence in design efforts prior to system deployment. The over-specification of a system's requirements (i) wastes limited resources, (ii) reduces system autonomy, which means the agility and flexibility of the system to respond to environmental shifts are reduced, and (iii) fails to permit subsystem elements to self-organise based on their contextual knowledge, understanding and proximity to the operating environment.

The SFM sees the design of an institutional Foresight activity as a creative process that will be engaged in designing a future system to fulfil goals and expectations. Therefore, the SFM specifies only the minimal requirements necessary to achieve the systems objectives. Thus, the SFM suggests a learning system, which structures a systems-based debate to formulate the basic processes of (1) Intelligence (scoping, surveying and scanning phase) (2) Imagination (creative and diverging phase), (3) Integration (ordering and converging phase), (4) Interpretation (strategy phase), (5) Intervention (action phase), (6) Impact (evaluation phase), and (7) Interaction (interactive and participative phase) which continues throughout activity.

The phases explain how systems such as human and social systems, industrial and sectoral systems, and innovation systems are understood, approached and intervened for a successful change process. They follow each other iteratively and can be repeated as many times until the practitioners believe that their complete function has been fulfilled. The aim is to guide practitioners to set their agendas for the different phases of the Foresight activity and to give direction to their thinking processes in order to (i) design a Foresight methodology, which fits well with the context and content of the exercise, and thus (ii) to decision making involved in thinking about the future and connecting the future with the present policies and actions.

While giving a process orientation for the design and implementation of Foresight exercises with these phases, three strands of Foresight (Miles and Keenan 2002) with three further additions are introduced, including: (i) Futures strand

[1] Forlearn Online Foresight Guide (http://forlearn.jrc.ec.europa.eu/guide/).

('when'); (ii) Capacity building strand ('who'); (iii) Strategic planning strand ('how'); (iv) Worldviews/goals strand ('why'); (v) Institutions/structures strand ('what'); and (vi) Theme strand ('which'). The six strands aim to provide an agenda for each phase of the Foresight activity.

The combination of the phases and strands constitute the conceptual framework of the SFM, which will be introduced following a brief overview of institutional Foresight as a systematic activity and the evolution of practice in time. The purpose is to demonstrate how the situations in the world have changed and how Foresight practice was adapted to address the expectations and challenges of different decades starting from the 50s. The key requirements for Foresight in the 2010s are characterised by uncertainty and complexity in the STEEPV systems with an increasing need for systemic thinking. Highlighting the need for more holistic and systemic thinking due to increasing interrelationships and interdependencies in complex systems, the paper discusses the underlying concepts of systems thinking, which will constitute the basis for the development of the SFM. The paper then will continue with the description of the SFM framework and its phases. Two case studies will be described, where the SFM was used first to give a process orientation to Foresight activities in Higher Education Institutions and then for the selection and combination of methods in a Renewable Energy exercise. The paper concludes that the SFM is a potentially useful conceptual framework when designing a Foresight exercise in complex and uncertain social and human systems.

## 6.2 Foresight: The Evolution of Practice

As practiced institutional Foresight is an outgrowth of a long and historic tradition of 'foresight'. Stemming from the *unavoidable human trait of thinking about the future* (Loveridge 2009) as a concept, and from planning and forecasting as a structured activity, institutional Foresight essentially implies some form of 'participative vision-based planning process'. First formal Foresight efforts existed from the sixteenth to eighteenth centuries when Foresight was used to improve decision making and public debate, and to anticipate long-term trends and long-term implications of short-term decisions. Wide array of issues were covered by those efforts, particularly after the Industrial Revolution which caused major transformations in science, technology and society and thus increased the concerns for the future. In the nineteenth century, efforts have been made to think about the future of capitalist economies. These efforts were mainly initiated by classical political economists. In the early 1900s, the principles of trend extrapolation and social indicators were established. First systematic methods of expert analysis (i.e. Delphi and Cross impact) were established around the mid-twentieth century. First computer simulation studies were well known around the same time.

During the 1950s and 1960s, which mark the post-WW2 period, Foresight was narrowed down to anticipate new technology areas. These efforts were mainly called 'forecasting' to explain that they were concerned with the 'probabilistic assessment of what is likely to happen in the future'. Applications were seen in military and large corporations with the main focus areas on science and engineering. The work was carried out with the participation of a limited group of experts and futurologists. Creative and consultative methods like Delphi, scenarios, brainstorming and expert panels were extensively used. The work undertaken by the US Department of Defence, the US Navy and field surveys such as on astronomy and life sciences can be given as examples.

A change in the understanding of forecasting was witnessed in the early 1970s due to major crises such as the unexpected oil-shocks. Such unpredictable events caused doubts on the reliability of forecasting. Around the same time, Meadows et al.'s (1972) famous book "*Limits to Growth*" depicted the complexity and uncertainty of the world systems. Consequently, towards the end of the decade forecasting tended to be less deterministic due to a common understanding of 'the future is simply not the extension of the past. The underlying assumptions of forecasting changed that discontinuities existed. During the 1970s, efforts were made in Japan to forecast the future of Science and Technology (S&T). Conducted with the aim of informing national S&T policy, Japanese national forecasting activities incorporated economic and social needs as well as the S&T advances.

The Foresight activities in the 1980s can be characterised by the consideration of 'multiple futures' to express a wider frame of uncertainties involved in the world and society. During this time institutional Foresight was widely acclaimed by national governments as an activity associated with the identification of priorities and development of long-term S&T policies. Activities carried out in France (e.g. National Colloquium on Research & Technology) and in the Netherlands (e.g. the Foresight exercises initiated by Ministry of Education and Science) can be given as examples (see Papon 1988; van Dijk 1991).

During the 1990s, exercises have been lengthily organised and carried out by government advisory boards, research councils, national academies of sciences, other governmental departments, industrial associations and in firms. Large scale national Foresight programmes were conducted in Germany, France and the UK, which then inspired a number of other countries in Europe and around the world to start their own programmes. S&T was the central focus of those activities. Developments in S&T were seen in relation to economic and social developments. This type of Foresight exercise is defined as: *the process involved in systematically attempting to look into the longer term future of science, technology, the economy, and society with the aim of identifying areas of strategic research and the emerging new technologies likely to yield the greatest economic and social benefits* (Martin 1995).

As the complexity of societies has increased, the scope and focus of Foresight activities have widened to cover a wide variety of issues in the 2000s. Reflecting its broad focus and application areas, the recent definitions of Foresight in the 2000s emphasised more on the process of Foresight than its scope or coverage (i.e. the use of science and technology to achieve economic benefits): Foresight is *the application of 'systematic,' 'participatory,' 'future-intelligence-gathering and medium-to-*

*long-term vision building process*' to '*informing present-day decisions and mobilising joint actions*' (Miles and Keenan 2002).

What is next? Foresight shapes the world through policy, but it is also shaped by the wider contexts and developments in these contexts. Transformations in today's society is ongoing at a higher speed due to the factors like the increasing importance of technological, organisational and social innovation; the development of service economies; and other developments such as rapid globalisation, and changing nature of demographical structures, cultural practices, environmental affairs and social services. These resulted with a world which is more interconnected, interdependent and complex than ever. Therefore, a need has occurred to improve the Foresight practice to tackle with these new situations in a more sensible way and to respond to more sustainable policy needs. Any new Foresight approach in this regard should aim for understanding these complex systems and their behaviours, thus needs to be 'systemic'. The current paper posits that the Foresight practice in the 2010s will be shaped by the notions of systems thinking. As a first step of understanding systems, the following section will discuss the underlying concepts of systems thinking, which will constitute the base for the development of a SFM.

## 6.3 Systems Thinking

The medieval hierarchical metaphor relating to society and the heavens was replaced by a mechanical metaphor with the rise of modern science from the 1500s to 1600s (e.g. Galileo and Newton). Science was transformed by a dramatic new idea that the rules based on mathematical equations could be used to describe the natural world. This mechanistic and reductionist principles fed the growth of the physical sciences phenomenally. In their interest for natural science, social theorists also enthusiastically adopted mechanistic model (Bausch 2002).

However, mechanistic models faced challenges when they were applied to complex problems. Thus, there occurred a need to study the interconnectedness of phenomena and the mechanisms that generate the phenomena, as well as the complex wholes with their 'emergent properties' emerging not from individual parts, but their interaction. The idea of using the concept of 'system' to understand phenomena is attributed to Ludwig von Bertalanffy's work in the late 1920s. According to Bertalanffy (1929), a singular causal analysis was no more possible when considering the complexity of the whole organism.

This gave rise to the introduction of the idea of 'systems' as an approach to deal with the complexity inherent in physical, living and social systems (Churchman 1968; Beer 1979; Ackoff 1981). Thus, the central concept of a 'system' embodies: *A set of elements connected together which form a whole, this showing the properties which are properties of the whole, rather than properties of its component parts* (Checkland 1981).

Stemming from this definition, 'systems thinking' is about viewing 'events' as a system and/or parts of larger systems. Systems thinking inherited a set of powerful systems ideas such as ‘system’, ‘element’, ‘relationship’, ‘input’, ‘output’, ‘boundary’, ‘feedback’, and ‘communication’. These ideas led to the development of the basic features of systems thinking including: (i) Causality, (ii) Holism, (iii) Hierarchy, and (iv) Continuity. Systems approaches and methodologies have been built upon these concepts. Therefore, it is useful to give a brief definition of each.

***Causality.*** Represents the effect of one or more system elements on the properties or the behavious of the other(s). It is embodied through communication among system elements via ‘feed-back’ and ‘feed-forward’ channels (Kay et al. 1999; Hammond 2002). The communication among system elements is due to the reason that they are (1) interrelated, and (2) interdependent (Modarres and Cheon 1999). Interrelatedness explains the connections between the elements of the system and implies that the system taken as a whole has properties that differ from those of the simple sum of the effects of the individual relationships between the pairs of elements. Interdependency is more specific and is the way the relationships are conducted. The properties and behaviour of each system element and the way they affect the whole, depend on the properties and behaviour of at least one other element in the set. This advocates holism in systems thinking.

***Holism.*** One of the key features of systems thinking is the claim that it is holistic, giving three messages: (i) the whole is more than the sum of its parts, (ii) the parts cannot be considered in isolation from the whole, and (iii) the behaviour of the system cannot be understood independent from its context.

***Hierarchy.*** Hierarchy explains the grouping or arrangement of system according to their higher and lower influence and coverage levels (e.g. upper level systems and sub-systems or nested systems). Hierarchy emerges naturally in all evolving systems (Simon 1962). This is because, systems exist as parts of larger wholes, while they themselves provide organisation to their sub-systems (Koestler 1967; Churchman 1968). A system hierarchy may not always indicate well defined conceptual boundaries, particularly in complex systems where the relationships are not simple or complicated. This holds true both for present and future systems, which the FTA is concerned with.

***Continuity.*** Systems thinking recognises that systems transform themselves continuously, and therefore are dynamic. Thus, continuity in systems explains an iterative, dynamic and non-linear process. In systems terms, two types of continuity can be mentioned (i) the continuity of a looped action sequence, and (ii) the recursion of the looped action sequence in time. The first type of continuity can be best represented with Argyris and Schon’s (1978) ‘single-loop’ and ‘double-loop’ learning systems. During these loops a system reproduces a continually changed self (Argyyis 1976; Argyyis and Schon 1978). The recursion of the looped action sequence in time brings the second type of continuity. Vickers’s (1965) “Appreciative System” can be given as an example to demonstrate this type of continuity, where the flux of events and ideas in time generate a new appreciation, and appreciation itself leads to action while improving standards and norms.

A number of different systems can be mentioned including ‘closed’ and ‘open’ systems. Various systems approaches have been suggested to deal with those systems like ‘hard’ or ‘functionalist’ systems approach (Churchman et al. 1957);

'soft' or 'interpretive' systems approach (Checkland 1981); and a more recent addition 'emancipatory' or 'radical' systems approach (Jackson 2001). These approaches have all been built upon the basic features of systems thinking. They suggest various ways of understanding and solving the problems in either mechanical or social systems.

The dominant systems thinking of the post-WW2 period evolved in the context of mechanistic thinking. This understanding was based on a body of well-developed and tested theory stemming from engineering systems. It was assumed that systems of all types could be identified by empirical observation of the reality and could be analysed by the same approaches which had brought success in natural sciences. Supporting one single perspective of the reality, it was assumed that systems were the 'objective' aspects of reality, which could be represented equally by different observers. The components of the system were considered to have clear causal interconnections and relationships between them. The functionalist approaches have seen successful applications in 'bounded' situations, where the components of the system behave in a manner that is nearly optimal with respect to its goals and resources (Simon 1957, 1962). However, this type of approach can only cope with low human complexity and low to medium divergence of interests.

The interpretive (soft) allows a greater responsiveness to the peculiarities of each situation. Thus, the intervention to systems evolves as the situation changes. Therefore, it can be said that a system is defined for a particular situation given. The interpretive approach accepts that human and social systems cannot, in principal, be explained in a purely functional way. In the interpretive approach, the definition of a system reflects the observer's world view. Therefore, there is a subjectivist view of systems, which means that no assumption is made to represent the system as it is in reality. Rather, it is seen as a conceptualisation of what the observer views as a useful and convenient representation of elements and interrelationships in view of learning more about the behaviour of a system.

Like the interpretive approach, the emancipatory systems approach takes a subjectivist view of systems. The emancipatory approach has evolved in response to challenges imposed by complexities of socio-cultural systems in 'radical' cases where, for example, conflicts and unequal power distribution occur. The basic idea of emancipatory approach lies in its thinking that various stakeholders in society may see systems radically different with different values and boundary judgements. The radical view accepts that these stakeholders may be in conflict of confrontational relationship with each other and may be unequal in terms of their power. Thus, the emancipatory approach aims to identify inequalities and promote radical changes.

The nature of the situations under investigation determines the kind of system approach to be used for understanding and intervention.

## 6.4 Systemic Foresight Methodology (SFM)

### *6.4.1 Background of the SFM*

The review of literature and the evaluation of current Foresight practice reveal that there is a great potential that systems thinking might assuage the Foresight practice when dealing with complex social and human systems and situations involved in them. With its basic features outlined above, systems thinking recognises complexity and uncertainty involved both in real world systems (physical and social) and in idea creation, while attempting to propose actions within either bounded or open systems. If institutional Foresight acknowledges the importance of '**causality**', then it would be possible to understand how system elements affect the properties or the behaviours of other system elements and thus the behaviour of the whole system. Understanding the interrelationships and interdependencies is necessary for the discussion and definition of system boundaries, which is one of the most crucial phases of Foresight.

Consideration on the relationships between and within systems turns attentions from individual system elements to the wholes. With the adoption of the '**holistic**' thinking, the SFM pays attention to the forces outside, which may have impacts on the viability and success of the system under investigation. Thus, decisions taken will be better prepared against the influences originating from the wider context. Similarly, the decision makers will appreciate the impacts of their decisions on wider social and environmental systems. Foresight focuses on the systems or bits of them which can have strong potentials to change or transform the wider systems.

Understanding the '**hierarchy**' of systems provides structural and functional boundaries for Foresight. Structurally, attentions are turned to the description of the system, its parts and other higher and lower level systems, their arrangements and interactions. This would allow Foresight to facilitate communication and information flow via feed-back and feed-forward mechanisms, which will allow: (i) to provide continuous adaptation of the Foresight system to changing internal and external conditions, and (ii) to secure improvement and further development while providing for maintenance of stability. Furthermore, the understanding the functional hierarchy will bridge the principle purpose of doing Foresight with the activities carried out throughout the exercise. From this viewpoint, activities can be considered as the functions and sub-functions of the overall objectives. The realisation of functions and sub-functions will assure that the objectives of Foresight are achieved. Having this viewpoint, the systemic approach will enable the integration of 'ends' (what is wanted) and 'means' (how to get there) of the Foresight activity.

Systems thinking recognises that systems transform themselves continuously and therefore are dynamic. This implies a dynamic and non-linear process for Foresight. **'Continuity'** for Foresight first means that the process flows from understanding to anticipation and then to transformation, and the recurrence of this process in a looped manner. This continuous looped action sequence in time brings the second type of continuity. Here the Foresight system learns, evolves and intervenes into situations through the modification of norms, policies and objectives.

Having set its underlying assumptions, the SFM claims that a robust Foresight exercise involves a continuous interplay between the context, content and process of change together with skills in regulating the relations between the three (Fig. 6.2). Any change activity, like Foresight, should be linked to a broader context. The lack of attention away from the context leaves the critical issues unrecognised. Thus, Foresight should not strive to understand the issues as episodes divorced from the historical, organisational and/or economic systems from which they emerge. Three important points can be specified for further examination of the context of Foresight:

1. The need to gain a rich understanding of existing systems and procedures, their history and possible futures
2. The analysis of different stakeholder perspectives and their social relations in the system, which can affect and be affected by the process
3. The impacts of formal and informal networks and procedures, which can be in favour or in conflict with other systems

Considering the nature of the Foresight activity, two context levels can be distinguished: (1) External context, and (2) Internal context. Foresight is embedded in these two contexts which produce and are produced by the activity. The Foresight activity is then about perceiving the context through a holistic scanning exercise; capturing the points of intervention, which constitute the content of the change programme; and anticipating, and developing future-oriented policies and strategies on this content through a designed process. Thus the overall SFM can be represented as follows (Fig. 6.1):

The Social, Technological, Economic, Environmental, Political, and Value (STEEPV) systems constitute the external context, where the Foresight activity is embedded in and thus is influenced by the factors in them. Foresight aims for improving or changing one or more parts of these systems. The content, or agenda, of the Foresight exercise is extracted from the STEEPV systems, which are interrelated and interdependent and constitute the real world situations. Loveridge and Saritas (2009) have formulated three questions to be asked as a starting point to investigate into those situations (Fig. 6.2).

The contents of the first two questions are recognised in the context of science (possible) and technology (feasible). However, both have added contexts and contents that extend into the third question of desirability where the social, political and value contexts intersect with the two questions in interdependencies of governance, regulation, precaution, social acceptance and policy.

Besides understanding the external context, it is also essential to investigate on the internal context, which can be considered as a filtering factor when the external context is viewed and appreciated and the content of the Foresight activity is built. The internal context relates to the structures (e.g. internal processes, procedures, equipment and technologies) and behaviours (e.g. culture, politics, social

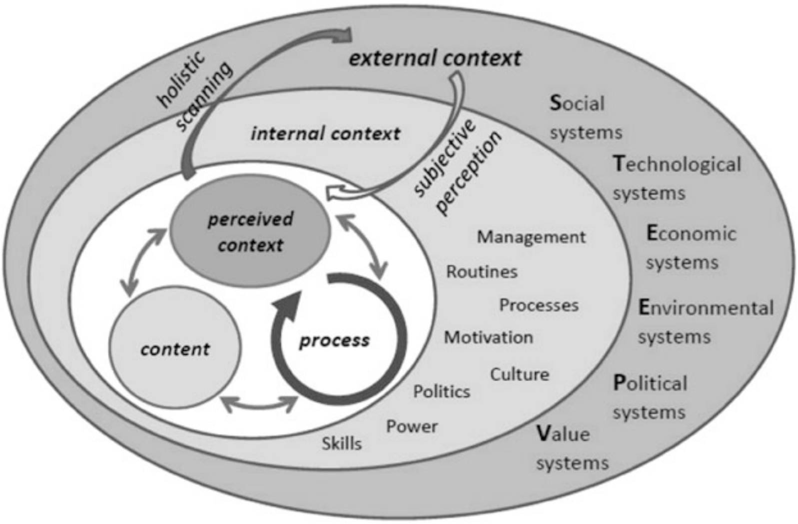


**Fig. 6.1** Systemic Foresight concept

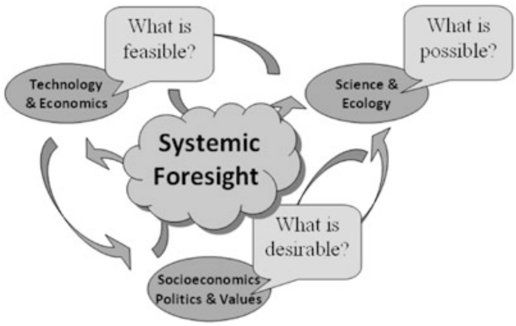


**Fig. 6.2** Questions for systemic Foresight

interaction, skills, motivation, power and management styles) within the context of the organisation where institutional Foresight is organised and carried out. The internal context covers all parties involved in designing, organising and deploying the Foresight activity. The success of the activity is dependent on a large extent on these parties and their motivation and expertise in field.

In Foresight, the ‘what’ of change is encapsulated under the label of content, which refers to (1) the subject area(s) taken into consideration, which are captured from the context through scanning, and (2) the ideas created related to those areas during the Foresight activity. The main goal of Foresight in this sense is to introduce change or improvements into the content of the exercise and thus to provide further changes or improvements in the context.

#### 6.4.1.1 Behavioural Matters in Foresight

Foresight creates information for the future of society under uncertainty and complexity. It is expected to place greater emphasis on the need for the active participation by a balanced but wide spread of stakeholders who, through involvement in decision making and behavioural matters will help to shape the future of society, in this way distinguishing the proposals from other future oriented policy making tools. Changing scope and focus of Foresight requires the activity to be enabled a much wider cross section of people to take part. In order to achieve this inclusivity, the organisers of the activities need to put much effort into understanding these behavioural matters. The SFM also considers the behavioural matters and recognizes their pervasive influence throughout all Foresight process. Behavioural matters are inherent both in systems and in the Foresight process itself.

The notion of 'open' system comes from the unpredictability of the behaviours of the system elements. In this respect, systems, particularly human and social systems, behave differently both spatially and in time under different circumstances. Therefore, systemic investigations require specific approaches, which are developed following an 'understanding' phase.

The Foresight process itself is 'soft' and 'open' due to the inclusivity of various actors and stakeholders in the process with different perceptions, worldviews and visions. *Inclusivity is a matter of creating trust across a wide range of communities in discussions of future developments (...). The objective ought to be to enable the participation of a broad spectrum of people who are concerned about the feasibility of technological developments and their desirability. To introduce inclusiveness will require a change in mind-set by programme sponsors, organisers, practitioners, the direct participants and the audience to whom the outcome is directed. Indeed, the process has to be one in which experts and non-experts regard each other as equal but different agendas and capabilities that each needs to understand. Bringing this mutual appreciation about will test communication and interpersonal social skills to their limit. In this sense inclusiveness is a matter of definition and process. Extending participation introduces specific management and process needs if Foresight programmes are to be extended into the social sphere without becoming chaotic* (Loveridge and Saritas 2009).

Understanding the behavioural matters in Foresight would lead to a more dynamic and adaptive way of conducting the activity. During the process of Foresight, the organisers and participants of the activity should be seen not only as the technical experts, but also as the key agents of social and organisational change. Transformation of a system from its present state to a more desirable future state requires actions to change the individual and organisational behaviours. The role of behavioural matters in Foresight will be discussed with the case of the Higher Education Foresight case, which will be presented in the next sections of the paper following the description of the phases of the SFM.

## 6.4.2 *The Phases of the SFM*

The SFM sets out to create systemic concepts that are useable for future-oriented idea creation in complex human and social systems. The SFM considers the Foresight activity as a 'systemic inquiry' where the actual design of the system can only be partially specified in advance of system operation. This is because, when human and social systems are dealt with, the most thoughtful and carefully designed systems may have unintended consequences. System behaviour and informal structure emerge only through system operation regardless of the detail or diligence in design efforts prior to system deployment.

The SFM considers the design of an institutional Foresight activity as a creative process that will be engaged in designing a future system to fulfil goals and expectations. Therefore, the SFM specifies only the minimal requirements necessary to achieve the systems objectives. Thus, the SFM suggests a learning system, which structures a systems-based debate to formulate the basic phases of: (1) Intelligence, (2) Imagination, (3) Integration, (4) Interpretation, (5) Intervention, (6) Impact, and (7) Interaction. These phases aim at guiding Foresight practitioners to set their agendas for the different phases of the Foresight activity and to give direction to their thinking processes. The benefits of this approach lies in its systemic guiding (1) to the design of a Foresight methodology, which fits well with the context and content of the exercise, and thus (2) to decision making involved in thinking about the future and connecting the future with the present.

The consecutive phases explain how systems such as human and social systems, industrial and sectoral systems, and innovation systems are understood, approached and intervened for a successful change process. They follow each other, as the steps of the Foresight process, but they are iterative and can be repeated as many times until the practitioners believe that their complete function has been fulfilled.

The SFM is suggested as a conceptual base for the design, organization and deployment of Foresight exercises. Methods are not the departure points of the SFM approach. They are used to support and develop understanding of the situations, to discuss and develop alternative models of the future and achieve outcomes through networking, mutual learning and collective visioning, and outputs in the form of policies and strategies. Methods are selected and integrated following a comprehensive 'understanding' exercise. In this way, methodological solutions are produced after the diagnosis and conceptualisation of situations. Figure 6.3 illustrates the phases of the SFM.

#### 6.4.2.1 Intelligence (Scoping Phase: Surveying, Scanning, Evidence)

Intelligence is the first and fundamental step of the SFM. Foresight deals with are usually complex systems, which consist of a large number of interacting elements (Roe 1998). According to Roe, the appropriate approach to complexity is to embrace it and resulting uncertainty and to analyse different subsets of interactions

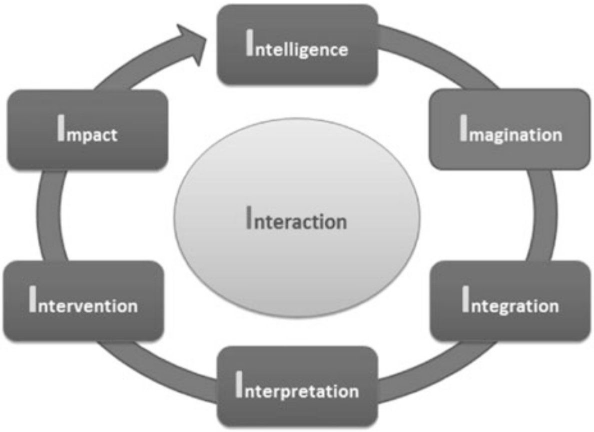


**Fig. 6.3** Phases of the Systemic Foresight Methodology

which may be relevant from a number of fundamentally different operational and philosophical perspectives.

Holling (2000) and Gunderson and Holling (2001) suggest alternative ways of dealing with complexity. Holling (2001) states that *the complexity of living systems of people and nature emerges not from a random association of a large number of interacting factors rather from a smaller number of controlling processes. These systems are self-organised, and a small set of critical processes create and maintain this self-organisation (…) There is a requisite level of simplicity behind the complexity that, if defined, can lead to an understanding that is rigorously developed but can be communicated lucidly* (p. 390). Whatever way of understanding the complexity is adopted, when the complex systems are examined, the following criteria suggested by Holling (2001) should be satisfied:

- Be "as simple as possible but no simpler (Einstein)" than is required for understanding and communication
- Be dynamic and prescriptive, not static and descriptive. Monitoring of the present and past is static unless it connects to policies and actions and to the evaluation of different futures
- Embrace uncertainty and unpredictability. Surprise and structural change are inevitable in systems of people and nature (p. 391)

As the first phase of the systemic process of inquiry, the Intelligence phase begins with a comprehensive understanding and scanning exercise, which provides input for the overall activity. Understanding seeks to attain a reasonably comprehensive view of situations involved in the STEEPV systems. The aim is to gain a shared understanding and mutual appreciation of situations, issues, and influencing factors as systems within their own contexts by uncovering uncertainties about the values and preferences of actors and stakeholders, and clarifying the goals of the entire activity. In this way, the SFM offers a mind-set for understanding how systems work and behave. The aim is not necessarily to bring about a convergence of views, but, at least a partial convergence is likely to emerge from this process in practice.

As an integral part of the Intelligence phase, scanning provides basic input to the entire activity. Overall, scanning is concerned with the systematic examination of potential threats, opportunities and likely future developments, which are at the margins of current thinking and planning (DEFRA 2002). Selecting the main areas for intervention, the boundaries of the Foresight are drawn and the 'content' of Foresight is built through an initial scanning activity. Various quantitative and qualitative Foresight methods can be used to create input at this phase including horizon scanning, bibliometrics, literature review, and analysis of trends, drivers, weak signals, wild cards/shocks/surprises, and discontinuities (Saritas and Smith 2011).

As a result of this process, the initial boundaries of the system under investigation can be drawn and the content of change can be defined by capturing the key drivers of change, and other factors which may have strong potential impacts on the future of the systems under investigation.

#### 6.4.2.2 Imagination (Creative Phase: Concepts, Models, Scenarios, Visions)

The input gained from the Intelligence phase is synthesized around the models of the situations involved in the real world. These are conceptual models to a large extent which are shaped by the subjective perceptions of the observers involved in the activity. The aim is not to obtain the true representations of the situations, but to achieve agreeable and workable models, which should be able to represent:

- Wealth of a system: The inherent potential of a system that is available for change, since that potential determines the range of future options possible. Wealth or potential of a system sets limits for what is possible and determines the number of alternative options for the future
- Controllability of a system: A measure that reflects the degree of flexibility of the rigidity of a system. It determines the degree to which a system can control its destiny
- Adaptive capacity: The resilience of a system as a measure of its vulnerability to unexpected and unpredictable shocks

The boundaries of the Foresight activity are finalised based on the modelling exercise. The next step is then the development of future models to explore alternative images of the future based on anticipation. These models will cover a range of possible, plausible and desirable future systems. Independent from existing systems and their influence, fundamentally new systems can be suggested with the involvement of high level of creativity. New actors and stakeholders can be brought in, existing ones can be removed, and/or new roles can be suggested for them. Similarly, new relationships between the system elements can be established and existing ones can be modified and/or removed. The overall aim is to create a desirable future system.

Visual representation tools are very valuable to understand systems, their elements and the relationships between them. Systemic models represented can portray how the impacts of trends and emerging issues move inward and outward, and influence the structure, behaviours, opportunities and constraints. These models lead to the creation of various alternative scenarios for the future. Modelling, Scenario planning, Gaming and Simulation are the methods which may be of help to explore alternative futures. The analysis of Weak Signals and Wild Cards may help to test the adaptive capacity of systems under extreme conditions, and surprises. The Imagination phase involves high level of creativity and innovative thinking.

#### 6.4.2.3 Integration (Ordering Phase: Analysis, Negotiations, Priorities)

Following the construction of alternative models of the future in the Imagination phase, the Integration phase is concerned with the systemic analysis of those alternatives and selecting the most desirable one. The analysis and selection of a desired system is multifaceted as there is a variety of worldviews and expectations to be negotiated. According to Ackoff (1981), for a system to be viable in the long term, the claims of different stakeholders must be considered adequately, and therefore, attention must be given to ethical and aesthetic aspects for the pursuit of ideals such as beauty, truth, good and plenty. Therefore, there is a strong element of negotiations involved to determine priorities in the light of an agreed vision.

During this process, decisions on the desired future system need to be aligned with the normative goals and values. An inclusive process, where the creative exchange of ideas and information sharing among participants is experienced, is beneficial. The definition of the 'most desirable' future system is a matter of 'prioritisation'. The end product of this phase is an agreed model of the future. Methods like Delphi, Cross Impact Analysis, Multi-Criteria Analysis, SWOT and/or Cost/Benefit/Risk analysis can be considered among the methods to support this process.

#### 6.4.2.4 Interpretation (Strategy Phase: Agendas, Strategies)

Following the decision on the most desirable/preferable future, this phase aims to connect this future with the present and sets out agendas and strategies for action. Thus, the Interpretation phase establishes the relationship between the future and the present for a successful change programme. The transformation from the present system to a desirable future system requires strategic level decisions to be taken such as on: (i) skills and educational systems needed; (ii) awareness of market and social demands for innovations; (iii) public acceptability of particular lines of advance, (iv) scope for formation and growth of firms, and (iv) financial institutions and incentives.

Due to the systemic relationships between these elements, the transformation process needs to bring a broad range of STEEPV factors together. The following factors constitute conditions for the successful transformation strategies:

- Assessment (e.g. processing information; developing an understanding of the continuously changing context; and becoming an open learning system)
- Leadership (e.g. having a context-sensitive leadership; creating capabilities for change; linking actions with resources; and constructing a climate for change)
- Linking strategic and operational change (e.g. supplying visions, values and directions; implementing intentions over time; and implementing supportive activities)
- Management of human resources (e.g. raising human resource management consciousness; demonstrating the need for change in people and behaviours; creating a longer term learning process with successive positive spirals of development)
- Coherence (e.g. achieving the consistency of goals, creating an adaptive response to environment; and maintaining competitive advantage)

A backcasting or roadmapping procedure would be beneficial to define the steps of the transformation process in the long, medium and short run.

#### 6.4.2.5 Intervention (Action Phase: Plans, Policies, Actions)

Any Foresight exercise has to inform policies and actions. Therefore the main action of the Intervention phase is action with the main activities involving the creation of plans, policies and actions to inform present day decisions concerning immediate change actions to implement structural and behavioural transformations. Actions suggested at this phase aim to give messages on the first and most immediate interventions to the existing systems. Operational level questions are asked for actions such as: ‘what and how’, ‘where and how’ and ‘who and how’. The actions for change are determined by considering the following capabilities of the system under investigation: (i) Adapting; (ii) Influencing and shaping its context; (iii) Finding a new milieu or modelling itself virtuously in its context; and (iv) Adding value to the viability and development of wider wholes in which it is embedded. Action plans, Operational plans, Priority lists, Critical/key technologies can be among the outputs produced at this phase.

#### 6.4.2.6 Impact (Evaluation Phase)

Foresight process requires substantive investments, often through public funding, and imply considerable costs in terms of time and expertise invested. If impacts of Foresight cannot be made clear, the commitment for investing resources will decrease, and as a result the activity will be discontinued. Therefore, an Impact phase is added to the process, which is concerned with the review, evaluation and renewal of the Foresight exercise. This phase will examine the impacts during the process (e.g. production of baseline reports, articulation of visions, and building new linkages), immediately after (e.g. new integrated projects and programmes) and sometime later (e.g. innovation impacts and new working communities).

The impacts of Foresight should be kept in mind from the beginning of the Foresight process, and the methodology should be designed to achieve those impacts. An effective communication strategy is essential during and after the Foresight process for assisting the participants and target audience in making sense of the results. Impacts of are measured through an evaluation exercise, which is commonly conducted based on three criteria including (i) appropriateness of objectives and methodology; (ii) efficiency of implementation with a focus on management and organisational processes, and appropriate use of funds; and (iii) impact and effectiveness through the recognition of the results, creation of a Foresight culture and new combinations of stakeholders and networks. Although the Impact phase can be considered as the final phase of the process, there is a strong learning element involved in this process, which determines how to design and implement and better Foresight exercise. Thus, it can also be considered as a beginning of the next cycle of Foresight.

#### 6.4.2.7 Interaction (Participative and Interactive Phase)

Foresight is an inclusive activity. Interaction with the systematic involvement of stakeholders in an inclusive process with long-term perspective for the analysis of different perspectives and their social relations in the system are crucial for the Foresight process. The SFM recognises the inclusiveness and equity through freedom of association and expression and the role of the democratic society, which may influence, restrain or block policy design and implementation. The Interaction phase emphasises the need for effectiveness and efficiency in meeting society's expectations and sustainable use of resources, and therefore, aims to develop mechanisms to provide contributions of society, institutions, corporations, and associations to enhance policy with a normative and legal framework.

All phases of the SFM described above are systemically interrelated. Each of them builds on the previous one, culminating in policies, strategies and actions for the design of a future system. However, information and action flow between the phases are not necessarily in a linear way, but from one to the others in a systemic way. Each phase can be iterated more than once until the outputs and process outcomes planned are achieved. Upon completion of the process the phases link back to create a full circle of Foresight in a continuous loop (Fig. 6.1) in a similar stance with Vickers's (1965) "Appreciative System" and Argyris and Schon's (1978) double-loop learning. This allows the continuous development and adaptation of systems. It is important to highlight that the process of Foresight is just as important as the end-product, and that the commitment to the process by participants is essential if the policies and strategies are to be successfully implemented.

In order to assist practitioners to build an agenda for each phase, the six strands of Foresight are introduced:

1. Futures strand ('when'): systematic exploration of trends, projections, scenarios, wild cards, and policy responses
2. Capacity building strand ('who'): a systematic development of shared learning, networking, collaboration and intelligence between stakeholders involved
3. Strategic planning strand ('how'): a systematic application to longer term policy, in the context of uncertainty, complexity and controversy of the issue – along with the following three further strands:
4. Worldviews/goals strand ('why'): the worldviews, values ad discourses between different stakeholders
5. Institutions/structures strand ('what'): factors in the institutions or structures related to the way systems are organised
6. Theme strand ('which'): specific areas in sectors or technologies as the focus of enquiry

First three have been suggested by Miles and Keenan (2002). Three more strands have been added to allow fuller information gathering and action planning. The SFM brings together the phases with the six strands of Foresight (Fig. 6.4).

The phases of Foresight provide a process orientation of the activity, while the strands of Foresight set out agenda for each phase.

### *6.4.3 The Use of Methods in the Systemic Foresight Methodology*

The systemic process described above does not take the methods as a starting point, as the methods need to be regarded as process and decision aids ('means'), not as the overall aim of the exercise in themselves ('ends'). Strengthened by the ideas of systems thinking, the SFM views Foresight methods as the tools to be used as part of the means to explore ideas, acquire information and data, clarify situations and negotiate solutions. Foresight is suggested to be not only a methodologically 'systematic' activity, but an activity, which creates its own methodological approaches with the consideration of the nature of the issue at hand and its context. It is due to, first, the peculiarities of each situation and, second, the subjective interpretation of those peculiarities, the SFM does not attempt to impose any methods from the earlier phases of the systemic inquiry. Instead of putting the methods at the forefront of investigation, the SFM suggests a more conceptual and flexible 'process orientation', which starts with a comprehensive 'understanding' of situations. Methods will be used, modified or tailored whenever needed. Furthermore, new methods will be created to handle the unique requirements of systems under investigation. While doing this, the SFM benefits from a pool of available foresight and forecasting methods and other planning and policy tools. It is

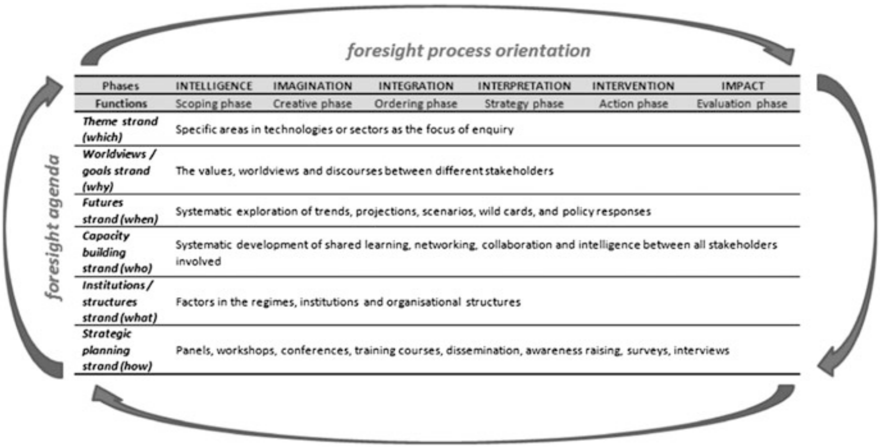


**Fig. 6.4** Architecture of the Systemic Foresight Methodology

considered to be useful, particularly for the practitioners, to specify various methods, which might be of use for each phase of the Foresight process (Fig. 6.5).

Each column in the figure indicates a phase of the systemic foresight process with their functions and key activities involved. The selection and integration of methods in the list are done under the guidance of the phases with a close interaction with the context, where the Foresight activity takes place and is expected to improve. Ranging from divergent and more creative methods to convergent and more quantitative, all methods involve a certain degree of information input, creativity, expertise and participation. The methods given in the table are indicative and the list can be extended with other methods given that they fulfil the functions of different phases described above. It is important to note that the use of the methods will also be determined by available resources including expertise, skills, time and budget along with the level and type of participation required.

## 6.5 SFM in Practice: Two Case Examples

The SFM described in this paper has been applied fully or partially in various Foresight exercises in different contexts. This section will describe two cases. The first case is about the implementation of the SFM in two university departments to first to develop visions and then formulate research and teaching strategy. In this case, the SFM is used to provide a process orientation to the overall Foresight activity. Two parallel cases, which started at the same time, highlight the soft and evolutionary nature of the Foresight process and emphasises the relationship between the context, content and process of Foresight. Both Foresight exercises resulted with different processes and methodologies. The reasons for this will be discussed from the SFM viewpoint. The second case briefly demonstrates how a

| Phases | INTELLIGENCE | IMAGINATION | INTEGRATION | INTERPRETATION | INTERVENTION | IMPACT |
|---|---|---|---|---|---|---|
| **Functions** | Scoping / surveying | Creative phase | Ordering phase | Strategy phase | Action phase | Evaluation phase |
| **Activities** | Survey, scan, evidence | Concept model, visions, scenarios | Priorities, analysis, negotiations | Agendas, strategies | Plans, policies, actions | Review, revision, renewal |
| *Divergent Methods (more open, creative)* | Horizon scanning | Scenario stories / images | Backcasting | SWOT analysis | Communication planning | Interview |
| | Social Network Analysis | Gaming | Delphi | Strategic planning | R&D planning | Policy review |
| | Knowledge / research map | Visioning | Success scenarios | Roadmapping | Operational research | Impact indicator development |
| | Literature review | Agent –based modelling | Multi-criteria analysis | Cross-impact analysis | Action planning | Policy impact assessment |
| *Convergent methods (more specific, quantitative)* | STI policy analysis | Scenario modelling | Risk assessment | Logic framework | Critical / key technologies | Survey |
| | Text/data mining & patent analysis | System dynamics | Cost-benefit analysis | Linear programming | Priority lists | Bibliometric analysis |
| **INTERACTION** | Panels, workshops, conferences, training courses, dissemination, awareness raising, surveys, interviews | | | | | |

**Fig. 6.5** Classification of Foresight methods

methodological approach was developed for a Regional Foresight exercise on Renewable Energies in Berlin-Brandenburg in the context of the EU-funded "Benchmarking and Foresight for Regions of Europe (BEFORE)" project (Selecting and combining methods with the use of the SFM framework). This case describes how the SFM was used to combine quantitative and qualitative methods in line with the objectives, context, content of the Foresight exercise under resource limitations. The impact phase of the SFM process is not demonstrated, as the cases have not been evaluated.

### *6.5.1 Systemic Foresight in Higher Education Institutions*

Two Systemic Foresight exercises were designed, organized and implemented in order to demonstrate the first applications of the SFM. For this purpose, two academic departments, the Department of Project and Construction Management in Istanbul Technical University (PYY), and the Department of Civil Engineering in Bogazici University (BUIM), were selected as host organizations. Thus, two institutional Foresight exercises took place in two different organizational settings with the participation of two different groups simultaneously. The involvement of two contextually different organizations in parallel was a unique opportunity to test the SFM and see how the interaction of different contexts, contents and processes would give rise to different practices and outcomes.

#### 6.5.1.1 The Process

A Foresight process was designed with the use of the SFM framework. Being the integral parts of the projects, the phases gave to the activities by defining minimal requirements for the systemic process of inquiry. In addition, an introduction phase was added, which aimed at introducing the activity, presenting the methodology, and clarifying the goals. Thus, the phases of projects consisted of:

1. Project proposal and definition of goals (Introduction)
2. Systems, elements and relationships (Intelligence)
3. Construction2023[2] (Imagination)
4. PYY/BUIM2023 visions and priorities (Integration)
5. Road mapping (Interpretation)
6. Research and Development, and Education and Training strategies (Intervention)

As the projects moved forward, the actual project process was elaborated through the interaction among the context, content and process.

##### Project Proposal and Definition of the Project Goals

This phase aimed to promote Foresight with a presentation and form commitment via group decisions on the project goals. Having the contributions of the project participants in the definition of the goals helped to provide the commitment needed. In the end of phase 1, both PYY and BUIM established a set of project goals in order to develop their visions as academic institutions including:

1. Thinking about the long term future in a holistic manner, and
2. Developing future visions for the construction industry and for their departments, with
3. A wide participation, to
4. Identify the future R&D and T&E areas, and to
5. Develop research and teaching policies and strategies for long, medium and short terms

##### Intelligence: Understanding Systems, Elements and Relationships

Understanding and appreciation of the systems were seen as imperative. Intelligence gathering aimed to attain a reasonably comprehensive view of the issues within its wider context in order to gain a shared and mutual understanding of the systems. Thus, **this** phase:

[2] The year 2023 was determined based on the considerations on the nature of the construction sector, where disruptive changes are not usually introduced earlier than 20 years.

1. Applied the basic principles of systems thinking on the academic units' own organizational settings
2. Widened the participants' views on the system by helping them to understand the system that they operate in
3. Helped to appreciate the hierarchy of systems and understanding the higher and lower level systems and the relationships between them
4. Focused on departmental systems and on the external systems. Considered not only on the relationships between departments and other systems, but also on the interrelationships between other external systems
5. Provided understanding on how different systems interact and affect each other by analysing the relationships between them

### Imagination: Modelling Construction 2023

This phase aimed at exploring, designing and integrating alternative systems. Considering the systems in the construction sector and relationships between them, the aim was to initiate a dialogue on the future of the construction sector. Besides exploring alternative futures for the construction industry, this phase also gave 'visionary messages' to PYY/BUIM from a wide variety of stakeholders. The visionary messages carried clues on: (1) The general future orientation of the department in the light of the developments in the sector; (2) Possible areas for R&D; and (3) Relevant education and training (E&T) areas.

### Integration: Analysis and Vision Building

In the scope of the outcomes of the previous phases, including the systems and the possible and desired futures for the construction industry, the aim at this phase was to open a discussion on the future of the departments and to explore alternative futures for PYY and BUIM. Following the production of the models of the future, this phase was concerned with the analysis of alternative systems and the decision on the most desirable future system that PYY and BUIM preferred to create and be a part of in the construction sector.

### Interpretation: Transformation

With the aim of transforming the present system to a desired future system, this phase defined a relationship between future and present focusing on the overall change of the existing system. In both PYY2023 and BUIM2023 exercises, the kind of structural and behavioral changes needed were identified and planned at this phase. In this transformation process, Normative, Strategic and Operational level decisions were made on the future Research and Development (R&D) and

Education and Training (E&T) areas, the need for new research and teaching staff, and infrastructural needs.

Intervention: Actions

This phase was concerned with the creation of action plans to inform present day decisions for the initial interventions to the existing system. In light of the decisions taken in this phase regarding the medium and short term future, the departments were asked to come up with a 'to do list' for present. This was a tactical document for PYY and BUIM where the members of PYY and BUIM identified actions to be taken at the operational level.

The methodologically systemic exercises aimed at creating ideas which were not fragmented and disconnected. The focus was given to wider systems in a holistic manner. The methods applied were not imposed instead they were used and developed during the course of the exercises (e.g. methods on Value System, Systems-Actors, Systems-Success Factors, Baseline Scenario Systems). Some common methods were also adopted with a systemic perspective such as integrated scenarios produced from the earlier methods designed. The framework of the integrated scenario was based on the transformations of the goals, behaviors and structures over long, medium and short terms. The same structure was used in a survey, Construction2023, which aimed to collect the ideas of stakeholders on the future of the construction industry.

#### 6.5.1.2 The Outcomes

The outcomes of the PYY2023 and BUIM2023 Systemic Foresight exercises included:

– **Future directions for PYY and BUIM:**
  - **Broad strategies and issues** that raise points of leverage, priority lists with detailed action plans for the implementation of the strategy
  - **Thematic strategies for new areas of research and new research in established areas** specifying where PYY and BUIM should make research applications relevant to the long, medium and short term future
  - A program, which forms a coherent pool of themes suitable for creating **new topics for Ph.D. and M.Sc. theses and dissertations** allowing PYY and BUIM to benefit from their current and future graduate students contributions to the research topics identified at the departmental level and research theme level for the next 15–20 years.
  - **New courses, teaching methods and media:** New courses were identified for the next 5-10-15 and 20 years. The R&D areas were also considered to be potential areas for E&T. Along with the content; ideas were developed to use novel teaching methods and media. Necessary modifications of existing

graduate and undergraduate curricula in light of identified E&T areas were defined.

– **Strategy for human resources:** From the systemic Foresight process, PYY and BUIM gained knowledge of their current potentials with all their research and teaching human resources, their areas of interest and the infrastructure of the departments including:

  • **Improved allocation of research and teaching potential:** After the exercises, the departments knew which staff members are interested in the identified research and teaching areas now and in short, medium and long term future
  • **Recruitment:** Knowing the research and teaching potential and the future R&D and E&T areas, the departments decided on the profile of the research and teaching staff required and when they are needed. For instance, PYY now knows that researchers working on 'the use of remote sensing in construction' might be needed around 2012–2015, since this topic has been higher on the agenda recently. This also means that PYY should select graduate students willing to work in this field immediately to produce potential researchers by 2015.
  • **New infrastructure needed:** Knowing the human resources needed for the future, the departments determined their infrastructural needs, which could come into existence in the following years in relation to the allocation of its budget
  • **Collaborations:** PYY and BUIM became clearer with whom to collaborate. By showing the other relevant systems, the systemic Foresight exercises helped the departments to identify the actors to take collaborative actions in the future including other academic institutions, public and private sector organizations, and NGOs
  • **Knowing themselves:** The systemic Foresight process opened new communication channels between the members of the departments who usually have limited interaction during the problem-driven departmental meetings and who do not know actually who does what, and who wants to do what in the future

Besides these commonalities, both exercises involved substantial differences in terms of processes and methodologies used. These will be reported in the discussion section, where both cases will be discussed in the light of the lessons learned from the implementation of the cases. Before doing that the following section will describe the second case briefly.

### 6.5.2 Development of a Methodology for a Regional Foresight exercise

A Regional Foresight exercise was conducted in the Berlin-Brandenburg region in the context of the EU-funded BEFORE (Benchmarking and Foresight for Regions of Europe) project. One of the objectives of the project was to carry out Foresight studies with the aim of analysing the future challenges on the subject of Research and Technological Development (RTD) of the selected European regions. First regional Foresight activities started in Brandenburg in 2008 on two sectors: Renewable Energies and Logistics. The particular exercise on Renewable Energies aimed at supporting Research and Technology Development (RTD) programs and to set policies for sector. First, actions were taken for the comprehensive 'understanding' of the regional context and the sector. The activities undertaken included:

- Descriptions of the sectors at the regional level
- Analysis of the trends and drivers in Renewable Energies and Logistics sectors
- Review of other Foresight exercises at different levels including global, European, national, regional and sectoral level exercises, which could provide context for the sectoral Foresight exercises
- Preparation of a scoping document for Regional Foresight, which aimed at clarifying the rationales and key objectives of the exercise, regional and sectoral actors and stakeholders, and a list of participants of the exercise

Based on the initial analysis of the region and the sector, a workshop proposal document was prepared, which provided an in depth 'understanding' of the regional and sectoral contexts and the content of the exercise. Following this preparatory work, the first workshop was held in Potsdam, Germany in late September 2007. This inclusive meeting hosted participants from research centres, academia, regional policy makers and representatives of associations. The goals of the meeting were to discuss and develop an understanding of the regional and sectoral contexts. This activity informed the methodology of the Foresight exercise in a greater detail.

In the light of this background work and during the interactive discussions during the workshop, key objectives were agreed for the Foresight exercise. These objectives were classified under three main pillars, which constituted also the outcomes expected from the Foresight exercise:

1. Key technologies (e.g. identify key technologies for the next 10–20 years; promote technology learning; strengthen technology transfer; utilize existing technologies; and involve in the development, shaping and expert technologies)
2. Structural and organizational improvement of the sector (e.g. improve collaboration among actors; improve supplier/value chains; initiate new partnerships and investments; establish state-wide SME network; and establish international activities)

3. Policies and strategies for the Renewable Energies sector (e.g. improve competitiveness of companies, scientific organizations and intermediaries; establish the capital region as relevant and attractive location; improve services; and exploit a large market in the region and beyond)

Following a comprehensive thought experiment to understand the sector, three methodological pathways were suggested in line with the objectives, which then led to the development of the overall methodology: (1) Technology Path; (2) Structural Path; and (3) Policy path

#### 6.5.2.1 Technology Path

The following methods were used to identify critical technologies in line with the objectives given above:

- **Scanning:** For the analysis of STEEPV systems and discuss their implications on technologies
- **Bibliometrics/Literature Review:** For the review the technologies to generate energy and discuss in panels which are relevant and promising for Brandenburg (considering industry's and people's needs, other energy needs – i.e. to produce and to export energy generation devices/instruments)
- **Key Indicators/Forecasts:** Analysis of sectoral forecasts and long term projections on technologies
- **Synthesis:** For the review and synthesis of the previous Foresight work
- **Scenarios** with wide participation (including citizens) identify the 'demands of society' from the technology
- **Delphi:** Represents the 'supply' side – whether the demands in the scenarios are possible and feasible or not. Helps to define time of realisation for selected technologies and technology areas. Also helps to identify priority technologies
- **Roadmaps:** For the development of Technology Roadmaps for prioritised technologies at different levels such as Technology – Product/Capability/Development/Research
- Produce a list of **critical technologies**
- Suggest **R&D projects** and plan R&D activities and resources

The Technology path is illustrated in Fig. 6.6.

#### 6.5.2.2 Structural Path

A combination of the following methods was used to propose actions for structural and organisational transformations:

- **System Analysis:** Analysis of the value chain helps to come to a better understanding of how the sector works and what the actors/stakeholders are

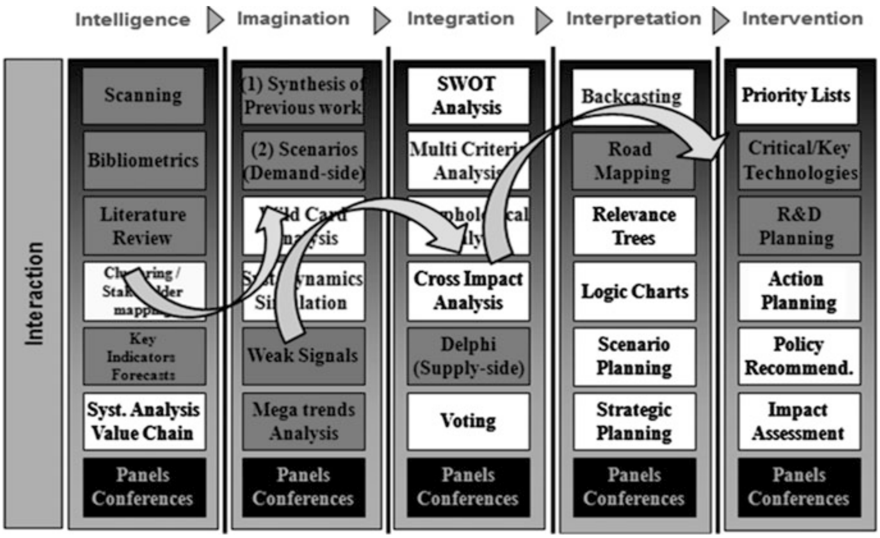


**Fig. 6.6** Technology path

- **Clustering** by stakeholder mapping helps to map the actors in the sector and to indicate 'who is doing what'
- **Mega trend analysis:** Sectoral megatrends will give clues on changing roles in the sectors and inclusion of new actors/stakeholders in the process in the future
- **Scenarios:** Various scenarios around Input–output relationships illustrate the future organisation of the sector
- **SWOT analysis** of the existing structures against the structures suggested in the visionary/most desirable scenario
- **Delphi:** To identify types of collaborations needed among stakeholders in order to establish new links in the system
- **Strategic plans:** for the restructuring of the sector in the medium term
- **Action planning:** To suggest immediate actions to change/improve structures and organisations and to introduce new rules and regulations

The Structural path is illustrated in Fig. 6.7.

#### 6.5.2.3 Policy Path

A Policy path was designed for the Renewable Energies sector with the combination of the following methods:

- **Scanning:** For the analysis of Social, Technological, Economic, Ecological, Political and Value (STEEPV) systems to understand what type of energies will be needed and what kind of demand will come out

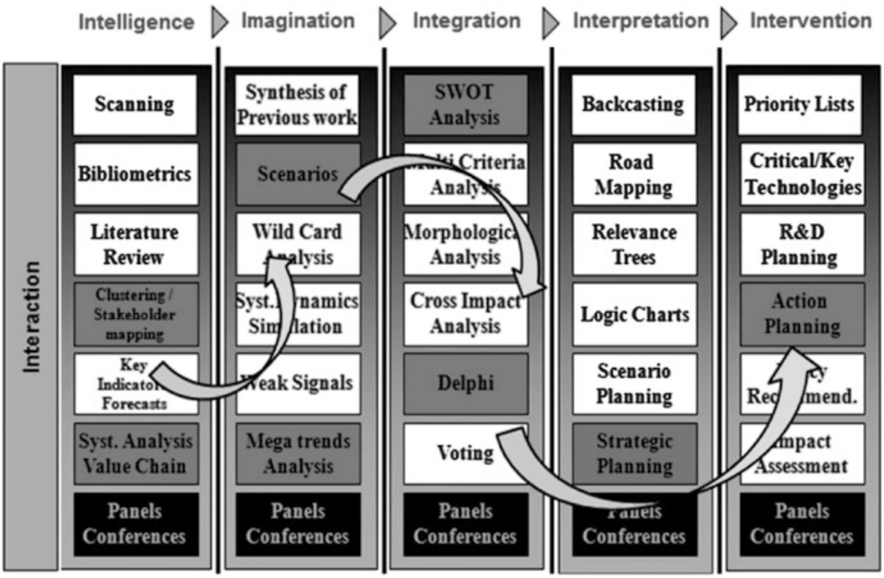


**Fig. 6.7** Structural path

- **Key Indicators/Forecasting:** For the analysis of sectoral forecasts and long term projections
- **Mega trend analysis:** To understand the broad policy tendencies at the Global/European/National levels
- **Synthesis of previous work:** Large amount of the work on energy futures exists including plenty of scenario work (reviewing those scenarios would be useful to suggest a set of "synthesis scenarios")
- **Scenarios:** To discover alternative futures on policy developments
- **SWOT analysis** of the regional capabilities against the visionary scenario
- **Roadmapping:** Illustrating the priority areas, the actions to be taken in long, medium and short terms and the distribution of initiatives among the actors in the sector
- **Policy Recommendations:** Policy actions to be taken in the short term

Figure 6.8 illustrates the Policy path to achieve socio-economic and technological transformations.

## 6.6 Discussion

Both cases presented above aimed to demonstrate two applications of the SFM. The purpose was to explore whether or not there was a practical support for the SFM. Overall, the cases have revealed that:

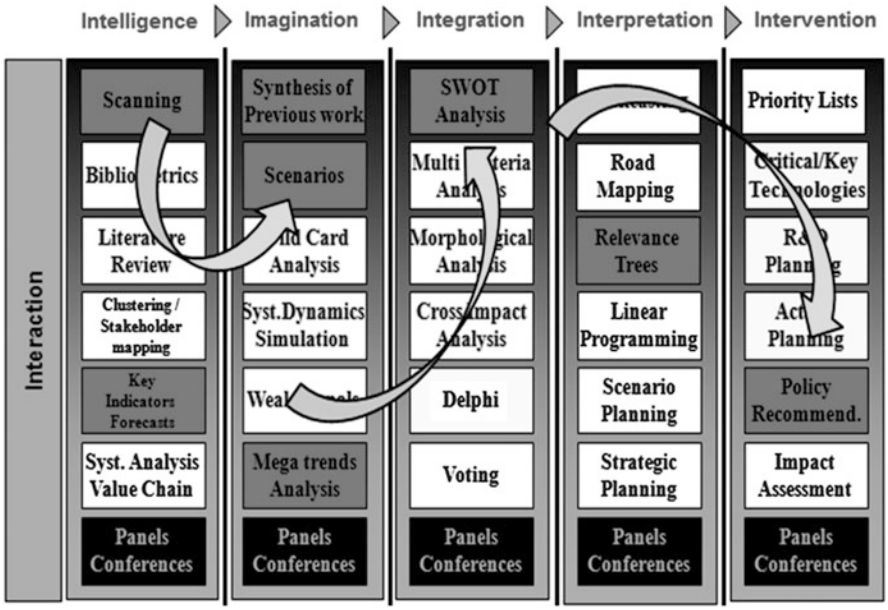


**Fig. 6.8** Policy path

1. The ideas created in institutional Foresight exercises can be placed within a systemic framework, once systems with wider boundaries are constructed, are considered in idea creation, and are shared with the participants and wider stakeholders
2. The institutional Foresight system can be integrated into the system in which it operates through the systemic understanding of the external and internal contexts and the construction of the contents in the Systemic Foresight process
3. Institutional Foresight exercises can be carried out without systematic and method-bound approaches. The sum of purposeful and coordinated activities exhibit positive and functionalist characteristics where the pedestrian nature of the institutional Foresight process is mainly overlooked. Due to their soft characteristics, interpretive approaches allow for the design for the minimally bounded exercises and for the development of methodologies, which can reflect the unique context of the activity and nature of the issue at hand.

Now, the following section briefly discusses how these three fundamental propositions of the SFM were illustrated.

**The ideas created in institutional Foresight exercises can be placed within a systemic framework, once systems with wider boundaries are constructed, are considered in idea creation, and are shared with the participants and wider stakeholders.** In both cases, attempts were made to understand how the systems were constructed as parts of the same upper level system and/or as interacting systems in the scope of the Construction and Renewable Energy sectors.

The holistic view adopted helped to turn attentions to other external systems and how they are constructed. The content of the exercises consisted of a model of the context as a representation of the reality from the perceptions of the two academic units. Models were used from the beginning of the exercises. Thus, the participants had representations of the present and future systems. Through these exercises, the participants came to a better appreciation that the future success and viability of their organizations were also dependent upon the other systems. Seeing their organizations as parts of other larger systems, they were also able to see how their decisions at the organizational level can have impacts on society and other external systems.

The systemic models produced were shared also with the external participants when consultation was needed, for instance via the Construction2023 survey in the case of PYY and BUIM. The use of similar systemic framework made it possible to integrate the information coming through external consultation with the ideas produced in the exercise during the entire process.

Throughout the exercises systems were represented in a relatively diverse forms such as systemic influence diagrams (e.g. systems-actors-factors representations, construction scenario systems, value chain systems, and roadmaps) and matrix forms (e.g. actors-success factors matrix); and in the form of scenarios (e.g. systemic scenario framework, which led to the development of a number of scenarios and finally success scenarios). Consequently, the idea creation was systemic throughout the exercises, and the ideas created were integrated and connected, and thus were not isolated and fragmented.

The PYY2023 and BUIM2023 Systemic Foresight exercises helped the academic units to acknowledge their need and desire for the rectification of their underlying norms, policies and objectives. This was an example of the "*double-loop learning*", where fundamental changes in the organizational behaviours and structures are introduced such as the revealed need for the departmentalization of the division of PYY. The SFM also suggests that this is a continuous process, which is congruent with Vickers's (1965) "*Appreciative System*". The first cycle of the loop was completed with the completion of the exercises, which resulted with a list of actions to be implemented for the change process. This first cycle should be followed by other iterations of the SFM to achieve continuous improvement.

Both cases also attempted to provide continuity and consistency with the other future oriented efforts at the regional, national and European levels. For this purpose, the outcomes of the Foresight exercises at these levels were made available to the participants during the process. The idea was that the outcomes of the other regional, national and European Foresight exercise would guide decisions taken at the sectoral level and thus could prevent 'punctuation'.

**The institutional Foresight system can be integrated into the system in which it operates through the systemic understanding of the external and internal contexts and the construction of the contents in the Systemic Foresight process.** Both Construction and Renewable Energy sectors were embedded in various systems including the global, national, industrial and academic systems. These systems constituted the external contexts for the institutions where the exercises were conducted. The internal organizations, cultures, values and behaviours constituted the internal contexts. From the beginning of the Systemic Foresight exercises, these contexts were considered and incorporated. Due to the differences in the contexts, the exercises were approached from an interpretive perspective, where the host organizations were considered as social and living systems.

When the exercises started, the phases of the SFM were introduced to provide a methodological framework to ensure that the academic units achieve the objectives and complete the exercises successfully. The processes then evolved and differentiated through the interplays with contexts and contents. For instance, different practices emerged in the exercises due to the internal contexts of PYY and BUIM. The analyses revealed the strong impacts of structural and behavioural factors. In addition, the nature of the different subjects at hand, including PYY's construction and management and BUIM's civil engineering affected the processes.

Systemic representations used, such as the relationships between systems through their impacts on each other, helped to visualise that PYY and BUIM were affected by and could affect not only the developments in the construction sector. Before this activity, it was considered that the construction industry is one of the most vulnerable the economy and this vulnerability had negative impacts on PYY and BUIM. However, this activity helped the members of PYY and BUIM to understand that their success could also correspond to the developments in the world, other international and national academic systems and in the global construction industry. Consequently, both the sector and academic departments were not as vulnerable as they considered themselves against the negative developments in the national economy and the construction sector.

It is important to emphasize that the impacts of the content on the process was more predictable compared to the impacts of the behavioural factors, which revealed only through the process of the exercise.

**Institutional Foresight exercises can be carried out without systematic and method-bound approaches. The sum of purposeful and coordinated activities exhibit positive and functionalist characteristics where the pedestrian nature of the institutional Foresight process is mainly overlooked. Due to their soft characteristics, interpretive approaches allow for the design for the minimally bounded exercises and for the development of methodologies, which can reflect the unique context of the activity and nature of the issue at hand.** Based on the assumptions of the SFM, where Foresight is considered as a social and living process of inquiry, the Systemic Foresight exercises described started with the (i) Specification of systems, (ii) Identification of external and internal contexts, (iii) Characterization of the nature of the subject at hand, which then constituted the content of the exercise, (iv) Clarification of the goals. In this respect, an interpretive approach was developed which could deal with the unique structural and behavioural characteristics of organizations.

The formal methods used in the exercises came onto the agenda once the exercises started to follow the specification of the external and internal contexts and the contents. Based on the consideration that well-established, procedural and

**Table 6.1** Methods used in the Renewable Energy Foresight exercise[a]

| Phases | Methods | Technology path | Structural path | Policy path |
|---|---|---|---|---|
| Intelligence | Scanning | ⋆ | | ⋆ |
| | Bibliometrics | ⋆ | | |
| | Literature review | ⋆ | | |
| | Key indicators | ⋆ | | ⋆ |
| | Stakeholder mapping | | ⋆ | |
| | System analysis | | ⋆ | |
| Imagination | Megatrend analysis | ⋆ | ⋆ | ⋆ |
| | Scenarios | ⋆ | ⋆ | ⋆ |
| | Weak signals | ⋆ | | |
| Integration | SWOT analysis | | ⋆ | ⋆ |
| | Delphi survey | ⋆ | ⋆ | |
| Interpretation | Roadmapping | ⋆ | | |
| | Relevance trees | | | ⋆ |
| | Strategic planning | | ⋆ | |
| Intervention | Critical/Key Tech.s | ⋆ | | |
| | R&D planning | ⋆ | | |
| | Policy recommendations | | | ⋆ |
| | Action planning | | ⋆ | |

[a]As mentioned earlier the Renewable Energy project has not been evaluated, therefore the table does not involve the impact phase

prescriptive rules would not be suitable for social and human systems, no predetermined method was imposed. Consequently, the exercises started with the basic phases of the SFM. Methods came onto the agenda once an understanding of the situation was developed and possible solutions were negotiated. Specific methods were used whenever they were needed. New uses for common methods were also developed, such as the 'systemic scenario development', which used interaction diagrams to develop a number of different scenarios for the future. Table 6.1 shows how quantitative and qualitative methods were selected and used in the Renewable Energy Foresight exercise in Berlin-Brandenburg based on the phases of the SFM. The table demonstrates the methods, which served for policy, technology and structural paths. It is notable that some methods such as scenario planning can serve for all three purposes.

Both exercises created ideas in systemic frameworks, which prevented fragmentation and punctuation. Focus was given to higher and lower level of systems. The hierarchy and interrelationships between these systems and their elements were considered throughout the exercises.

## 6.7 Conclusions

Institutional Foresight is a combination of technical and thought processes. Technical process is largely a matter of organising and managing a Foresight exercise as a 'systematic' activity. The SFM suggests that Foresight also involves a set of 'systemic' processes, which are about how systems (e.g. human and social systems, industrial/sectoral systems, and innovation systems) are understood, approached and intervened for a successful change programme. The success of a Foresight activity will largely depend on how well the technical and thought processes fit and follow each other. The phases and strands of the SFM provides a conceptual systemic framework to provide methodological guidance for the organizers and practitioners of Foresight. Designing a Systemic Foresight exercise geared to a specific field and its specific nature has three advantages as it:

1. Provides a greater flexibility in dealing with specific issues
2. Leads to the development of diverse and more appropriate approaches in Foresight
3. Makes implementation easier as the products (i.e. policies and strategies) would be more compatible with the nature of the subject at hand

Briefly, the Systemic Foresight claims that:

1. The process of policy creation (means) and policy content (ends) are entirely complementary
2. The content is a determinant factor for the process
3. The process itself is a conditioning factor on what might emerge as content

The SFM suggests an iterative, dynamic and non-linear process for Foresight. Thus, attentions are turned from individual elements/issues to systems. Attempts are made to see and understand how systems are constructed and integrated. Then, models are generated on the future systems and interconnected policies and strategies are suggested. During this process, the SFM considers the uniqueness of systems, which is due to their structures and behaviours. Therefore, the SFM considers the 'soft' characteristics of systems while creating information for society under uncertainty and complexity.

The discussion on methods comes after clarifying the systems and their boundaries. The SFM suggests that the contexts in which Foresight lies have continuously evolving characteristics and are dominated by subjective views. Therefore, each situation requires a specific methodological approach. Last but not least, the SFM aims to provide a conceptual framework to meet expectations for inclusivity, transparency and interaction. Fully fledged applications of the SFM are currently in progress. Among those Energy and Security Foresight exercises for the University of Manchester; National Research Foresight Programme for Mauritius; and Foresight for International Natural Fibers Organization (INFO) can be given as examples.

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## References

Aaltonen M, Sanders TI (2006) Identifying sys-tems' new initial conditions as influence points for future. Foresight 8(3):28–35

Ackoff RL (1981) Creating the corporate future. Wiley, New York

Argyyis C (1976) Increasing leadership effectiveness. Wiley-Interscience, New York

Argyyis C, Schon D (1978) Organisational learning: a theory of action perspective. Addison-Wesley, Reading

Bausch KC (2002) Roots and branches: a brief, picturesque, personal history of systems thinking. Syst Res Behav Sci 19:417–428

Beer S (1979) Heart of the enterprise. Wiley, Chichester

Bertalanffy LV (1929) Vorschlag zweier sehr allgemeiner biologischer Gesetze – Studien über theoretische Biologie, III. Biologisches Zentralblatt 49:83–111

Checkland P (1981) Systems thinking, systems practice. Wiley, Chichester

Churchman CW (1968) The systems approach. Dell Publishing, New York

Churchman CW, Ackoff RL, Arnoff EL (1957) Introduction to operations research. Wiley, New York

DEFRA (2002) Defra's horizon scanning strategy for science, science directorate, Defra Scince Strategy Team. Available at: http://www.cgee.org.br/atividades/redirKori/284. Last visited on 13 Mar 2012

Gunderson L, Holling CS (2001) Panarchy: understanding transformations in human and natural systems. Island Press, Washington

Hammond D (2002) Exploring the genealogy of systems thinking. Syst Res Behav Sci 19:429–439

Holling CS (2000) Theories for sustainable futures, conservation ecology, 4, 7. Available at: http://www.consecol.org/vol4/iss2/art7. Last visited on 20 May 2011

Holling CS (2001) Understanding the complexity of economic, ecological and social systems. Ecosystems 4:390–405

Jackson MC (2001) Critical systems thinking and practice. Eur J Oper Res 128:233–244

Kay JJ, Reiger HA, Boyle M, Francis G (1999) An ecosystem approach for sustainability: addressing the challenge of complexity. Futures 31:721–742

Koestler A (1967) The ghost in the machine. Macmillan, New York

Loveridge D (2009) Foresight: the art and science of anticipating the future. Routledge, London

Loveridge D, Saritas O (2009) Reducing the democratic deficit in institutional Foresight programmes: a case for critical systems thinking in nanotechnology. Technol Forecast Soc Change 76(9):1208–1221

Martin B (1995) Foresight in science and technology policy. Technol Anal Strateg Manage 7(2):139–168

Meadows DH, Meadows DL, Randers J, Bahrens WW III (1972) The limits to growth: a report for the club of Rome's project on the predicament of mankind. Universe Books, New York

Miles I, Keenan M (2002) Practical guide to regional Foresight in the UK. Publications of the European Communities, Luxembourg

Modarres M, Cheon SW (1999) Function-centred modelling of engineering systems using the goal tree – success tree technique and functional primitives. Reliab Eng Syst Saf 64:181–200
Papon P (1988) Science and technology policy in France: 1981–1986. Minerva 26(4):493–511
Roe E (1998) Taking complexity seriously: policy analysis, triangulation and sustainable development. Kluwer, Boston
Salo A, Konnola T, Hjelt M (2004) Responsiveness in Foresight management: reflections from the Finnish food and drink industry. Int J Foresight Innov Policy 1(1–2):70–88
Saritas O, Smith JE (2011) The big picture – trends, drivers, wild cards, discontinuities and weak signals. Futures 43(3):292–312
Simon H (1957) Models of man. Wiley, New York
Simon H (1962) The architecture of complexity. Proc Am Philos Soc 106:467–482
van Dijk JWA (1991) Foresight studies: a new approach in participatory policy making in the Netherlands. Technol Forecast Soc Change 40(3):223–234
Vickers G (1965) The art of judgement: a study of policy making. Chapman & Hall, London

# Part II
# Foresight Instruments for Innovative Markets

# Chapter 7
# Sectoral Foresight Studies: Future Perspectives of Nanotechnologies

**Oleg Karasev and Anastasia Edelkina**

## 7.1 Introduction

Today all leading countries have a rather precise view of the most important socio-economic and S&T priorities often including nanotechnologies (Sokolov et al. 2009). Nanotechnologies are commonly defined as "a complex of processes and techniques used to research, design and manufacture materials, devices and systems enabling object-oriented control and management of structure, chemical composition and interaction of their nanoscale components (elements with at least one of their dimensions on the scale of 100 nm or smaller), which results in improvement or development of additional operating and/or consumer characteristics and parameters of products" (Glossary of Nanotechnology and Related Terms).

The manufacturing of products cannot be realised without technological advancement related to new materials. To achieve leading positions in this field middle- and long-term prospective national nanotechnology initiatives have been implemented in almost all developed countries. In 2008, more than 60 countries around the world announced programs of nanoindustry development (Wang and Shapira 2011). In particular, the U.S., the E.U., and Japan, have long considered nanotechnologies and new materials to be national priorities. In Russia, attention to nanotechnology markets was given for the first time in 1996 with the framework of the development of a list of critical technologies at government level. Afterwards relevant nanotechnology-related developments have been implemented in several federal target programmes aimed at supporting the nanotechnology infrastructure and R&D in this area (Sokolov and Karasev 2009).

In the long run, the prospects of nanoindustry depend on the development of the economy as a whole. There are different scenarios for economic development based

O. Karasev (✉) • A. Edelkina
Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE), Myasnitskaya st., 20, Moscow 101000, Russia
e-mail: okarasev@hse.ru

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on a number of existing and emerging macroeconomic trends of both the global, and Russian, economies. The development of a Russian nanoindustry, and its competitiveness, will be significantly determined by the government's timely response to global economic and socio-economic challenges, especially since the ongoing changes in the sectoral structure of economy are caused by global economic trends.

## 7.2 Method

This analysis is based on results of Foresight research executed by the Higher School of Economics with the purpose to define prospective directions of nanoindustry S&T and market development in the middle- and long-term period (until 2030). The objective of the study is to determine nanotechnology-enabled product groups having best innovation and demand potential those support might be the subject of public policy and investment projects (Gokhberg et al. 2012).

Within the framework of Foresight the nano-enabled products having superior technical or economic characteristics or new consumer properties compared to traditional products which were considered. The list of the named products has been built with the participation of an intersectoral expert panel which includes 140+ specialists representing scientific and industrial sphere in order to reflect key tendencies in all main branches of nanoindustry.

The basic method of nanotechnology Foresight is Delphi – the two-round survey which involves 520+ national and foreign experts. Additional information has been gathered in the course of subject-oriented HSE studies – analysis of determinants of nano-enabled products internal demand and population innovation readiness. The results have been discussed by nine thematic expert panels involved in roadmapping for nanoindustry (510+ experts) and foreign expert's panel (90+ specialists from OECD, UNIDO, EU Institute for Prospective Technological Studies, US National Academy of Science / National Research Council, Massachusetts Institute of Technology, Princeton University, University of Manchester, UK Foresight Horizon Scanning Centre etc.).

## 7.3 Results

The achievements in the field of nanotechnology affect almost all sectors of the economy. In particular, this is the case in the innovation scenario of national economy development. By 2015, sales of nano-enabled products will account for almost US$2 trillion (Lux Research, Inc. 2010); and in comparison with 2011, sales will increase almost four times (Fig. 7.1). However, the dynamics of the market growth of nano-enabled products will be determined by external and domestic conditions of the implementation of the innovative development of Russia by 2020. Domestic conditions include a decreasing inflation rate, the strengthening of the Rouble against the U.S. Dollar and the Euro, rising wages and salaries, an

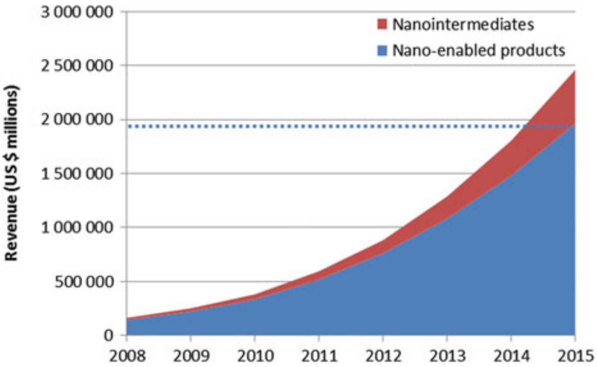


**Fig. 7.1** Global sales of nano-enabled products and nanointermediates (*Source:* Lux Research, Inc. (2010))

improving investment climate, increased competitiveness of the economy and the growth of a middle class; whereas external conditions include the increasing share of knowledge-based industries and the value of human capital as major factors of economic development, the strengthening of social stratification, and global population aging (Ministry of Economic Development of the Russian Federation 2012).

These conditions will change the underlying structure of industries, which in turn will significantly alter the structure of future demand for various types of nanotechnology products (Fig. 7.2).

It should be noted that the demand for such products is generated in both the baseline and the innovation scenarios. In the baseline scenario, demand for products of traditional industries will remain strong (for example, catalysts for oil refining), whereas in the innovation scenario demand will shift to high-technology products applicable in the knowledge sectors (electronics, etc.). In the innovation scenario, the implementation of targets set out in government economic development policy will reduce the share of the fuel and energy sector of GDP substantially by 2020 (Ministry of Industry and Trade of the Russian Federation 2003). This reduction will be mainly due to the depletion of natural resources and the necessity to find new sources of economic growth. These new drivers of growth likely will be knowledge-intensive services whose share of GDP will on average increase by about 7 %. The construction sector will also show a significant increase, while the share of the transport sector will not change, but will continue to grow at a gradual annual rate. The ICT and the telecommunication industry will develop rapidly, so that by 2020 it will have grown by more than five times. Table 7.1 summarizes the changes in the structure of the economy that would occur in both the baseline, and the innovation, scenarios.

### *7.3.1 Nanotechnology Markets*

The sectors outlined in Table 7.1, on the one hand, will develop due to the implementation of new nano-enabled products, and, on the other hand, will promote further development of nanotechnology markets. According to recent estimations,

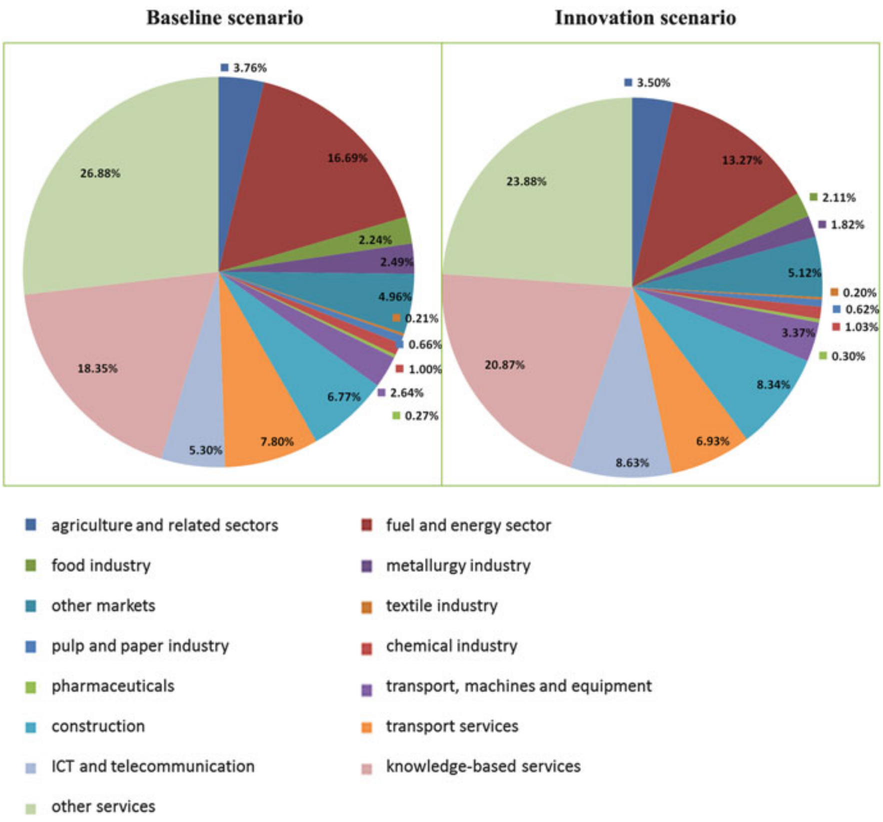


**Fig. 7.2** Forecast of Russian economy's structure (2020) (*Source:* Higher School of Economics (2012))

**Table 7.1** Expected changes in the structure of Russian economy

| | Baseline scenario | Innovation scenario |
|---|---|---|
| Fuel and energy complex | ⇧⇧ | ⇩ |
| Transport | ⇧ | □ |
| Construction | □ | ⇧⇧ |
| Other services | ⇩ | ⇩ |
| Knowledge-based services | □ | ⇧⇧ |
| ICT and telecommunication | ⇧⇧ | ⇧⇧⇧ |

⇧⇧⇧ Considerable growth of the sector's share in GDP, ⇧ Moderate growth, ⇧⇧ Average growth, □ Unchanged, ⇩ Decrease

by 2015 the total volume of the Russian market of nano-enabled products in a baseline scenario could reach 1 trillion Rubles in constant prices, and then grow by more than seven times by 2030. Eventually the structure of the nanotechnology market will change, as shown in Figs. 7.3 and 7.4.

In the figures above, in the long-term the largest and fastest growing areas of nano-enabled products are electronics and communication, automobiles and road

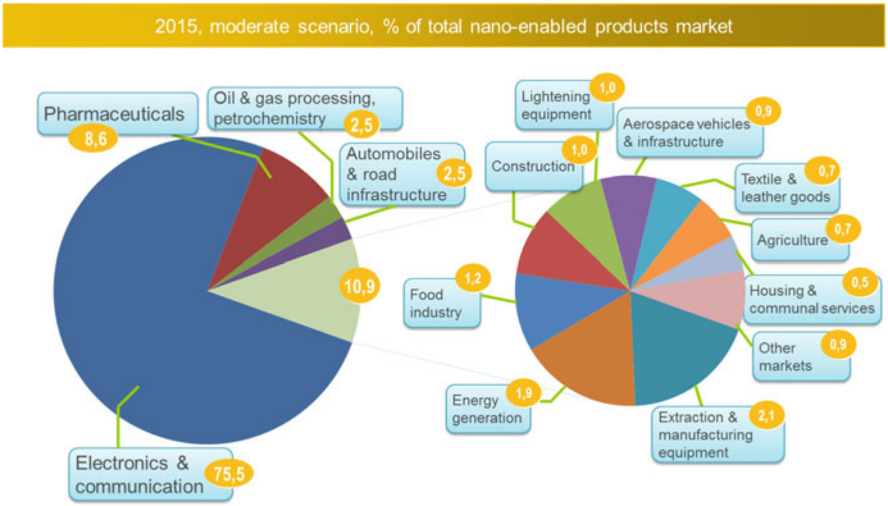


**Fig. 7.3** Middle-term market forecast of nano-enabled products (till 2015)

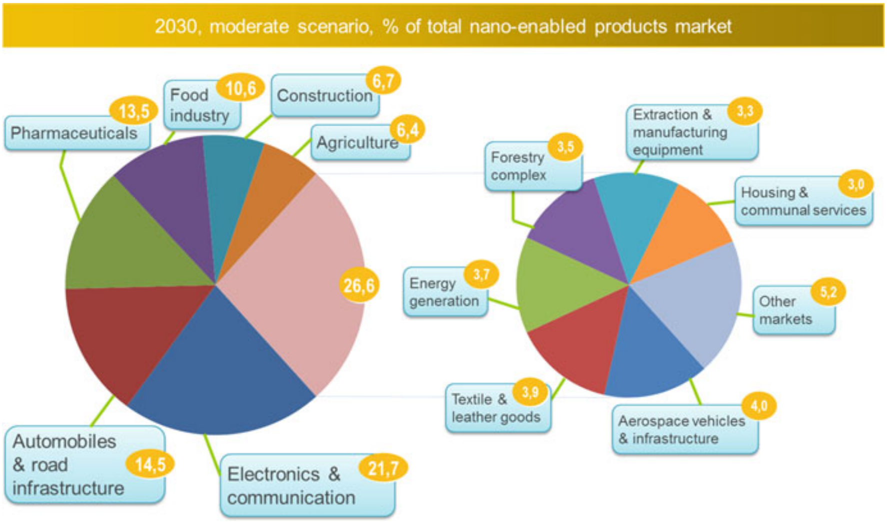


**Fig. 7.4** Long-term market forecast of nano-enabled products (till 2030)

infrastructure, pharmaceuticals, and construction. In the next 3–5 years nanotechnology products will enter the markets of lighting and medical equipment, sporting goods, and textiles, after which there will be a gradual expansion of nanotechnology applications, in particular, in the transportation, food processing, household products, and perfume sectors. Traditional industries will also benefit from the achievements of nanoindustry. For example, in the agricultural sector experts mention the promise of drugs for the pre-treatment of seeds and plant protection, new covering materials, etc. Nanotechnology products markets are growing and will reach their peak within the coming ten years. After that they will become mature markets with high value but moderate growth rates. The high growth potential of these areas is partly explained by the fact that they can serve as a source of funds for diversification as well as R&D support. To obtain the maximum benefit from the commercialization of nanotechnology products, it is necessary that the market becomes characterized by both high value and high growth rates at the same time. In the long-run, such a combination can be reached by nanotechnology applications in the automobile industry, energy, construction, the textile and food industries, as well as the manufacturing of medical equipment (Karasev et al. 2011).

It is worth paying attention to small-volume markets with high-growth potential. The combination of low barriers to entry and timely investments can determine the rapid development of those segments. Such markets are housing and communal services, sporting goods, household chemicals, and perfumes.

The most promising nanotechnology markets are shown in Table 7.2. Their application potential, and hence their market potential, were evaluated using criteria which include the market size, long-term growth prospects, the ability to meet consumer preferences, and the absence of barriers to entry. These criteria were used to assess the prospects of market commercialization of nanotechnology products. Eventually, it is important to monitor the development of the markets and to consider to what extent this potential can be used for the creation of novel products, based on innovative solutions that will meet increasing consumer demand. From the perspective supporting domestic manufacturing, it is important to consider barriers to entry for a particular market.

This assessment confirms the importance of innovation, not only in high-technology industries, but in low-technology ones as well. Both high-tech, and low-tech, industries will generate mass consumer demand for nano-enabled products, although the type of consumer may differ.

These promising markets, measured by nanoindustry market potential, and the opportunities of its use are shown in Fig. 7.5. The assessment of market potential is based on the forecasts of market volume and long-term growth rates. Market potential is determined by the total score of two indicators, namely, the ability to meet consumer preferences, and the absence of barriers to entry.

Considering all these aspects, strong focus is drawn to large markets, such as those which allow the consumer to realize unique product features as in electronics and medicine. There are some other important markets – the food industry, housing and communal services, textile and leather goods, etc. – in which innovation is focused on broad groups of consumers.

Analysis of the competitive advantages of Russian producers showed that aerospace engineering deserves special interest, both in terms of direct application of innovation in this industry, and in terms of the spread of such innovations to other areas of application.

To meet the increasing needs of various industries, it is necessary to increase the supply of scientific and technological achievements in the field of nanotechnology;

**Table 7.2** Market potential of nano-enabled product groups

| | Market volume | Long-term growth prospects | Ability to meet consumers' preferences | No entrance barriers | Total score |
|---|---|---|---|---|---|
| Automobiles and road infrastructure | | | | | |
| Aerospace vehicles and infrastructure | | | | | |
| Electronics and communication equipment | | | | | |
| Pharmaceuticals and medical equipment | | | | | |
| Petrochemicals | | | | | |
| Construction complex | | | | | |
| Extraction and manufacture equipment | | | | | |
| Textile and leather goods | | | | | |
| Consumer chemicals and perfumery | | | | | |
| Lightening equipment | | | | | |
| Housing and communal services | | | | | |
| Energy generation | | | | | |
| Food industry | | | | | |
| Shipbuilding (vessels and port infrastructure) | | | | | |
| Sporting goods | | | | | |
| Railroad transport (rolling stock and infrastructure) | | | | | |
| Forestry complex | | | | | |
| Agriculture | | | | | |

- Least promising market - Most promising market by this criteria

*Source:* Authors' analysis, Higher School of Economics (2012)

i.e. product technological solutions with great potential applications in various markets are becoming extremely important.

## *7.3.2 Prospective Nano-Enabled Product Groups*

The analysis indicates that the capacity of nanomarkets to meet the demand for new technologies and materials is distributed very unevenly. The R&D and manufacturing level, as well as market potential are used as metrics to describe the prospects of nano-enabled products. For composition of these indicators the following subindex have been calculated: the composite index of product's (of product group) potential which aggregates expert's opinions of Russia's presence among the leading countries in the studied technology area, the gap between Russia and countries-leaders in R&D and in the creation of manufacturing technology, as well as expected time of R&D results achievement and mass production readiness. These composite indexes expresses the strength of the joint effect of technology-related factors, while the market prospects index of products includes an assessment of the benefits to consumers of a product in comparison with analogous products, as well as evaluation of expected market growth. The composite indexes serve as an

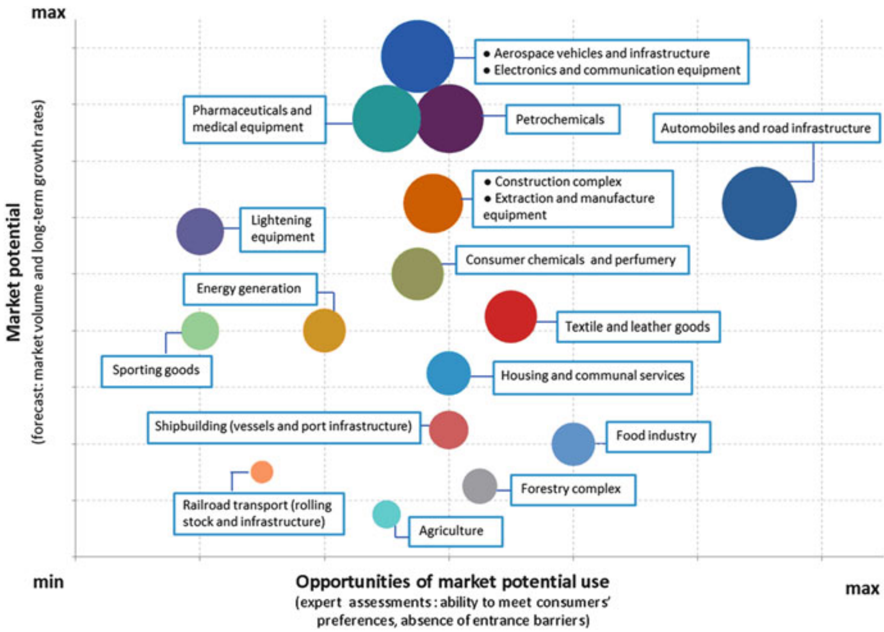


**Fig. 7.5** Market potential versus opportunities of it's use (*Source:* Higher School of Economics (2012))

assessment of the current and future capabilities of Russia in the development and commercialization of nanotechnology-enabled products (Karasev et al. 2011).

Table 7.3 reflects the main areas for product classification depending on market potential, as well as Russia's positions in R&D and manufacturing. Product groups are identified by at least one of the following features:

- The same area of technology;
- The similar functional properties;
- The similar application areas.

Due to the progressed development stage and high market potential of the listed product groups, the most promising areas of project financing are also concentrated in these areas.

In total, 275 nano-enabled products were identified as representative of the most promising product groups. The area of high demand risks illustrates product groups with a "strong position of Russia in the field of R&D and production and high demand for products from the market". Due to the progress and high market potential of these product groups, they are the most promising areas for project financing as well. Product groups within the area of high technology risks have high market potential, but lack a developed market in Russia. Due to the demand for these products, it is necessary to develop them by various support measures, including attraction of foreign investment. The gap between consumer needs and

**Table 7.3** The main areas of product classification

| | | Market potential | |
|---|---|---|---|
| | | Low | High |
| R&D and manufacturing potential | Strong | **Area of high demand risks**<br>High-risk areas<br>Screening of projects | **Commercialization area**<br>Project financing<br>Promising areas for investment in manufacturing |
| | Weak | **Area of high technology risks**<br>The highest risks<br>Assessment of projects upon the rationality of its development | **Gap between consumer needs and capacities**<br>Comparative analysis of foreign and domestic scientific and technology capacities |

*Source:* Authors' analysis, Higher School of Economics (2012)

capacities is characterized by the strong position of Russia in the field of R&D and production and low demand for products from the market. In order to determine the prospects of these products, it is necessary to make a balanced analysis, identifying the promising product groups despite their riskiness.

Based on the product classification described above, several examples are shown in Fig. 7.6 within different areas for product development.

The most promising product groups within the area of commercialisation include the following:

| | |
|---|---|
| Optical precise positioning systems | Elastomeric materials with multifunctional properties |
| Sensors of electromagnetic, infrared, terahertz radiation | Radio-absorbing composite nanocoatings |
| High-strength polymer composite and ceramic nanomaterials, metals and alloys | Dielectric polymer nanomaterials |
| Wear-resistant polymer composite and ceramic nanomaterials, nanocoatings | Nanofluids with particular properties |
| Anti-corrosion polymer composite nanocoatings | Nanomaterials for energy (including fuel cells) and high-energy processes |
| Hydrophobic polymer composite nanocoatings | Solar cells |
| Heat-resistant polymer composite and ceramic nanomaterials, coatings, nano-structured metals and alloys | Superconducting materials |
| Heat-insulating polymer composite nanomaterials | Nanomaterials for application in a transparent flexible electronics |
| Sound-and heat-insulating ceramic nanomaterials | Nanocomposite wires for electronic and electrical equipment |
| | Emitters (including lasers) based on nanoheterostructures, light emitting nanocoatings |
| | Sensors and tags for medical diagnostics |

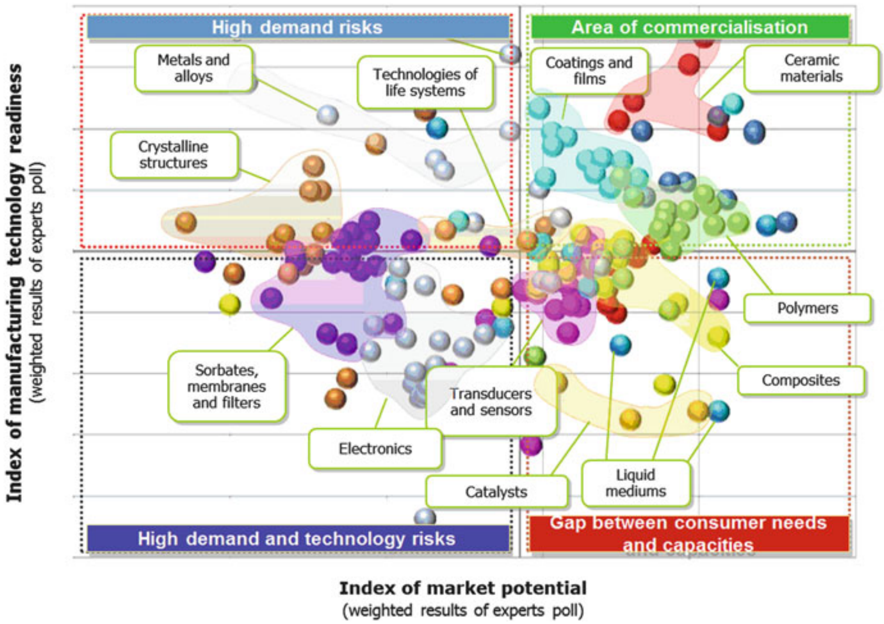


**Fig. 7.6** Joint analysis of supply and demand potential of nano-enabled products (*Source:* Higher School of Economics (2012))

The above mentioned product groups are shown in Fig. 7.7 depending on the value of composite indexes measuring their S&T and manufacturing potential as well as their prospects from the future demand.

Within the markets that were previously identified as most promising – aerospace, electronics, and medicine – there are a number of key product features which determine the demand and market developments.

For the development of the aerospace industry, it will be essential to create high-strength nanostructured metals and alloys. These materials will allow for the creation of high-strength and cold-resistant tools for various applications, including transportation equipment. The production of lightweight, corrosion-resistant, and cold-resistant structural alloys will have a significant positive impact on various sectors of the economy, allowing for:

- The increase of tool life, parts of machines, and structures;
- The reduction of metal consumption in the manufacturing of machines and structures;
- The increase of useful loads of different modes of transport;
- The increase in the speed of machines;
- The reduction in fuel consumption and pollution.

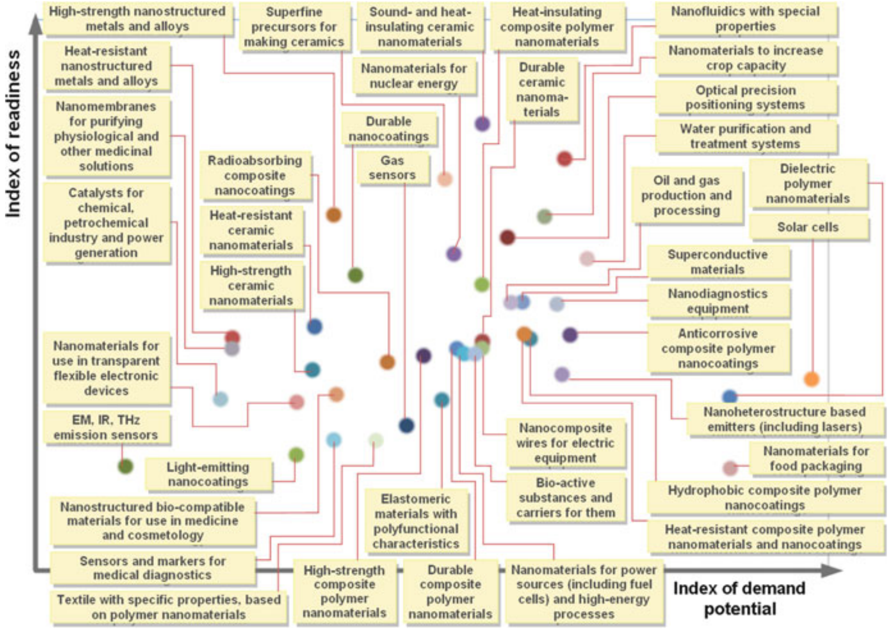


**Fig. 7.7** Most perspective nano-enabled product groups (*Source:* Higher School of Economics (2012))

At present, carbon fibers (high strength composite polymer nanomaterials) have widespread use, and are the most promising structural materials for the creation of critical components. Composites based on carbon fibers are characterized by high strength, stiffness, and low specific weight.

Composite materials based on carbon fibers are increasingly used in the aviation and aerospace industry. In addition, research has shown that there are opportunities to expand the use of carbon fibers into other industrial sectors, particularly the automobile and shipbuilding industry, as well as the construction, energy, and consumer product sectors. The overall demand for such materials is estimated at 65 billion Rubles in 2030 and, according to the some estimates, it will increase by more than 1.5 times by 2030 (HSE 2010).

There are numerous studies on the development of hydrophobic polymer nanocomposites. In the long-term, the development of these products will provide opportunities to enhance aviation safety through the creation of anti-icing materials and coatings, as well as the safety of other means of transportation by creating fog- and dirt-resistant glass, mirrors, and other optical instruments and equipment. In addition, significant benefits are also expected in the development of sectors such as road construction and housing and communal services, by increasing the strength and durability of building materials and structures, pavement, as well as the application of new paint and insulating materials.

Significant progress in the development of various types of nanoheterostructure based emitters – emitters that can be applied in the field of communications, information processing and storage, medicine, and everyday life – can be expected. Moreover, the development of this product group will allow for the creation of light-emitting elements, which will open new prospects for products used as luminophores and high-brightness white LEDs, to create flat-panel displays and lighting systems. Research in this area provides opportunities for fiber-optic communication lines and space, medicine, manufacturing equipment, and commonly used household appliances, such as equipment for control and visualization.

Significant achievements in the field of alternative energy are also expected as a result of the creation of nanomaterials for energy and high-energy processes. The development of this area will allow for the creation of electric power devices that will increase the operating temperature range of fuel cells and lower their moisture dependence. These nanomaterials will be resistant to carbon dioxide, high thermal stability, and overheating. They will be widely used in transportation (including aerospace), energy, consumer electronics, housing and communal services, and other industries.

One promising scientific and practical nanotechnology direction is the development of solar cells. By 2050, the development of the photovoltaic market will provide about 11 % of the world's electricity and will allow 2.3 Gt of $CO_2$ emissions per year to be avoided (OECD/IEA 2010). The capacity of the global photovoltaic market grew from 39.7 GW to more than 68 GW by the end 2011 (EPIA 2012).

The creation and use of solar cells is particularly relevant especially in light of the predicted increase in the consumption of solar energy in the long term (Fig. 7.8).

As noted above, in the long-term, the demand for innovative products will be generated not only by the high-tech sector, but by traditional industries as well. One example is the food industry, where the development of nanomaterials for food storage needs to receive special attention. Based on these materials, it will be possible to create high-strength and environmentally safe high-polymer compounds containing nanoparticles for food. These nanomaterials will increase the production of modern packaging materials based on nanofilms, which will increase the shelf life of food products, as well as biodegradable materials for food packaging. The broad application of these products is expected in the agricultural, processing, and food industries.

Recent trends show that today it is extremely important to develop nanotechnologies to address worsening/deepening environmental problems, including an especially crucial one: access to clean and safe drinking water. In Russia, structural problems of the water industry have led to: insufficient drinking water of acceptable quality, uneven distribution of infrastructure across regions, as well as worn-out and obsolete communications. Therefore, the main drivers of the development of nanotechnology in water treatment in Russia are:

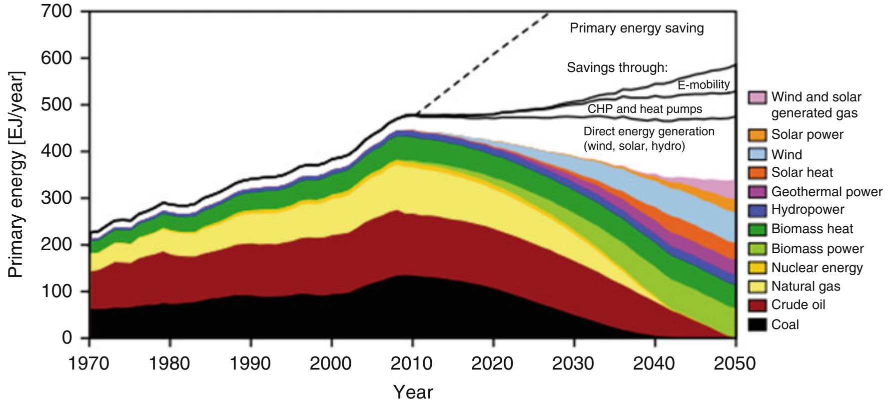


**Fig. 7.8** Growth of consumption of various power sources (*Source:* German Advisory Council on Global Change (2011))

- The contamination of surface and underground water sources (for example, in 2011, about 40 % of the surface sources of centralized drinking water supply did not meet health standards and regulations);
- The lack of facilities and water treatment mismatch level of pollution of water resources;
- Depreciation of fixed assets of water supply and sanitation sector. (For example, depreciation of fixed assets of this sector is between 50 % and 70 %; this causes excessive chlorination, resulting in secondary water pollution, (Rosvodokanal 2012));
- The increasing demands on water quality from consumers.

Additionally, significant innovation growth in the field of ecology is also projected (Fig. 7.9).

Membrane technologies are the most important projects with high innovative potential aimed at addressing the water treatment problem; the use of these technologies will significantly improve the quality of drinking water and reduce diseases caused by pollution and its sources of water supply systems. The application of membrane nanotechnology offers broad prospects for medical, pharmaceutical, petrochemical food, and other industries as well. Medical nanoproducts are among the prospective groups as well, with the main product groups being the targeted delivery of biosensors, as well as biochips and diagnostics systems discussed above.

### *7.3.3 Technological Breakthroughs*

Production of advanced products is impossible without technological breakthroughs in new materials, hence investment in research and development in these areas can bring significant measurable benefits for the economy as a whole.

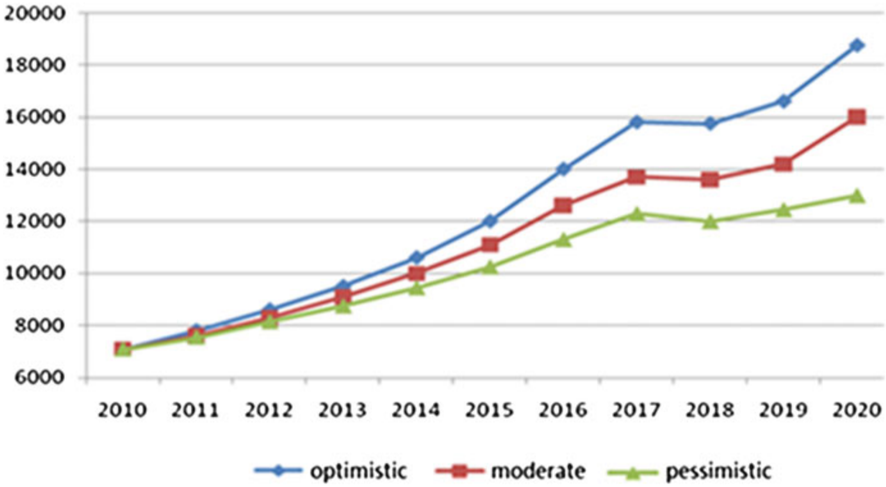


**Fig. 7.9** Current and expected volume of the world market of nanotechnologies applied to water purification, bln dollars (*Source:* Authors' analysis, Higher School of Economics (2012))

To achieve that, it is necessary to shift the focus of the scientific community towards studying the feasibility of establishing and implementing the production of breakthrough nanotechnologies.

Great achievements are expected in the development of smart materials, which can change their properties in a controlled manner in response to external stimuli. The main properties of such materials are the shape memory effect, or the ability of certain materials to recover their original shape when exposed to heat; the ability to convert one form of energy into another; as well as the piezoelectric effect, manifested in the ability of materials to create an electrical charge in response to mechanical force.

In developed countries, one of the priorities of the nanotechnology sphere is the creation of hybrid materials and structures, as well as relevant convergence technologies. Research in this area is related to the integration of various technological areas for synergies at the intersection of nano-, bio-, information, and cognitive technologies. The results of developments in this field can be widely used in medicine, electronics, and other related fields. Moreover, these technologies can be used in "smart" structures to ensure synergy from systems of self-diagnosis, self-adaptive, self-healing and self-healing, etc. Thus, it is important to develop composite materials with improved properties to be widely used in many industries – from aircraft to the paint industry.

The creation of gradient materials can lead to significant improvements. These materials have high hardness and toughness. Gradient materials will find the wide application in many areas of the economy due to their properties, including heat resistance.

In many countries, efforts in the field of nanotechnology are focused on the creation of materials for nanoelectronics and nanophotonics, which are widely used in computer electronics, telecommunications, and consumer electronics. The development of such materials will allow for the production of a new generation of lighting devices, environmentally safe displays, as well as metamaterials for optoelectronic devices, sensor technology, magnetic imaging, etc.

It is also important to create diagnostic systems that allow diagnosing quality, as well as gathering information about the internal structure of nano-enabled objects.

Given the high dependence of the national economy on oil and gas, the development of domestic hydrocarbon raw materials on the basis of deep processing of oil and coal is of great interest to Russia. The main applications of these technologies and materials are the integrated, waste-free processing of ores; the production of nanoscale materials for structural, heat-resistant, radiation-resistant materials; and the obtaining of high-purity metals – components of catalysts, electronic devices, etc. The development and implementation of new and improved catalysts are the most promising direction in the development of nanotechnology in the oil refining and petrochemical industries.

## 7.4 Conclusions

The identification of the most promising nanoindustsry product groups, as well as the technological breakthroughs in these areas allow summarizing the potentials of different developments of nanotechnology. This research helped to gain a coherent vision of the future of nanotechnology markets. It showed that Russia has the prospect to establish a niche for itself in the nanotechnology market by making an measured choice of priorities and focusing efforts on achieving them.

The implementation of the priorities of the Russian nanoindustry requires coordinated efforts of its key actors throughout the life cycle of nanoproducts, from development to commercialization. The effectiveness of the taken measures will depend on the extent to which recommendations based on Foresight studies will be used for specific management decisions affecting the scientific, technological, and market development of nanoindustry.

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## References

EPIA (2012) Annual report (2011). European Photovoltaic Industry Association. http://www.epia.org/publications/epiapublications.html. Accessed 12 Apr 2012

German Advisory Council on Global Change (2011) World in transition – a social contract for sustainability. WBGU, 2011. http://www.wbgu.de/en/flagship-reports/fr-2011-a-social-contract/. Accessed 14 Mar 2012

Glossary of Nanotechnology and Related Terms (2009–2011) http://eng.thesaurus.rusnano.com/wiki/article1377. Accessed 26 Sept 2012

Gokhberg L, Fursov K, Karasev O (2012) Nanotechnology development and regulatory framework: the case of Russia. Technovation 32:161–162 (in Russian)

Higher School of Economics (2010) Roadmap Using Nanotechnology in the production of carbon fibers and related products. Research study sponsored by RUSNANO. http://rusnano.com/ipload/oldnews/files/33652/current.pdf last accessed 20 July 2012

Karasev O, Rudnik P, Sokolov A (2011) Emerging technology-related markets in Russia: the case of nanotechnology. J East West Bus 17(2–3):101–119

Lux Research, Inc. (2010) The recession's impact on nanotechnology. http://www.luxresearchinc.com/blog/page/16/. Accessed 04 Mar 2012

Ministry of Industry and Trade of the Russian Federation (2003) Energy Strategy of Russia until 2020 (in Russian)

Ministry of Economic Development of the Russian Federation (2012) Strategy of the development of Russia until 2020 (in Russian)

OECD/IEA (2010) Technology roadmap. Solar photovoltaic energy. International Energy Agency. http://www.iea.org/papers/2010/pv_roadmap.pdf. Accessed 12 Apr 2012

Rosvodokanal (2012) Present activity. Official web-site. http://www.rosvodokanal.ru/ru/branch/present/. Accessed 04 Mar 2012

Sokolov A, Karasev O (2009) Foresight and technology roadmaps for nanoindustry. Russ Nanotechnol 4(3–4):8–15 (in Russian)

Sokolov A, Shashnov S, Karasev O, RUD V (2009) Long-term forecast of the development of the Russian nanoindustry based on Delphi surveys. Russ Nanotechnol 4(5–6):8–15 (in Russian)

Wang J, Shapira P (2011) Funding acknowledgement analysis: an enhanced tool to investigate research sponsorship impacts: the case of nanotechnology. Scientometrics 87:563–586

# Chapter 8
# A Toolkit for Integrated Roadmaps: Employing Nanotechnologies in Water and Wastewater Treatment

**Oleg Karasev and Konstantin Vishnevskiy**

## 8.1 Introduction

This chapter introduces a new approach of roadmapping for emerging technologies. This approach provides special trajectories of R&D, technologies, products and markets for a given application. The chapter highlights the use of roadmapping techniques for emerging technologies from a technological, as well as a market perspective; the integration of technology and market roadmaps; how such roadmaps can be included in the process of strategic decision-making at different levels; and how such roadmaps can be used for different purposes while ensuring a sustainable innovation flow for specific application fields.

This new approach – the integrated roadmapping approach – combines new manufacturing opportunities with potential consumer preferences towards innovative products. To determine alternative paths of innovation, the roadmap uses a scenario-based approach. These scenarios provide a long-term framework for roadmapping by constructing socio-economic narratives of the future, and by specifying future challenges. The roadmaps appear as a time-scheduled sequence of steps towards the implementation of scenario options.

The integrated roadmap determines a set of strategic goals for technology markets and develops measures to achieve these goals by taking into account alternative scenarios (or paths), and then choosing the most effective one. The roadmap is also aimed at the implementation of a co-ordination mechanism of stakeholder actions in order to achieve the strategic goals. It gives an opportunity to make a connection between grand challenges and concrete measures to meet them. One of the most urgent issues today is a sharpening of ecological problems. A variety of researchers concur that the key challenge for future development is

O. Karasev (✉) • K. Vishnevskiy
Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE), Moscow, Russia
e-mail: okarasev@hse.ru; kvishnevsky@hse.ru

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providing pure water for citizens. Thus, the feasibility and appropriateness of the integrated approach has been tested on selected nanotechnology related applications and markets.

This chapter assesses the role of Foresight and roadmapping in policy-making, strategic planning and project and innovation management at both an industry as well as more general level.

Maintaining a constant, clean, consumable water supply is one of the major challenges nations around the world are facing however the technological challenges of water treatment (for the general public as well as industry), remain insufficiently resolved. Correspondingly, the problem of water quality – and hence the closely related problem of water purification – remains one of the biggest social concerns in modern world. Importance of water supplying issue is also corroborated by social surveys. As evidenced by the Eurobarometer, 68 % of Europeans consider water quality problems as very serious for these countries. Around nine out of ten respondents in Romania (94 %), Italy (91 %) and France (89 %) consider water quality a serious problem for their country (Flash Eurobarometer 2012). Concerns over water quality are expressed by 34 % of the population of Russia, dominating almost all other social and domestic/household problems (Shuvalova 2010). Accordingly, a wide range of technology specialists and policy-makers are becoming increasingly interested in these challenges.

The survey presented in Fig. 8.1 clearly indicates that Russian citizens most frequently consider socially relevant technologies among priorities. People believe that technologies that contribute to solving ecological problems are of the utmost importance, along with new cures for illnesses that cause high mortality and disability rates in Russia (cancer, cardio-vascular diseases, injuries etc.). It becomes evident that the development of water treatment and purification systems is a primary concern to the end users – in this case, the country's population. Hence, new approaches to advance technologies that can address these problems are urgently needed.

Given the existing level of water treatment technologies, there is evidence to suggest that just 1 % of surface water sources in Russia meet the standards that would guarantee that the production of drinking water meets all hygienic requirements defined by WHO (2011). The amount of water intake sources that do not meet such standards and requirements generally exceeds 35 % (WHO 2009a, b; Onishchenko 2011). Between 50 % and 70 % of the Russian water supply and sewage infrastructure is worn out to the point of causing secondary pollution (Rosvodokanal 2011), which leads to the excessive use of chlorination, causing increased risks of disease. The consequences of this are 12,000 deaths a year caused by poor-quality water (WHO 2009b), and an increased accident rate, causing both direct and indirect waste of water (soil erosion, damage to roads and building basements, etc.). According to WHO data the disability-adjusted life year (DALY) connected with water-related problems in Russia is one of the worst in the world (Fig. 8.2). It means that existing systems of water supply in Russia is ineffecient at all and it follows that there is an urgent need for new technologies – such as nanotechnologies – to meet these challenges.

Since poor water infrastructure is one of the most urgent issues facing both the whole world and Russia, it is necessary to elaborate a clear strategy of long-term

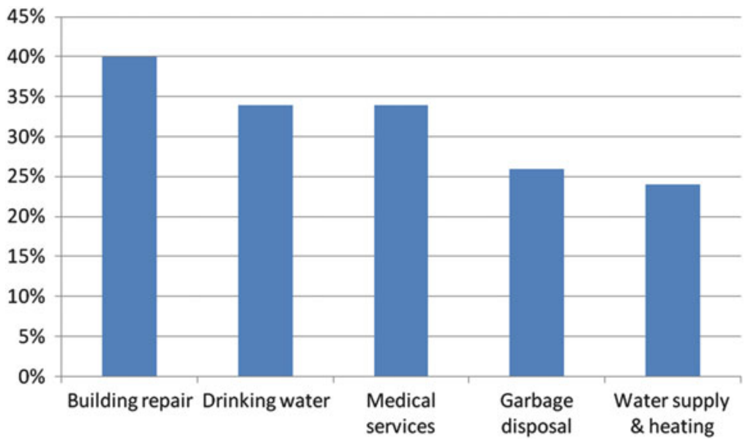


**Fig. 8.1** Most common social concerns in Russia (Shuvalova (2010)) (*share of all respondents*)

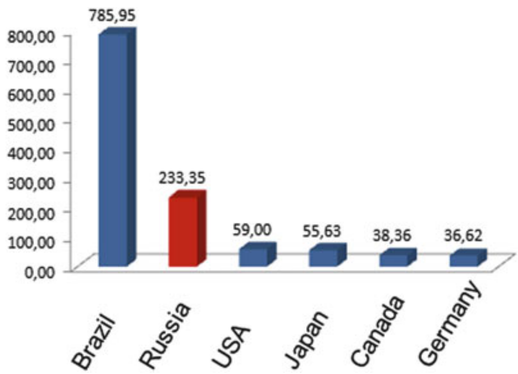


**Fig. 8.2** DALY connected with water-related problems in different countries (WHO (2009b))

development on the basis of integrated roadmapping approach. The integrated roadmap takes advantage of a broad range of expert knowledge relating to the most important nanotechnologies, nanoproducts, and nanocomponents (interim products) that could be used for water treatment purposes. Roadmap development procedures as part of Foresight include a broad discussion among the representatives of science and research, as well as education and business networks to establish a consensus on future development (Ahuja et al. 2005; De Smedt 2006; Heger and Rohrbeck 2012; Kappel 2001; Kynkäänniemi 2007; Rohrbeck 2008; Saritas and Oner 2004; Vishnevskiy and Karasev 2010; Whalen 2007).

This chapter suggests a new methodological approach to integrated roadmapping that allows the best, and most promising innovative products to be revealed, and the potential impact of emerging technologies to assess.

**Table 8.1** Benefits and limitations of technology push and market pull approaches

| Approaches/ features | Benefits | Limitations |
|---|---|---|
| Technology push | Wide analysis of prospective innovation technologies, products development, and detailed investigation of their main properties | Inadequate investigation of future market requirements, stakeholder behavior, and preferences |
| Market pull | Comprehensive study of potential market development employing different scenarios, revealing which innovation products will be in great demand in the long-term | Insufficient revelation of resource basis for meeting market needs |

## 8.2 Roadmapping for the Investigation of the Water Treatment Industry

Roadmaps as an element of Foresight studies have a rather short history, spanning only a few decades (Willyard and McClees 1987). However, the importance of employing roadmaps has grown significantly in recent years and they have come into great demand both in the corporate and public sectors. Roadmaps are now one of the most important tools of strategic planning and are actively used for shaping investment and innovation policies.

There are two main methodological approaches to roadmaps: market-driven and technology-driven (Table 8.1). The market-drive approach presupposes that the first point of the analysis is a market demand (see Albright and Kappel 2003; Daim and Oliver 2008; Holmes and Ferrill 2005; Lee et al. 2009a; Phaal et al. 2001 etc.), while the technology-driven approach identifies new technologies and seeks to define the market needs that could be served by them (see Kim et al. 2009; Lee et al. 2007; Lichtenthaler 2008; Lee et al. 2009b etc.).

Given the scarcity of freshwater resources, the establishment of a water resources management system is becoming essential (IWMI 2007; IAASTD 2008; UNEP 2010, 2012b). While global water assets are sufficient enough to supply global human demand, the water deficit is worsening (IAASTD 2008; UNEP 2012a).

With the rise of global awareness of water scarcity and the intensification of international collaboration for the management of water assets, the demand for reliable water management within national borders is also increasing (UNEP 2012b, Molden and Freken 2007; Whalen 2007, WWDR 2009; Young 2011). The tools to design, vector, monitor, and modify a national water management system and to boost its performance are currently of growing interest. In this regard, a roadmapping framework is commonly used in international practice to align objectives, strategic priorities, and participation of multiple actors in national water treatment systems.

An overview of the roadmaps developed for water treatment systems provides some considerations to take into account while making the roadmap for the employment of nanotechnologies in the Russian water treatment industry.

Roadmapping practices at the national level fall either into the proactive or reactive categories. They are proactive when they address the problem, in terms of prevention, before it arises. The approaches are classified as reactive when they overcome pre-existing issues and deal with their consequences. As the study of international economic practices shows, the roadmap-building processes in the water industry is triggered by issues of water resource availability (initial resource scarcity or its eventual shrinkage), the allocation or coordination of water assets, and infrastructure issues. All of these issues are aggravated by reactive strategic decisions.

Milestones in the use of roadmaps for water treatment have occurred in the following countries: the United States of America (which is a leader in this respect), Australia, the Scandinavian countries, Egypt, and China. On the one hand, there are countries that rely on roadmapping because they face physical water scarcity,[1] often due to areas with arid climates (Middle East and North Africa, Central Africa and Central Asia, etc.). Even rather water-sustained regions often comprise local zones where water assets are strongly limited. Countries mentioned in Table 8.2 have areas of physical water scarcity (SNL 2003; Hinkebein and Price 2005; Youssef et al. 2006; Arnold et al. 2008).

On the other hand, many countries face areas of economic water scarcity[2] – those with inadequate infrastructure, rather than a resource deficit. These include areas of Central Africa, South Asia, and certain areas in the North-East of Latin America. These examples exhibit a water shortage caused by, or attributed to, human impact, rather than to matters of ecosystem water assets (Hinkebein and Price 2005; Arnold et al. 2008, etc.).

The motivation for a roadmap is most often an indigenous one, related to water system performance, rather than an exogenous one, induced by naturally determined water problems. Roadmapping is uniquely in its ability to combine and visualize a multilateral analysis of economic factors, investments, risks, and stakeholders (Saritas et al. 2004, etc.).

The call for water-steering system to give the public audience knowledge about water management is becoming louder. The misbalancing factors amount to administrative, economic, social, technological, or environmental issues, and sometimes their combination (SNL 2003, 2006; Means 2004; Youssef et al. 2006; NWAR 2009).

Today competition for freshwater resources among the agricultural, domestic (municipal) and industrial sectors is iinntensifying. This competition is causing an increase, water consumption, treatment, supply, and sewage facilities construction (SNL 2006; IWMI 2007; FAO 2012). While the agricultural sector is frequently

[1] Under a physical scarcity, water consumption is limited by ecosystem frontiers, while water assets development is approaching or has already exceeded sustainable limits (IWMI 2007).

[2] In the areas of economic water scarcity, natural water assets could be available locally to meet human demands but the access to water is limited by human, institutional, and financial capital, or sometimes infrastructure capacities (IWMI 2007).

**Table 8.2** International roadmaps: examples of water industry and infrastructure enhancement

| Project | Country | Research problem | Research area | Type | Foresight methods |
|---|---|---|---|---|---|
| Sandia National Laboratories (2003) | US | Establishing the governmental policy for the water industry using scenario approach conveying water assets, supply system demands with technology solution | Water supply system demands<br>Water treatment technologies assessment and alignment<br>Traditional<br>Enhanced traditional<br>Alternative<br>Sustainable<br>Technology process and consumer properties<br>Implementation issues (R&D and financing)<br>Global collaboration | Market pull (mixed with technology push) | Working groups<br>Scenario analysis<br>Literature review<br>Expert Interview<br>Rudimentary routes based on relevance tree analysis<br>Backcasting<br>The elements of SWOT-analysis<br>Cross-impact analysis<br>Mapping<br>Risks analysis |
| Means (2004) | US | R&D and project evaluation and selection to meet the challenges | Water treatment technologies<br>Regulations and system management<br>Technology process properties<br>Sustainability issues (energy efficiency) | Market pull | Workshops<br>Desk research<br>Literature review<br>Technology portfolio analysis<br>Backcasting<br>Elements of SWOT-analysis<br>Voting |
| Elliott (2005) | US | Problem-oriented approach: Effectiveness of energy usage within water treatment and supply industry | Comprehensive water system development (water treatment, supply and sewage infrastructure mutual development)<br>Stakeholders and target audience consolidation | Market pull | Questionnaires, surveys<br>Workshop<br>Brainstorming |

| | | | | | |
|---|---|---|---|---|---|
| Hinkebein and Price (2005) | US | To identify, evaluate, prioritize research areas, to provide R&D to satisfy near, mid and long-term water supply challenges addressing the implementation issues and collaboration at the global scale | Financial aspects and profitability of technologies<br>Water treatment technologies<br>Advanced traditional (evolutionary)<br>New-generation (revolutionary)<br>Product-technology properties<br>Technologies sustainability improvement<br>Post-treatment waste disposal<br>Water resources<br>Available now<br>Unavailable (challenges) | Market pull | Working group<br>Workshops and sessions<br>Five-steps roadmapping process<br>Quantitative evaluation<br>Cross-impact analysis<br>Mapping |
| Youssef et al. (2006) | Egypt | Shared vision for Government water industry strategic planning up to 2025 regarding the broad political, technical, economic and social context within the scenario development | Water resources modes<br>Water treatment technologies modes<br>Driving forces<br>International collaboration on water facilities<br>Technology process properties<br>Sustainability issues | Market pull | Content analysis<br>Driving forces analysis<br>Questionnaire survey<br>Scenario analysis (mini-scenarios for policy-making and 2–3 global scenarios)<br>Experts panels<br>Focus groups<br>Brainstorming |
| Arnold et al. (2008) | Scandinavian Countries (which Scandinavian countries? There are only three/four. . . they should be named) | Investigate the innovative technology niches to consolidate the stakeholders' to provide the larger global market share | Water and wastewater treatment technologies assessment and alignment | Technology push | Content Analysis<br>Patent analysis<br>Bibliometric analysis<br>Technical project expertise |

(continued)

**Table 8.2** (continued)

| Project | Country | Research problem | Research area | Type | Foreseight methods |
|---|---|---|---|---|---|
| | | | Advanced traditional<br>New and emerging<br>Estimation of product-technology properties<br>Technology process performance<br>Consumer attributes<br>Sustainability issues<br>Assessment of technologies for core competences zones | | Working group<br>Technology portfolio<br>The elements of SWOT-analysis |
| National Water Account Roadmap (2009) | Australia | Shaping the profile and instruments of water provision public policy at the national and sectoral level for both supply and demand sides | Sectoral water resources management<br>Water production and consumer portfolio<br>Risk-analysis:<br>Water resources<br>Treatment technologies<br>Key stakeholders | Market pull (with elements of technology push) | Expert Panels<br>Simulation<br>Quantitative indicators<br>Scanning<br>Desk research<br>Data modeling<br>Benchmarking<br>Reporting<br>Stakeholder analysis |

limited in its use of treated water,[3] the municipal sector puts very strong requirements on treated, e.g. purified water. The issues that roadmaps address in the examples above – namely, water scarcity, and wastewater industry performance – fall into two categories: water supply capacities, and water quality provisioning (Arnold et al. 2008). The supply issue refers to the availability of water and wastewater supply and disposal networks to the population. The quality issue refers to the goal of water safety and quality. To meet standards and requirements, the treatment process is under governmental control.

Judging by the countries listed in Table 8.3, the roadmapping process within the water industry is typically under the guidance of governmental bodies or state-owned organizations. Moreover, the majority of roadmaps are government-initiated and implemented by relevant management maturity systems and institutes.

Analyzing the methodology framework of these roadmaps it becomes clear that the technology push motivations behind roadmapping tend to be water supply, capacities, and/or infrastructure provision. The demand-side reasons explain why roadmap development is performed mostly by market pull methods (Means 2004; Elliott 2005; Hinkebein and Price 2005; Youssef et al. 2006) rather than technology push methods (Arnold et al. 2008). Also the consistency of demand and supply-side drivers illustrates the need for both tmarket pull and technology push methodologies (SNL 2006; NWAR 2009).

The limitations of the water industry supply system vary from a lack of infrastructure to insolvency and inconsistency of facilities (obsolescence, wear and tear, etc.). It is these issues which tend to drive roadmapping in the countries listed in Table 8.3. This is also because large economies (in terms of population or territory), such as Russia, China, Australia, and the United States, are more vulnerable to infrastructure issues.

The significant investments required for roadmapping initiatives are the main reason why few developing countries have implemented such projects. The bulk of countries utilizing roadmaps for water systems belong to either the higher- or upper-middle income countries, according to the World Bank classification (the one exception being Egypt).

Consequently, national roadmaps illustrate the problem-oriented approach towards the consistency of water treatment technology processes (SNL 2003; Youssef et al. 2006); technology properties adjustment (Means 2004; Arnold et al. 2008) and customization (Youssef et al. 2006; NWAR 2009) often within the functional and communication alignment across stakeholders (SNL 2006; NWAR 2009). Evolution in the scale and scope of roadmapping is also quite evident: the resolution of a single concern, which initiated the roadmap, might develop into a broader and more complex analysis of systemic issues.

[3] On the global scale the largest amount of fresh water for agriculture (up to the 80 %) is coming from green water (rainfall stored in soil moisture); the rest is usually given by blue water (water withdrawals from rivers, reservoirs, lakes, and aquifers) (IWMI 2007).

**Table 8.3** National water assets: context for water industry management applying the Foresight approaches

| Country | Water sources scarcity | Welfare (income-based) | Population supplied by water supply system | Population supplied by wastewater system | Water industry issues addressed | Water management strategy |
|---|---|---|---|---|---|---|
| Egypt | Absolute water scarcity | Lower middle income country | 98 % (2009) | – | Physical water resources scarcity<br>Collaboration among water industry agents<br>International collaboration on water resources provision | Reactive |
| Australia | Areas of physical water scarcity<br>Areas with poorly estimated water assets feasibility | High income country | 98 % (2004) | 90 % (2004) | Bating the water scarcity in local areas | Reactive |
| US | Local areas of physical water scarcity<br>Approaching physical water scarcity<br>Areas with poorly estimated water assets feasibility | High-income country | 85 % (2005) | 70 % (2005) | Physical water scarcity in local areas<br>Water assets allocation<br>Water treatment technologies and supply system<br>Regulation of industrial agents coordination | Reactive |
| Russian Federation | Local areas of physical water scarcity<br>Areas of approaching physical water scarcity | Upper middle income country | 80 % (2010) | 60 % (2010) | Coordination | Reactive |
| China | Areas of physical water scarcity<br>Areas of approaching physical water scarcity<br>Local areas of economic water scarcity | Upper middle income country | 50 % (2005) | 45 % (2004) | Physical and economic water scarcity in local areas | Reactive |

| | | | | | | |
|---|---|---|---|---|---|---|
| Scandinavian Countries | Neither physical nor economic water scarcity | High income country | 85–90 % (2007) | av. 85 % (2007) | Thorough analysis of social and environmental water issues<br>Water resources international provision | Proactive |

*Source*: FAO Stat, World Bank Databank, UN Data, Wisinfo

## 8.3 Roadmapping Methodology

Roadmapping pilot first began with the formulation of research questions. Based on these, the authors developed an integrated roadmap approach. This integrated roadmap took into account the well-established, and commonly applied, concepts of market and technology roadmaps. After that, both approaches were combined and their inherent limitations minimized, while the potentials benefits of both methods were integrated and leveraged. Furthermore, the integrated roadmap allowed for alternative options to be explored and prioritized from a more systematic viewpoint, including from both the market and the technology perspectives. At the same time, an area of technology (or field of study), suitable for a pilot study of the integrated roadmap, was sought. Eventually the methodology pilot was tested on nanotechnology applications for water purification solutions in Russia (Gokhberg et al. 2012; Sokolov et al. 2011; Vishnevskiy and Karasev 2011, 2012; Vishnevskiy et al. 2012).

The integrated roadmap is a resumptive document performing a multilevel system of strategic development in the subject area within a given time frame. It includes indicators that quantify the economic effectiveness of new technologies and products, which possess high demand potential. This roadmapping exercise relies on multiple Foresight methodologies, employing a multi-staged process of desk research, field study, expert involvement, and scenario development. The framework developed by the integrated roadmap highlights priorities for the further development of nano-enabled products for water treatment, and serves as a source for future study.

The roadmap is developed using both qualitative and quantitative methods, including survey data and evidence-based analytics. It summarizes expert opinions regarding the most important nanotechnologies, nanoproducts, and nanocomponents (interim products) that could be used for water treatment purposes. The study was based on analysing marketing data, official statistics, and expert, as well as population, surveys.

One of the most significant challenges when researching emerging technologies is the collection of valid and reliable data; this is accomplished mainly by the creation of expert groups. As a result, we introduced an approach based on both objective and subjective criteria.

The quality of a roadmap is strongly determined by the quality and reliability of the information used in its development. For the chosen pilot study, such information and data was mainly gathered from experts. However, because their knowledge and experiences, as tacit knowledge, were not sufficiently documented, it was necessary to identify and chose these experts carefully. Therefore, a unique approach – based on specific selection criteria – was applied, in order to identify and select those holding a suitable level of tacit knowledge. First, knowledge holders had to be authors of publications in internationally reviewed scientific journals included in the ISI Thomson database with a citation index for the previous 5 years in the nanotechnology field above the world average. Second, these knowledge holders had to represent an enterprise or organisation recognized as a leading Russian nanotechnology-related enterprise/organisation, and had to have been nominated as experts by the management of that organisation/enterprise. Finally, they needed to have been nominated as experts by at least three other previously recognized technology and/or market experts; this condition was justified by the fact that the science and technology communities are closely interrelated.

Based on these criteria, 100+ knowledge holders were identified and selected.

These experts contributed to the collection and processing of a large amount of data and information. For this purpose a variety of methods were used. The methods were grouped into several categories on the basis of the Foresight diamond (Popper 2008), taking into consideration practical experiences with these methods in a wide range of Foresight studies. Eventually the process of developing the roadmap was completed in five phases (Fig. 8.3).

Thus, the proposed sequence of methods for the evaluation of emerging technologies is as follows. In the first phase, the field of study is analysed on the basis of surveys, Delphi, and a study of key domestic and international technologies. This analysis allows for the identification of project scope, targets, and directions of further research. These directions are discussed in a special workshops, giving us an opportunity to specify the main themes of research during the second stage.

The desk research phase identifies the most significant trends in the researched field and brings to light the most promising technologies, products, and services. During this stage the creation of a preliminary version of a list of top-ranking experts in the subject field is a reasonable goal.

During the third stage, in-depth interviews with the most qualified experts in the field are conducted. This allows for the collection of so-called “tacit knowledge” – information that is not yet codified in papers, books, etc. After the aggregation of interview results, expert panels are held on each direction of the research, followed by a final expert panel to achieve a consensus between major stakeholders concerning chains R&D-technologies-products-markets.

Then a vision of the future is created using brainstorming and creative analysis. Through backcasting, the most desirable future scenario is formulated on the basis of the results of the previous stages, and after that the necessary actions to achieve this scenario are outlined. At this stage, special attention is given to stakeholders analysis, which determines how the roadmap, and its results, will be used by its beneficiaries. In the next stage, all the elements of the R&D-technologies-products-market chain, including SWOT-analysis and cross-impact analysis, are employed. In order to reveal extraordinary events that could dramatically influence subject field, methods to identify wild cards – low probability, high impact events – and weak signals – early warning signs of changes in trends and systems – are appropriate. These provide a set of innovation strategies for the subject field, taking into account alternative pathways.

At the final stage, possible scenarios of future development in the subject field are discussed and workshops with leading project experts. During these workshops

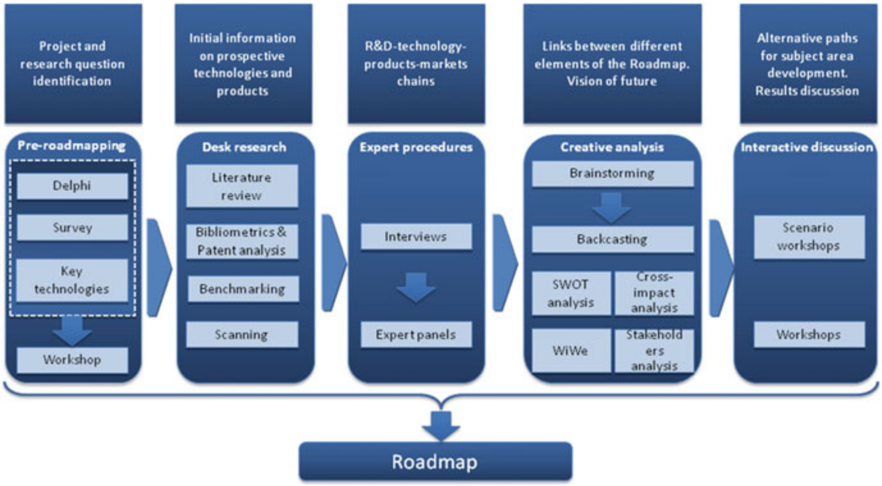


**Fig. 8.3** Proposed scheme of integrated roadmap

quantitative and qualitative assessments of future market dynamics are finalized, a draft of the roadmap is produced, and a discussion with a broad circle of stakeholders is held. After public discussions have been held a final version of the roadmap is completed.

Employing these methods gives us an opportunity to develop a roadmap with the following structure (Fig. 8.4).

The integrated roadmap includes four main layers:

- **Technologies**. This layer contains a description of the most promising technologies within the defined time frame. It provides a SWOT-analysis of these technologies that summarizes the benefits and limitations of each one. It also provides a forecast of target properties required to satisfy market needs and a set of technological tasks necessary to reach these. In the final analysis, it gives an opportunity to estimate prospects for each technology in terms of readiness for implementation and potential outcomes.
- **Products**. This layer provides a brief description of prospective products in terms of readiness for commercialization and potential effects for the researched area. It also provides a time frame for commercialization as well as the most promising market niches for each product.
- **Markets**. The methodological approach illustrates three scenarios of potential market development: pessimistic, optimistic, and moderate. It also provides a brief description of the main market features and possible strategies for each market. Thus, all markets are ranked from the most promising down to the least.
- **Alternatives**. The integrated roadmap also reveals possible developments of alternative products. It takes into account the dynamics of the main product properties, the opportunities for export of these products, and their cost among others.

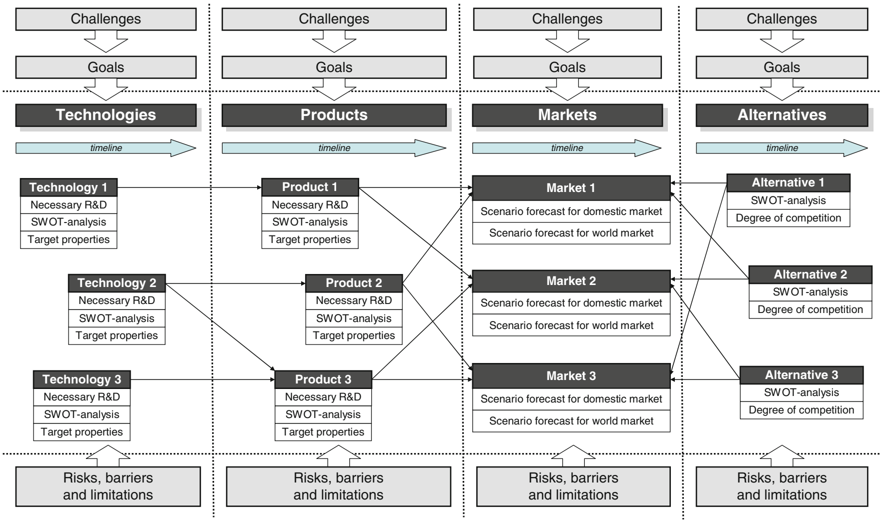


**Fig. 8.4** Proposed scheme of integrated roadmap

For each layer we consider challenges and set goals based on these, taking into account all the risks in the field. The roadmap outlines the most significant challenges for the subject field in question and these challenges in turn help to develop innovative technologies and products capable of addressing them. It is especially important to identify all the conditions that could prevent further development of the research area. The severity of any threats will be estimated by the roadmap.

### *8.3.1 Output and Outcomes of Roadmap Development for Supply- and Demand-Side Analysis*

Given the need for water resource, optimization of the water supply industry requires a large consolidation of stakeholder actions and views. The systematic efforts of resource convergence across the water and wastewater industry at various stages of the innovation and production cycle are assigned to the various layers of the integrated roadmap, and comprise multiple Foresight methods.

The roadmapping process was based on traditional industrial organization and demand-side conditions, and then extrapolated to technology issues aimed at tracking emerging technology trends. During the first stage, the distinguishing features of the water supply and wastewater industries, as well as the economic expectations of stakeholders, were identified.

The analysis shows that the Russian water industry faces several challenges regarding partial economic water resource shortages. Unequal water and wastewater supply infrastructure allocation, outdated and aging treatment facilities, obsolete treatment technologies, processes, machinery, and equipment, coupled with increasingly diversified water contamination across the regions are among them.

These terms shape potential demand for water technology solutions since the demand is driven by key industrial actors: large public-private (or government owned) agencies, which deliver treated water to industry and the public, and withdraw the sewage represent initial demand, whereas producers of technologies, processes solutions, and equipment is represent secondary demand.

During the second stage of the technological analysis which is aimed at tracking emerging technology issues, the roadmapping process employs the following steps from Foresight methods and mapping exercises: investigation of technology categories and technology products; linking together the R&D – technology – production chain; mapping out potential market segments for products introduction; developing an attainable time frame for product commercialization; identifying investment-attractive technologies.

First, consistent analysis of the technology portfolio, comprising the investigation of every single technology unit ranging from a particular technology to a technology cluster («technology group»), is made following the analysis scheme outlined below Table 8.4.

This scheme takes into account main technology properties; the application for market segments; the internal technical characteristics that make technologies or products superior or inferior to the alternatives, and those that indicate external water and wastewater treatment industry awareness. The list of methods used at this stage comprise a variety of desk research methods, expert panels, and a few creative analysis exercises (e.g., SWOT-analysis). On the one hand, this technology-side analysis resulted in the investigation of the processing properties of water-treatment technologies and products. For consistency, the primary nano-based technology is equated to the primary nano-based technological product unit due to similar "technology processes": for instance, microfiltration technology in water treatment matches the microfiltration membranes in terms of product development. On the other hand, the research for perspective market niches and competing products is also carried out, using SWOT analysis, mediating the technology and market extremes within the internal or external environment, while contributing to and limiting the distribution of technologies and products.

Table 8.1 shows the arguments in favour of microfiltration technology processes (microfiltration membrane technologies, components, and equipment) for certain water purification segments with tightened water quality standards; in particular, medicine, the food and beverage industry (including half-finished products, ingredients, and finished products), and air filtration. Both the technical properties and operational expenditures of the microfiltration membrane process are determined by consumer preferences, and based on this, market niches are assigned accordingly. The high level of technology readiness of these processes makes them applicable to the municipal sector at the initial stage of the water treatment process for centralized and decentralized water systems.

**Table 8.4** Example of technology analysis: microfiltration membranes

| **Main characteristics** | **Application areas of nanoproducts** |
|---|---|
| Process of mechanical filtration which allows to filter out fine suspensions, fine-dispersed and colloid impurities, algae, unicellular microorganisms larger than 0.1 μm | At initial stages of drinking water production and general water treatment<br>Special industrial applications: medicine; food industry (including half-finished products, ingredients and finished products, alcoholic and soft drinks, vegetable oil and other products)<br>Filtering for various technological environments<br>Air and gas purification |
| **Strengths** | **Weaknesses** |
| Compact size of equipment<br>Capacity can be easily increased due to modular structure<br>The process can be automated | Rather short useful life<br>Remove only some of the impurities working within a specific range<br>Need to be regularly flushed and cleaned |
| **Opportunities** | **Threats** |
| Need to upgrade existing water treatment facilities<br>More stringent requirements to waste water treatment<br>Extremely rapid growth of water consumption<br>Development of special-purpose water treatment segments | Conservative attitude of main users – centralised water supply systems<br>Budget limitations |
| **Competitive products** | |
| Gravel filters, aeration, chemical treatment, disinfection | |

In this way, the technology efficiency, and large-scale market application potential of microfiltration membrane processes in municipal and industrial water and wastewater treatment purposes, is proven.

Second, technological processes should be closely associated with market demand so that they can be brought to market quickly, and transformed and transmitted to products available for market application over short-, medium-, and long-term time horizons. Hence consumption properties are assigned to the product groups within the time scale which is differentiated by the basic stages of the innovation's life cycle, comprising research and development, technology prototype, and market application phases (Fig. 8.5). The nanotechnology-associated solutions are concentrated in physical and chemical treatment technologies, and therefore encompass the entire body of membrane processes (baromembrane, electromembrane, decontamination and membrane bioreactor processes); then sorption, coagulation and catalysis technologies; and finally some supplementary nanotechnologies and nanocomponents augmenting the filtration and purification processes.

The matrix view proposed above compresses the results of the analysis, and conveys the time frame of the R&D – technology – production chain of each technology process and product from the clusters listed above, along with the potential market niche available for its implementation and estimates. Here, the

| Key and promising products | Expected year of mass production in the RF | | | Market segment | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | CWS | CWC | IWT | SIWT | IWWT | MWWT |
| **Membranes** (LC, LPC, IR, IP) | | | | | | | | | |
| Microfiltration membranes | PP | MP | MP | X | X | X | X | X | X |
| Ultrafiltration membranes | PP | MP | MP | X | X | X | X | X | X |
| Nanofiltration membranes | PP | PP | MP | | | X | X | | |
| Reverse osmosis membranes | PP | MP | MP | | | X | X | | |
| Ion-exchange membranes | PP | MP | MP | X | X | X | X | | |
| Membranes for membrane degassing | PP | MP | MP | | | X | X | | |
| Membrane bioreactors | R&D | PP | PP | | | | | X | X |
| Membranes with dendrimers | PP | MP | MP | X | X | | | | |
| Membranes with fullerenes | R&D | PP | MP | X | X | | | | |
| Nanoreactive membranes | R&D | PP | MP | X | X | X | | | |
| Nanostructured membranes | R&D | PP | MP | X | X | X | | | |
| Nanocomposite membranes | PP | MP | MP | X | X | | X | | |
| Mixed membranes with non-organic and organic particles | R&D | PP | MP | | | X | X | | |
| Membranes based on zeolite molecular sieve | R&D | PP | MP | | | X | X | | |

| Key and promising products | Expected year of mass production in the RF | | | Market segment | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | CWS | CWC | IWT | SIWT | IWWT | MWWT |
| **Promising, supplementary and traditional technologies with potential nanocomponents employment (LC, LPC, IP)** | | | | | | | | | |
| Ion-exchange nanostructured membranes | PP | PP | MP | X | X | X | X | | |
| Nanosorbents | R&D | PP | MP | X | X | | | X | X |
| Active nanocatalysts inbuilt into membrane systems | PP | MP | MP | | X | X | | X | X |
| Nanosize biopolymers to remove impurities with adjustable properties | R&D | PP | MP | | | X | X | | |
| Nanoparticles-based coagulants | PP | PP | MP | | | | | | X |
| Nanocatalysts | PP | MP | MP | X | X | X | X | X | X |

*Legend*

| | |
|---|---|
| R&D – research and development; PP – pilot production; MP – mass production. | |
| LC – lower costs; LPC – lower power consumption; IR – increased resistance to high temperature and chemical agents; IP – increased productivity | |
| CWS – central water supply | SIWT – special industrial water treatment |
| CWC – collective water consumption | IWWT – industrial wastewater treatment |
| IWT – industrial water treatment | MWWT – municipal wastewater treatment |

**Fig. 8.5** Key features of nanoproduct estimation: R&D – technology – market chain

full set of potential market variables is listed, comprising centralized and decentralized water system treatment and supply, water treatment in industries with general purpose requirements (heating systems, some manufacturing processes, etc.), as well as specific requirements (medicines, medical solutions and liquids purification like hemodialysis, etc.).

The technology characteristics of the processes and products evolving through the phases of the innovation development cycle determine market options, and the time frame for commercialisation. For instance (Fig. 8.4), the broadest market application potential is found in micro- and ultrafiltrarion membrane processes in municipal and industrial water and wastewater treatment segments. The level of technological development of these baromembrane processes is one of the highest in comparison with the other applications. Jointly, these characteristics indicate a high probability of mass production market absorption in the near future. The other nanotechnology applications have smaller mass-market potential and consequently smaller-scale market implementation potential; for example, research on one of the supplementary nanocomponents in Russia – dendrimers and fullerenes for coupling the membranes – is at the initial stage of research and development. Sufficient time required for their realization as final products and the elaboration and production expenses, taking into account their adjusted technical properties, limit their application to municipal water treatment with vast differentiation of effective demand, various contamination level and treatment technologies objectives (Fig. 8.5).

At the next stage, the set of technology process parameters should be differentiated with respect to short-, medium-, and long-run time frames to show the evolution of the technology portfolio, and illustrate widest implementation possible (Fig. 8.6). This combination of supply- and demand-side analysis leads

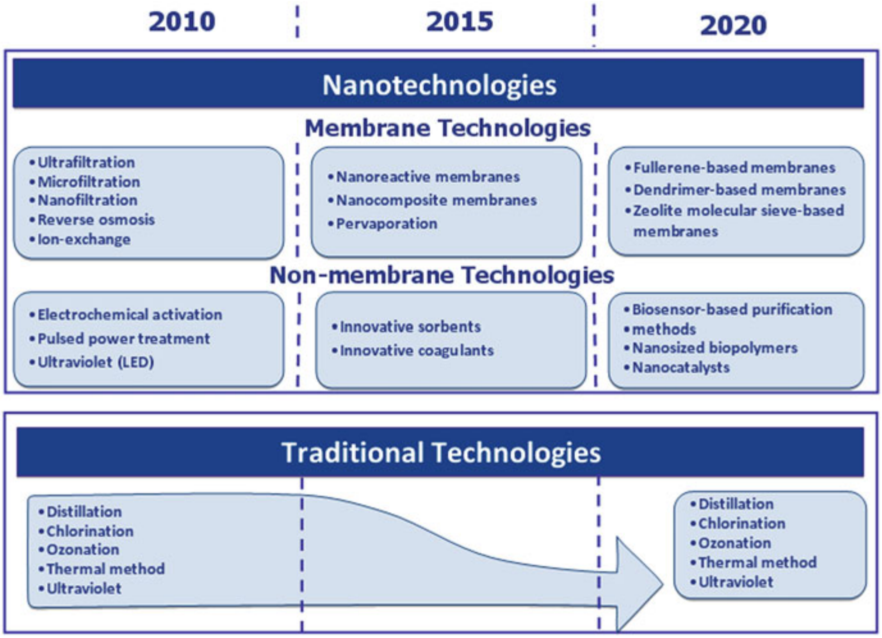


**Fig. 8.6** Mapping the technologies inside technology groups by anticipated market appearance date

to the outline of emerging technology trends, which match trends in the usage of nanotechnology and non-nanotechnology. This study shows that these two technology aspects should be regarded as complements rather than substitutes. This is due to specific water and wastewater treatment industry peculiarities, particularly market scale; the size of potential demand; the notion that treated and supplied water is a "public good production" expenses, along with technology peculiarities of water and wastewater purification, including the gradual and multistage treatment process; the strict and highly-scrutinized water quality standards; the wide variety of contaminants; the continuous fluctuation of contaminants level over time, coupled with the dependency on supply system solutions. Yet, traditional technologies cannot be abandoned or replaced by new and emerging technologies in a rush.

The predicted outcome is one of large technology breakthroughs in the nanotechnology industry for both membrane and non-membrane processes (Fig. 8.6), and the resilience of key non-nanotechnology clusters with some evolution in technology properties. In the long-run, so-called "traditional technologies" (filtration, distillation, chlorination, etc.) which appeal to non-nanotechnology processes will retain significant market share despite their relative diminishment. The overall efficiency of traditional technologies in terms of processing and consumption properties is expected to improve. Governmental policy in the form of regulation, standardization, and legislation is regarded as one of the leading drivers of the Russian water and wastewater industry. This is characterized in large part by public supply agencies that shape municipal and industrial water consumption with continued minor interference. Moreover, the shared vision of roadmap stakeholders – which includes public authorities; public and private water, wastewater treatment and supply agencies; producers of technology units; as well as innovation network participants from knowledge-generation, especially high-tech, sectors – in maximizing their benefits is another driving force of the industry sector progress, which is based on the combination of traditional and emerging nanotechnology processes..

Meanwhile the progress in the use of sectoral nanotechnologies is coupled with the shift in their application. The expansion of water treatment nanotechnologies in the long run will contribute to, and supplement, traditional technologies, leading to their radical enhancement. These breakthroughs in emerging technologies will induce the development of new market segments and niches. This effect is associated with fundamentally new technology properties, such as varied selectivity to special contaminants and targeted or "personalized" treatment processes, to expand the flexibility and variability of water treatment services, to make the adjustment to water subjected to purification easier, and to augment the scalability of treatment volumes.

Once this happens, a new generation of sorption or coagulation applications will emerge in the development of nanotechnology non-membrane processes, making them adjustable to the other stages of basic traditional and nanotechnology processes development.

Another mapping exercise employed is the double-criteria system for risk-assessment. This system estimates the market prospects of innovation technology clusters, in which each cluster's based on the criteria of "urgency" and "importance". In terms of urgency, it is the short-term significance of products with high commercialization potential, and a high level of technological readiness. The importance, on the other hand, is the long-term significance, that relies on demand-side conditions, establishing the necessity of R&D investments. The plotted technology portfolio for the purposes of strategic planning across technology pathways integrates financing, commercialisation, and market adaptation decisions.

## 8.4 Conclusion

In conclusion, the example provided above demonstrates that roadmaps could be employed as an instrument of forecasting and planning in the sphere of emerging technologies, under the stipulation that some requirements are fulfilled. These requirements include the creation of a group of experts who will provide the necessary level of expertise on all the issues related to the development of the subject area; accumulation of a sufficient informational background; construction of an adequate sequence of Foresight methods, integration of creative, interactive, expert- and evidence-based methods; combined consideration of market pull and technology push approaches, taking into account different kinds of effects of implementing new technologies.

The proposed roadmapping approach takes into consideration both technological issues and their contribution to overcoming socioeconomic challenges. Roadmapping allows for the elaboration of comprehensive innovation strategies both for short-run time frames concerning the commercialization of products with high market readiness, as well as for long-term strategies for water sector development.

The methodology allows for the prediction of both the direct and indirect effects of the implementation of emerging technologies in the researched area. It also gives an opportunity to outline possible future developments of researched technologies in interfaced sectors. However, the main limitation of the methodology is the insufficient consideration of the indirect effects of using innovative technologies in fields with many interfaces.

The introduced approach could be useful not only in the sphere of emerging technologies. With some adaptation, it could be used in forecasting and strategic planning both for corporations and government bodies.

## References

Ahuja G, Coff RW, Lee PM (2005) Managerial Foresight and attempted rent appropriation: insider trading on knowledge of imminent breakthroughs. Strateg Manage J 26(9):791–808

Albright R, Kappel T (2003) Roadmapping the corporation. IEEE Engineering Management Review 31(3):32–41

Arnold M, Koivunen K, Mroueh U-M, Paulsrud B, Rusten B (2008) NOWATECH – Innovative Nordic Water Technologies. Technology review. Nordic Water Technology Verification Centers, VTT, Aquateam, July 2008

Daim TU, Oliver T (2008) Implementing technology roadmap process in the energy services sector: a case study of a government agency. Technol Forecast Soc Change 75(5):687–720

De Smedt P (2006) Interactions between Foresights and decision-making. SVR – Research Centre of the Flemish Government, Boudewijnlaan 30, B-1000 Brussels

Elliott RN (2005) Roadmap to energy in the water and the wastewater in industry. American Council for an Energy-Efficient Economy, Washington, DC

FAO (2012) Food and agriculture organization of the United Nations. Database last updated Jan 2012, UN

Flash Eurobarometer 344 (2012) Attitudes of Europeans towards water – related issues. European Commission, Luxembourgh

Gokhberg L, Fursov K, Karasev O (2012) Nanotechnology development and regulatory framework: the case of Russia. Technovation 32(3–4):161–162

Heger T, Rohrbeck R (2012) Strategic foresight for collaborative exploration of new business fields. Technol Forecast Soc Change 79(5):819–831

Hinkebein TE, Price MK (2005) Progress with the desalination and water purification technologies US Roadmap. Desalination 182:19–28

Holmes C, Ferrill M (2005) The application of operation and technology roadmapping to aid Singaporean SMEs identify and select emerging technologies. Technol Forecast Soc Change 72(3):349–357

IAASTD (2008) The international assessment of agricultural knowledge. Database, GRID, United Nations Environment Programme

IWMI (2007) Water for food, water for life! a comprehensive assessment of water management in agriculture. In: Molden D (ed) Earthscan. International Water Management Initiative, London

Kappel TA (2001) Perspectives on roadmaps: how organizations talk about future. J Prod Innov Manage 18(2001):39–50

Kim C, Kim H, Han SH, Kim C, Kim MK, Park SH (2009) Developing a technology roadmap for construction R&D through interdisciplinary research efforts. Automation in Construction 18:330–337

Kynkäänniemi T (2007) Product roadmapping in collaboration (Tuoteominaisuuksien julkistus-suunnittelu verkottuneessa tuotekehityksessä) Espoo 2007. VTT Publications 625

Lee S, Kang S, Park Y, Park Y (2007) Technology roadmapping for R&D planning: the case of the Korean parts and materials industry. Technovation 27:433–445

Lee J, Lee CY, Kim TY (2009a) A practical approach for beginning the process of technology roadmapping. International Journal of Technology Management 47(4):306–321

Lee S, Yoon B, Lee C, Park J (2009b) Business planning based on technological capabilities: Patent analysis for technology-driven roadmapping. Technol Forecast Soc Change 76(6):769–786

Lichtenthaler U (2008) Integrated roadmaps for open innovation. Research Technology Management 51:45–49

Means E (2004) Water and wastewater industry energy efficiency: a research roadmap. McGuire Environmental Consultants, The California Energy Commission, The American Water Works Association Research Foundation

Molden D, Freken K (2007) Trends in water and agricultural development. International Water Management Institute Report, Part 2, Chapter. 2–3

NWAR (2009) National Water Account Roadmap. Bureau of Meteorology, Australian Government, Version 2.0, 4 June 2009

Onishchenko GG (2011) Information letter head of the federal service for supervision in the sphere of protection of consumer rights and human welfare. # 01/2175-1-32 dated March 1, 2011

Phaal R, Farrukh CJP, Probert DR (2001) T-Plan: the fast-start to technology roadmapping–planning your route to success. Institute for Manufacturing, University of Cambridge, Cambridge

Popper R (2008) Foresight methodology. In: Georghiou L, Cassingena J, Keenan M, Miles I, Popper R (eds) The handbook of technology Foresight. Edward Elgar, Cheltenham, pp 44–88

Rohrbeck R (2008) Innovating for the future – the roles of corporate Foresight in innovation management. European Center for Information and Communication Technology (EICT), Berlin, Germany & Technische Universität Berlin

Rosvodokanal (2011) Current situation in Russian water sector. http://www.rosvodokanal.ru/ru/branch/present/

Saritas O, Oner AM (2004) Systemic analysis of UK Foresight results. Joint application of integrated management model and roadmapping. Technol Forecast Soc Change 71:27–65

Shuvalova O (2010) Indicators of innovation climate in Russia (results of mass population surveys). Foresight Russ 4(1):38–52

SNL (2003) The federal desalination and water purification technology roadmap. A report of the executive committee. Sandia National Laboratories, U.S. Bureau of Reclamation, Jan 2003

SNL (2006) The energy-water roadmap process. Sandia National Laboratories, U.S. Bureau of Reclamation

Sokolov A, Karasev O, Rudnik P (2011) Emerging technology-related markets in Russia. J East West Bus 17:101–119

UNEP (2010) Sick water? The central role of wastewater management in sustainable development. United Nations Environmental Programme, New York

UNEP (2012a) Global environmental outlook 5: summary for policy makers. United Nations Environmental Programme, New York

UNEP (2012b) 21 issues for the 21 century. Results of the UNEP Foresight process on emerging environmental issues. United Nations Environmental Programme, New York

Vishnevskiy K, Karasev O (2010) Identifying the future of new materials with the use of Foresight methods. Foresight Russ 4(2):58–67

Vishnevskiy K, Karasev O (2011) Roadmapping for nanotechnologies in water purification: Russian experience. In: Proceedings of the Vth World Aqua Congress, New Delhi, 16–18 Nov 2011, pp 315–322

Vishnevskiy K, Karasev O (2012) Long-term planning tools for water purification sector: roadmapping for nanotechnologies in Russia. In: Morell M (ed) Water observation and information system for decision support. Faculty of civil engineering, Ohrid. ISBN 978-608-4510-10-9

Vishnevskiy K, Veselitskaya N, Karasev O (2012) Integrated roadmap for the nanotechnology water purification in Russia. In: 12th international GeoConference SGEM 2012. Conference Proceedings, STEF92 Technology Ltd., Sofia, pp 467–473

Whalen PJ (2007) Strategic and technology planning on a roadmapping foundation. Res Technol Manage 2008:40–51

WHO (2009a) Current situation in access to drinking-water. World Health Organization, Geneva

WHO (2009b) Mortality and burden of disease from water and sanitation. World Health Organization, 2009. http://www.who.int/gho/phe/water_sanitation/burden/en/index.html. Accessed 28 Sept 2012

WHO (2011) In: Cameron J, Hunter P, Jagals P et al (eds) Valuing water, valuing livelihoods. IWA Publishing, London

Willyard C, McClees C (1987) Motorola's technology roadmapping process. Res Technol Manage 30:13–19

WWDR (2009) Water in a changing world, United Nation World Water Development Report. 3rd edn. United Nations World Water Assessment Programme

Young MD (2011) Water investing in natural capital. United Nations Environmental Programme Report

Youssef R, Sabry R, Lotfy M, Salah A (2006) Foresight of water resources and management in Egypt. The Egypt Cabinet Information and Support Center, Center for Future Studies, June 2006

# Chapter 9
# Early Patterns of Commercialization in Graphene

**Philip Shapira, Jan Youtie, and Sanjay Arora**

## 9.1 Introduction

The adoption of science-driven technologies typically follows an uneven path. At times, adoption is rapid, but more often the pathway is bumpy and patchy, affected by factors such as limited knowledge of future product capabilities, process integration compatibilities with current manufacturing practices, and uncertainty about market acceptance. To explore some of the nuances of these commercialization patterns, this contribution examines early corporate entry and activity in graphene.

Graphene is a revolutionary nanotechnology material comprised of a single layer of carbon atoms in a hexagonal lattice pattern. This gives graphene distinctive features, including great strength, electrical and thermal conductivity, and lightness. In 2010, the Nobel Prize in physics was awarded to University of Manchester researchers Andre Geim and Konstantin Novoselov for their pioneering work on graphene (Nobelprize.org 2011). Graphene is anticipated to have great potential in a range of diverse applications such as enhancing performance in photon sensors,

P. Shapira (✉)
Manchester Institute of Innovation Research, Manchester Business School, University of Manchester, Manchester, M13 9PL, UK

School of Public Policy, Georgia Institute of Technology, D. M. Smith Building, 30332-0345, 685 Cherry Street, Atlanta, GA, USA
e-mail: philip.shapira@pubpolicy.gatech.edu

J. Youtie
Enterprise Innovation Institute, Georgia Institute of Technology, 75 Fifth Street NW, Suite 300, Atlanta, GA 30308, USA

School of Public Policy, Georgia Tech's School of Public Policy, D. M. Smith Building, 30332-0345, 685 Cherry Street, Atlanta, GA, USA

S. Arora
School of Public Policy, Georgia Institute of Technology, D. M. Smith Building, 30332-0345, 685 Cherry Street, Atlanta, GA, USA

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solar cells, display screens, composites, and building materials (Segal 2009). In electronics, graphene is referenced in the International Roadmap for Semiconductors, along with carbon nanotubes, as an emerging research material that will be important to interconnects, directed self-assembly for lithography extension, and assembly and package materials (ITRS 2010). Graphene's environmental, health and safety (EHS) profile has yet to be fully examined. Graphene may present fewer EHS risks than other carbon-based nanomaterials because it is nanoscale in only one-dimension (Segal 2009), although recent research suggests that graphene's novel shape could pose respiratory hazards in certain circumstances (Schinwald et al. 2012).

Although the science underlying graphene is still undergoing intensive investigation, there is already a significant and growing body of research knowledge about this new material and its characteristics. This research investigates two mechanisms – publishing and patenting – that offer initial evidence of enterprise interest in discovery and exploitation. We explore the relationships between these two mechanisms and consider what they tell us about early strategies of firm learning and commercialization. Engagement in scientific publication by firms (often in collaboration with university and public laboratory researchers) is an indication that these firms are active in seeking and acquiring new knowledge and capabilities to better understand an emerging technology. Engagement in patenting (which involves effort and expense in filing and maintaining patents as well the cost of research) suggests that firms are interested in exploiting (or potentially making it difficult for others to exploit) the knowledge and capabilities gained through research by targeting novel applications that may have competitive and commercial implications.

In the next section, we briefly review key literature and explain our methodological approach. We present descriptive findings and interpret the present state and evolution of graphene corporate publishing and patenting. These results are used to explore the patterns and strategies of early-stage graphene corporate entry and activity among countries, sectors, and leading firms. As well as examining relationships between corporate publication and patenting, we also identify various end-user application factors (i.e., logical clusters) that are then used to highlight activities of leading firms. The final section presents our conclusions.

## 9.2 Literature Review

The adoption of new technologies by firms is rarely straightforward or uniform. New technologies typically follow diverse and, at times, fragmented adoption rates and trajectories. At the company level, the decision to adopt a new technology is often framed by the uncertainty and risk it poses to the adopting unit. Firms draw on searching scopes that encompass internal and external knowledge to explore and learn about new technologies so as to assess the relative advantages of further exploiting existing technologies, generating or acquiring new technologies, or some combination of both strategies (March 1991; Katila and Ahuja 2002; Rogers 2003). The feasibility and potential value of the exploration of new technologies versus exploitation of existing technologies depends on whether the firm has or can establish the necessary competencies to address the opportunities and risks associated with the new technology or whether such capabilities are lacking and a tendency toward inertia prevails (Kogut and Kulatilaka 2001). A firm may pursue technological product or process innovations for competitive advantage but must weigh the benefits of the innovation with the concomitant costs of developing the new technology (Abernathy and Utterback 1978).

In game theoretic terms, this dilemma can be modeled as a "waiting game" in which uncertainty and rivalry determine the threshold at which a firm adopts a new technology (Hoppe 2002). Here, uncertainty refers to the arrival and value of the innovation while rivalry considers the type of interaction in the product market. The dilemma facing high-technology firms consists of both the commercial potential of the technology as well as current opportunity costs and future risks associated with product failures. Depending on a firm's internal rate of return and its value assessment of a new technology, it may choose to wait or adopt. Whereas adopting at the outset may provide first-mover advantages, waiting may offer better opportunities to capitalize on knowledge spillovers from technological improvements that originate from outside the firm. Furthermore, having greater capacity to store and process information increases the value of waiting. Waiting may not indicate idleness; rather, firms with greater absorptive capacity (or seeking to develop such capacity) may take additional time to acquire and process information in order to reduce risk and uncertainty (Cohen and Levinthal 1989). Notwithstanding, incentives to wait are moderated by expectations of the technology's profitability (Hoppe 2000); that is, if competitor firms predict a sufficient return based on information spillovers, they will engage in pre-emptive adoption in order to secure a portion of market share. Lieberman and colleagues also suggest that some companies find it is more beneficial to be the first to enter a new market if they have the pre-entry resources and expertise because early entry enables control of complementary assets, pricing that incorporates premiums and rents, and early market prominence which reinforces an advantageous position. On the other hand, another set of firms find the fast follower or second to enter position to be more beneficial because of the ability to learn from initial entrants, respond more quickly to market changes, and reduce customer education costs (Lieberman and Montgomery 1988, 1998; Helfat and Lieberman 2002).

The nature of the appropriability regime may also influence the decision to be an early entrant or a follower. Mechanisms for appropriability are diverse but include patenting, trade secrets, and other contracting tools, as well business strategies such as learning and pursuing first-mover advantages (Cohen et al. 2000). It has been suggested that firms have greater first-mover incentives in technological areas in which imitation barriers can be erected by patenting (Tuppura et al. 2010). In addition, some technologies enable a positively reinforcing cycle for early entry whereas incentives to be a later mover may be higher for technologies in which complementary capabilities (such as manufacturing or marketing specializations) retain their values (Teece 1986). We posit that graphene benefits from appropriability mechanisms in most global markets, which would encourage early entry by firms engaged in graphene R&D. On the other hand, it is unclear at this juncture whether graphene will eventually supplant capabilities in certain incumbent technologies (such as silicon), thereby advancing early entry incentives, or reinforce their value, thereby supporting follower motivations.

In determining whether and how to adopt a new technology, there are a series of factors that influence firms' decision-making. These embrace firm-level capabilities to adopt the new technology, relationships with customers' technical needs, market factors including the influence of others, and opportunities for positive network externalities (Liebowitz and Margolis 1995), sectoral or industrial conditions affecting the advantage from being the first mover; and factors such as the availability of finance, suppliers, and other forms of support. Porter (1990) argues that innovation is driven by industrial structure as well as input conditions, related and supporting industries, demand conditions, and government influences. Nelson and Winter (1982), Edquist (1997), and Lundvall (1992) suggest that differences in adoption of new innovations reflect particular attributes of sectoral and national innovation systems. This innovation systems perspectives stressess system and evolutionary factors including the role of learning within and between firms, interactions among enterprises and institutions, and systems of knowledge development and innovation. Sectoral innovation systems are composed of diverse networks of multinational firms, customers, suppliers, and linkages with universities and government laboratories that may cross national boundaries (Malerba 2005). Sectoral classifications suggest that some types of firms, such as science-based, are more likely to adopt new discovery driven innovations (Pavitt 1984). Moreover, although many sectoral value chains are international, R&D in certain sectors such as automobiles and wireless telecommunication has been found to evidence an explicit home country hi as (Cohen et al. 2009). National innovation systems perspectives advance the importance of country-level differences in organization and procedure, which help in better understanding the knowledge-based strategies of firms, the linkages of companies within the national system, and the type of commercialization strategies that are developed. Shapira et al. (2011) find that national innovation system characteristics are important in the commercialization of nanotechnology.

One way to assess variations in technology adoption is in terms of the length of time from discovery to application. Science-based technologies are often considered to require a lengthy period of time from initial work in the laboratory through to commercial activity in the business sector. Cockburn et al. (1999) note concerns about the long delay between science-driven discoveries in the biomedical area and adoption of these discoveries by the pharmaceutical industry. They find that the delay is associated with prior internal science as well as the types of products offered. Grupp (2000) describes how lasers underwent a science-driven phase, followed several years later by a technology phase. The second phase saw a significant period of decline and retrenchment (e.g., bankruptcies), followed again by market-driven production. Learning mechanisms underlie these phases in the transition from large lasers to semiconductor lasers. Schmoch (2007) suggests that the length of time between science and commercialization represents a "double boom" in which the first cycle is propelled by technological prospects and the second by marketing prospects. Schmoch observes that scientific trends generally lead technological trends by several years. Grupp and Schmoch each suggest that the time lag between science and commercialization is related to challenges faced in initial waves of growth in successfully reaching realization in the market.

The traditional (and earlier) linear model presents a contrasting framework to the double-boom concept. The linear model posits that research, development, manufacturing, and market phases are moved through in a sequential manner. Although this model has been criticized for overlooking feedback loops and external linkages, the linear model still remains prevalent in corporate processes and policy models (Rothwell cited in Hobday 2005). A variation to both the linear and double-boom models is the concept that science-based innovation proceeds through contemporaneous advancements in research and commercialization. Takeuchi and Nonaka (1986) observe that ever-shortening product cycles necessitate simultaneous rather than sequential development. Under this concurrent framework, we might also expect a significant level of patenting (a common measure of commercial interest) to occur alongside scientific discoveries rather than several years after these discoveries. As Mowery (2011) indicates, we are in a "pro-patent era" in which high rates of patenting are encouraged in universities and other research-intensive institutions as well as in companies.

These differing approaches are reflected in national R&D and innovation strategies. Many established R&D and innovation policies follow a linear model. For example, federal funds in the US are conventionally made available to sponsor basic research in universities and federal laboratories, with the private sector assumed to be responsible for developing this research and applying it to downstream applications. Yet, this traditional model is embedded in an R&D and innovation landscape where non-linear and more complex approaches are also evident. In the US, there is also significant federal and state policy support for public-private research partnerships, private sector R&D tax credits, innovation centers, small business innovation support, technology transfer, and other lateral and cross-cutting mechanisms of public support for applied R&D and commercialization. In particular, concurrent features are evident in the design of the US National Nanotechnology Initiative (NNI), which simultaneously promulgates four goals: "(1) advance a world-class nanotechnology research and development program; (2) foster the transfer of new technologies into products for commercial and public benefit; (3) develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; and (4) support responsible development of nanotechnology."[1] It is an approach underwritten by the Twenty-first Century Nanotechnology Research and Development Act (P.L. 108-153). Passed in 2003, this legislation seeks the integration of

[1] http://www.nano.gov/html/about/home_about.html. Accessed 15 Apr 2011.

societal concerns into nanotechnology R&D. While societal concerns include environmental, legal, and ethical issues, the Act also embraces economic development considerations by "ensuring that advances in nanotechnology bring about improvements in quality of life for all Americans." Policy and programmatic strategies pursued by the NNI under the aegis of P.L. 108-153 aim to shorten research-to-commercialization cycles and support accompanying human capital, societal assessment, and governance mechanisms so that economic development and societal outcomes from public R&D investments may be experienced sooner rather than later. To be effective, these policies need to stimulate companies not only to engage in knowledge discovery but also to translate new nanotechnology knowledge into usable (and responsible) applications.

Our literature review highlights contrasting generic models – linear, concurrent, and double boom – of how discovery transitions into commercial activity. It is thus appropriate to ask: under what circumstances will one or another of these models be most likely to prevail? It is plausible to expect that technical characteristics combined with industrial, market, policy, and innovation systems contexts will influence the particular pathways taken by a specific new technology. While game-based models imply that firms may delay adoption until a technology reaches a certain threshold, this may not be the case with graphene, where products reflecting incremental improvements are rapidly being prepared for the market. Indeed, diverse commercialization strategies are likely to be pursued given the wide scope of potential uses and markets for graphene-enabled applications. At the same time, the commercialization of graphene applications in any particular market is influenced not only by the technical advancement of features related to that application but also by multiple other factors including the ability to scale-up manufacturing, progress in competing materials, access to intellectual property and finance, and path dependencies that may present obstacles to deployment. In the realm of electronics, for example, preliminary research efforts focusing on graphene as a silicon replacement are prominent (Van Noorden 2011). Moore's Law, first conceptualized in 1965, states that the number of transistors in an integrated circuit doubles every 2 years. As the density of transistors reaches its physical limits using conventional silicon technology, exploring and exploiting higher performing materials such as graphene is attractive. Thus, in addition to optimistic profitability forecasts, limitations of current technologies (e.g., silicon) and the existing massive investment in them (including multi-billion dollar fabrication facilities) may attenuate the threshold at which firms decide to adopt the new technology or engage in information-seeking activities.

Corporate publishing and patenting are two indicators of private sector engagement with technology and associated investment interest (Shapira et al. 2003). These measures are not without well-known limitations. Corporations do not publish all they know or may delay the release of publications so as to protect intellectual property and knowledge advantages. Publications may also be viewed more as indicating research rather than development activities.

Corporations may choose not to seek patents for discoveries, keeping them as trade secrets, or may patent without necessarily having the intent to commercialize these inventions. Nonetheless, with these limitations in mind, evidence from corporate publications and patents can usefully be analyzed to signal what might be the technological and commercialization interests of companies in emergent fields. In the context of uncertainty and information seeking, scientific publishing suggests that companies are developing knowledge and capabilities and also exploring a new technology's utility and viability. Corporate patenting suggests that companies are generating or acquiring inventions that ex ante have potential significance for subsequent market applications and which promise value, be it through the intent to self-develop the new technology, through making it difficult for competitors to develop the new technology in the same way, through licensing, or by increasing the attractiveness of the company to external investors. These are not necessarily mutually exclusive objectives.

If extensive publishing output can be viewed as a penchant for exploration, with patenting seen as signaling an interest in exploitation, then the relationship between these two measures is of interest. Strategic management literature identifies the importance of both exploration and exploitation (see March 1991), with recent research streams emphasizing the advantages of pursuing both at the same time (i.e., ambidexterity) (e.g., Rothaermel and Alexandre 2009; Lavie et al. 2010). Pries and Guild (2011) describe the commercialization of innovative technologies from universities as a process consisting of technology, product, and business development activities. Technology development focuses on the science and design of the technology whereas product development incorporates new features into solutions addressing customer needs. Business development identifies, secures, and orchestrates the complementary assets needed to manufacture and sell products.

Firms in a particular technology domain may concurrently operate in one or more of these development cycles, depending on the firm's existing competencies and perceptions of the technology's value. High publishing output may indicate a firm's investment in technology development and information seeking, which reduces uncertainty and sets the stage for future commercialization efforts. Along the same lines, patenting reveals a firm's emphasis in business development, suggesting that a firm exhibits more confidence in a technology's commercial application. Abstaining from publishing or patenting could signal overt waiting or even complacency. Firms in this last category may view graphene R&D as untenable given the costs and/or lack of in-house absorptive capacity. Such firms are not studied in further detail here.

This study specifically aims to explore the timing and characteristics of graphene corporate activity based on publications and patents. We examine graphene publications and patents over time to understand whether any of the three key models previously discussed are being pursued. A linear model would be evidenced by a substantial lag between research publications and patenting activity; a concurrent model would be evidenced by a simultaneous or at least a much reduced lag between publication and patenting activity; and a double-boom model would be evidenced by a substantial downturn after an initial increase in corporate publication and patenting activity.

## 9.3 Method

This analysis is based on the development of databases of graphene-related publications and patents associated with companies. We identify records in which the company is addressed as an author or a co-author of a publication or as an inventor or assignee of a patent. As noted, limitations exist in using publications as a measure of science and patents as a measure of commercial interest. It would be ideal to have data on graphene-related products introduced by firms. However, as yet, it is too early in the research and commercialization cycle of this novel material for any significant product applications to appear on the market. The use of corporate publications and patents is common in investigating emerging technologies that are not fully at the product stage, which is the case with graphene, and thus is employed here.

Graphene publications were drawn from the Web of Science's Science Citation Index in October 2010, with an update occurring in February 2011, and represent the time period 2000–2010. Interviews with graphene researchers informed us that articles with graphene in the title were most apt to be in domain, whereas articles with graphene in the abstract, but not the title, would capture less relevant works. Hence, we restricted our search to title fields. Graphene patents were selected from Thomson Reuters Derwent Innovation Index in April 2011 and represent the time period 2000–2010. Guidance from patent experts led us to use a broader criterion for selection of graphene patents that includes a patent if the term graphene appears in abstracts and claims as well as titles. These definitions resulted in 4,787 graphene publications and 911 graphene patents in the 2000–2010 period. Most of these patents (97 %) are applications, but although they are not granted, they do give an indication of the types of commercial application interests foreseen by the companies that are involved.

Our analysis focuses on the diffusion of graphene across time, countries, and applications. After an initial year-by-year overview of the diffusion of graphene publication and patenting activity, we focus on five multi-year time periods: 2000–2002, 2003–2004, 2005–2006, 2007–2008, and 2009–2010. This multi-year approach is presented to smooth fluctuations that occur in year-by-year analyses in an emerging field that has grown rapidly from a very small initial base. (A test using 3-year time period finds results that are consistent. We thus use mostly 2-year periods to allow a greater number of data points.) Our analysis explores diffusion pathways that represent linear, concurrent. and/or double-boom trajectories.

## 9.4 Results

The analysis begins with an examination of the trajectory of graphene publications and patents in comparison with fullerene, another nanoparticle that was recognized by the Nobel Prize. Compared with fullerene, graphene has experienced a faster

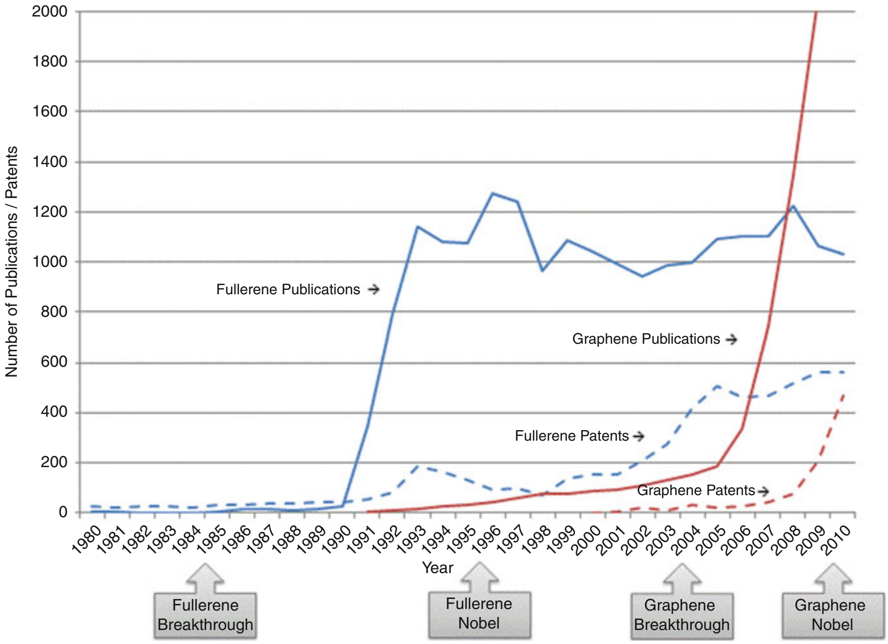


**Fig. 9.1** Graphene and fullerene publications and patenting by year (*Source:* Analysis of publications from the Web of Science for graphene ($N = 4{,}787$) and fullerene ($N = 20{,}701$); and patents from Dewent Innovation Index for graphene ($N = 911$) and fullerene ($N = 5{,}942$))

upward trajectory of publications and patents (see Fig. 9.1, which includes all graphene-related publications and patents, not just those associated with companies). After a mid-1980s breakthrough, fullerene publication counts totaled fewer than 30 a year until 1990–1991, when they rose to nearly 350 and eventually tripled in the next 2 years. By the time the Nobel Prize was awarded in recognition of the work on fullerenes, the fullerene publication growth rate had flattened. Graphene publication counts experienced a 13.5-fold increase from the 2004 breakthrough to the 2010 Nobel Prize award and have yet to level off. This lack of leveling may in part be due to the earlier Nobel Prize recognition of the graphene-related work than was the case for fullerenes (6 years for graphene vs. 11 years for fullerenes, respectively). Patenting pattern upswings (including both patent applications and grants) also show similar patterns and differences between the two nanoparticles. There were nearly 16 times more graphene patents in 2010 (the graphene Nobel year) than in 2004 (the graphene breakthrough year). This same figure for fullerenes was nearly three times (although from 2000 to 2010, the number of fullerene patents nearly quadrupled). On the other hand, both particles are similar in that once a steep increase in publications begins, an upswing in patenting follows (in about 2 years for fullerene and 4 years for graphene). The double-boom phenomenon can be observed in fullerene patent and publication trajectories but not as distinctly in graphene patent and publications trajectories.

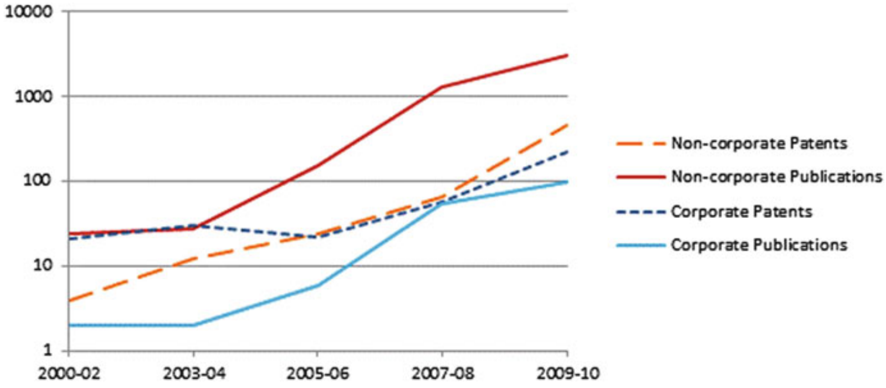


**Fig. 9.2** Worldwide graphene patents and publication trends, 2000–2010. *Y* axis = log scaled publication and patent counts (*Source:* Analysis of 4,787 graphene publications, 911 graphene patents)

It is unclear whether the graphene activity has had less history to present a definitive double-boom trend or whether graphene will continue to attract ever more scholarly and commercial interest.

The broader picture of the growth of graphene provides a backdrop for our focus on corporate publication and patenting activity in the graphene domain. Corporations account for 3 % of graphene publications (as authors or co-authors) and 35 % of graphene patents (as assignees). Even though companies make up but a small share of all graphene publications, these company-authored papers are very collaborative. Eighty-seven percent of company-authored papers with graphene in the title also have a university co-author. For all fields of nanotechnology in Georgia Tech's global nanotechnology database (Porter et al. 2008), the company-university co-authorship percentage is 67 %. More than 90 % of graphene publications with a corporate co-author and 65 % of graphene patents assigned to a corporation were published since 2006. The top companies based on number of graphene publications (through to the end of 2010) are IBM (32), NTT (12), AMO Gmbh and NEC (9 each), and Alcatel Lucent (8). The top corporations in terms of graphene patents are Samsung (32), Sandisk 3D (23), Teijin (21), and Fujitsu (17).

In this analysis, we look at the relationship between graphene publications and patents to understand the nature of the lag between the two. Graphene corporate and non-corporate publication and patent activity (which includes mostly universities, but also government laboratory and other research institutions) is presented on a log scale to enhance comparability (Fig. 9.2). The figure indicates that the initial (2000–2002) time period saw higher levels of corporate patenting and non-corporate publishing (growing by 43 % and 17 %, respectively) but a fourfold (i.e., 200 %) growth in non-corporate patenting, albeit from a small base of four patents in the first 3 years of the decade and 12 patents in the next 2 years. A second period since 2004 reflects the rapid growth of publishing, even in the corporate sector. Non-corporate publishing was 45 times larger and corporate publishing 28

**Table 9.1** Top ten countries for graphene patents and publications, 2000–2010, ranked by number of patents

| Country | Patents | | | | Publications | | | |
|---|---|---|---|---|---|---|---|---|
| | Rank | All | Corporate | % Corporate | Rank | All | Corporate | % Corporate |
| USA | 1 | 376 | 127 | 34 % | 1 | 1,086 | 55 | 5 % |
| Japan | 2 | 194 | 125 | 64 % | 4 | 286 | 30 | 10 % |
| China | 3 | 144 | 6 | 4 % | 2 | 400 | 3 | 1 % |
| South Korea | 4 | 127 | 48 | 38 % | 12 | 102 | 8 | 8 % |
| Canada | 5 | 20 | 8 | 40 % | 10 | 113 | – | 0 % |
| Germany | 6 | 16 | 5 | 31 % | 3 | 297 | 11 | 4 % |
| UK | 7 | 13 | 10 | 77 % | 5 | 215 | 6 | 3 % |
| France | 8 | 12 | – | 0 % | 7 | 166 | 2 | 1 % |
| Finland | 9 | 5 | – | 0 % | 24 | 34 | 1 | 3 % |
| Australia | 10 | 4 | – | 0 % | 34 | 10 | 1 | 10 % |

*Source:* Analysis of worldwide graphene patents ($N = 874$) in Derwent Innovations Index and graphene publications in the Web of Science ($N = 3{,}346$)

times larger in 2007–2008 than in 2003–2004. By 2007–2008, corporate publishing and patenting were on level terms. During this middle period, non-corporate and corporate patenting still grew significantly – by 450 % for non-corporate patenting and, after a decline in the 2005–2006 period, 87 % for corporate patenting –but at a slower rate than that of publishing. In the most recent 2 years (2009–2010), non-corporate and corporate patenting activity once again rose more substantially (by more than 590 % for non-corporate patenting and more than 290 % for corporate patenting). In sum, graphene has undergone different growth phases. The middle of the decade is dominated by publishing growth, followed by patenting growth at the end of the decade.

In the following section, we break down these overall metrics by country and application area. The breakdowns for the top 10 countries ranked by graphene patenting activity are shown in Table 9.1. The table shows that the US maintains the largest share of graphene patents and publications overall. Other countries are notable for their relatively higher share of corporate patents, for example, Japan and the UK. However, compared with the UK, South Korea has a far higher number of corporate graphene patents and holds third place by this absolute measure after the US and Japan. In addition to maintaining a high share of corporate patents, Japan also leads the ten countries in terms of corporate involvement in publications, with many large corporations (e.g., NTT, NEC, Toyota, Fujitsu, and Mitsubishi) publishing graphene research. China's graphene publication and patent data suggest another distinctive model, with more university-led activity in both patents and publications. Patenting participation is stronger in the university than the corporate sectors in China. Highly ranked countries in graphene patenting do not necessarily rank as high in publication: for example, Finland and Australia rank in the top ten countries for graphene patenting but rather lower for graphene publications.

We further examine the trajectory of patents and publications for the US and Japan, which have graphene publication and patenting activity throughout much of

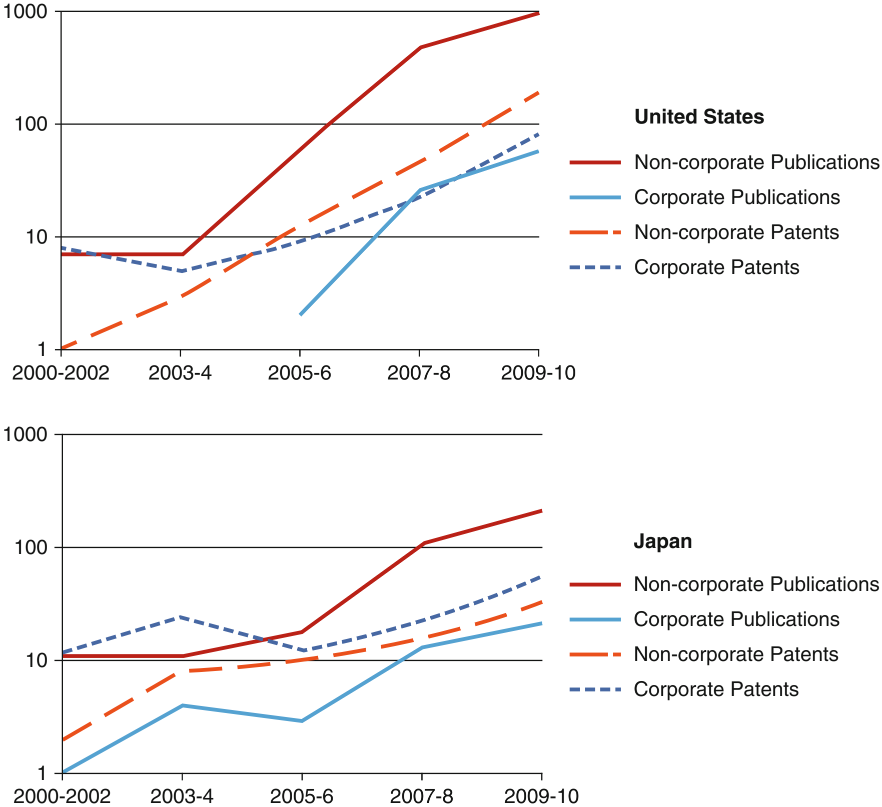


**Fig. 9.3** Graphene publications and patent trends: US and Japan, 2000–2010. *Y* axis = log scaled publication and patent counts (*Source:* Analysis of 569 patents and 1,948 publications)

the last decade. US academic graphene publications grew rapidly from 2003 to 2008 and US academic patents had a steep trajectory throughout the 10-year period (Fig. 9.3). US corporate patents moved downward between the first two time periods, moved upwards in the middle of the decade, and grew even faster in the last time period. Japan's academic activity showed a more modest growth rate, while Japan's corporate patents and publications demonstrate three distinct waves: early growth to 2004, decline to 2006, followed by a further period of growth to the end of the decade. Between the 2007–2008 and 2009–2010 time periods, corporate patents in the US grew by a factor of 3.8 and in Japan by a factor of 2.5.

Company involvement in a science-driven area is not evidenced solely through publication and patent records. For example, corporate involvement also occurs through the sponsorship of graphene research. When examining US-authored publications, we see that the Semiconductor Research Corporation (SRC) consortium is the fourth largest fonder of graphene research (after the National Science Foundation, US Department of Energy, and Office of Naval Research); this position

**Table 9.2** Number of companies by first year of entry in graphene publishing or patenting and country, for six leading countries, 2000–2010

| | Number of patents | | | | | |
|---|---|---|---|---|---|---|
| Country | 2000–2 | 2003–4 | 2005–6 | 2007–8 | 2009–10 | Total |
| USA | 6 | 1 | 5 | 22 | 37 | 71 |
| Japan | 14 | 20 | 4 | 14 | 14 | 66 |
| South Korea | | | | 3 | 4 | 7 |
| Germany | 1 | | | 4 | 4 | 9 |
| UK | | | | 5 | 1 | 6 |
| China | | | | | 4 | 4 |

*Source:* See Table 9.1

is measured by the counts of articles that acknowledge the SRC as sponsoring the work on which the articles are based. Intel also is a relatively significant funder as are foundations (e.g., Robert A. Welch Foundation). In addition, R&D programs in countries outside the US are also among the top funders including China (e.g., the National Science Foundation of China and 973 Program), Germany (Deutsche Forschungsgemeinschaft), European Union, and Korean Government.

With recognition of the limitations of using publication and patent records, we are able to estimate “corporate entry” (Shapira et al. 2011) into graphene by merging the publication and patent databases. Merger of this information yields a global list of 210 companies involved in graphene research and investment through to 2010. The 2000s saw an expansion in the number of companies entering into the graphene domain either through authoring scientific publications or seeking patents (Table 9.2). Up to 2004, Japan was the early leader by the number of companies involved with graphene, and has continued to be a strong player. The 2000–2002 time period saw the entry into graphene of Japanese companies NEC and GSI Creos; 2003–2004 saw the entry of Sony, Matsushita, Nissan, NKK, and Toyota; 2005–2006 saw the entry of Teijin and Fujitsu; 2007–2008 saw the entry of NTT, Casio, Mitsui, Stanley Electric, Tokai Rubber, Toshiba; and 2009–2010 saw the entry of Mitsubishi Chemical, Sekisui Chemical, Toyoda, and Vico. The US had a few companies enter into the graphene domain before 2007 including 2000–2002 with DuPont, BP Amoco, Fullerene International (a joint venture involving US and international partners); and Materials and ElectroChemical Research Corporation; 2003–2004 with MeadWestvaco; and 2005–2006 with IBM, Nanodynamics, Nanosource, Supracarbolic, Wave-Band Sierra. After 2006, there were many more US corporate entries, exceeding the number in Japan, including 2007–2008 with Dow, Nanoconduction, and Unidym; and 2009–2010 with Sandisk, Texas Instruments, Vorbeck, and Northrop-Grumman. Korea had no corporate entries until 2007–2008, when Samsung started patenting in the graphene domain along with Sodiff Advanced Materials and N-Baro Tech. In 2009–2010, additional Korean-based firms including Sang and Toray Advanced Materials Korea entered the graphene domain. Germany saw most of its corporate entries occur in 2007–2008 (including AMO GmbH, DaimlerChrysler, Nanofilm Technology GmbH) and 2009–2010 (DIC Berlin GmbH, KME Germany, Siemens, and Tyco

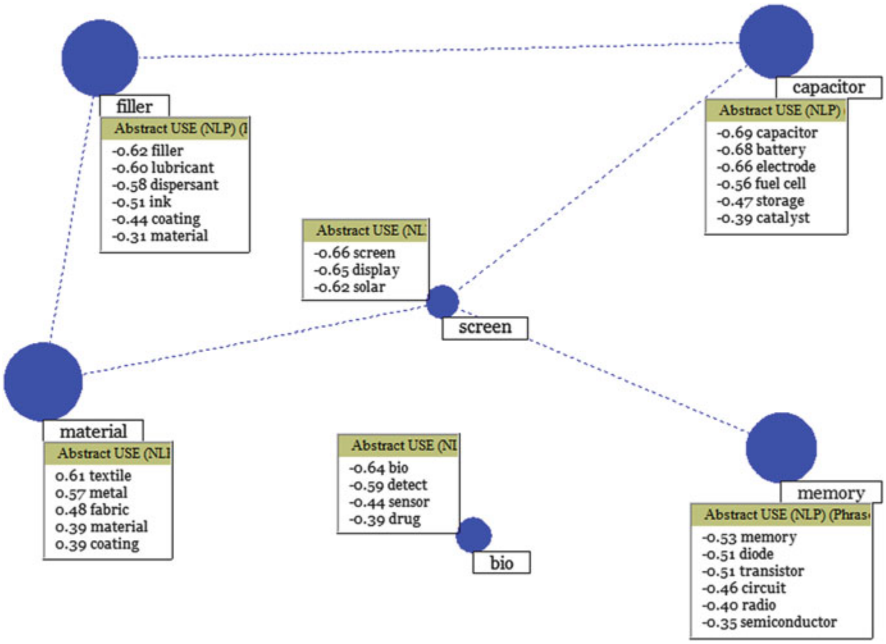


**Fig. 9.4** Factor map of graphene keywords in patent abstracts (six-factor solution shown) (*Source:* Analysis of 633 graphene patents, 2000–2010)

Electronics AMP GmbH), the exception being Dilo Trading AG (entering in the 2000–2002 time period). The UK's corporate entries occurred in 2007–2008, including Graphene Industries Ltd, and Hexcel Composites, with Solarprint entering in 2009–2010. China did not have any corporate activity through patenting or publishing until 2009–2010, at which time several Chinese-based companies became involved in graphene including the Longhai Naite Chemical Industry Company, the Shanghai Aowei Technology Development Company, and Tianjin Pulan Nano Technology.

The types of applications associated with graphene corporate activities suggest diverse use potential. There are prevalent applications related to fuel cells, sensors, and composite materials. To systematically probe potential uses, we use factor analysis to map groupings based on similarity of mentions in the patent abstract. The results in Fig. 9.4 indicate six clusters: (1) screens/displays for computer devices, (2) semiconductor memory chips, (3) biomedical-related detection devices, (4) batteries, (5) filler, coatings, and ink, and (6) materials. Some of the application keywords fall in multiple factors, for example, coating. These six clusters represent 69 % of the patent records, although some patents involving composites, paper, and optics were not statistically incorporated into these six clusters. Although the electronics industry is prominent in some of these application areas (especially screens/displays, memory chips, batteries), we also see diversity in applications in materials, coatings, and the biomedical area.

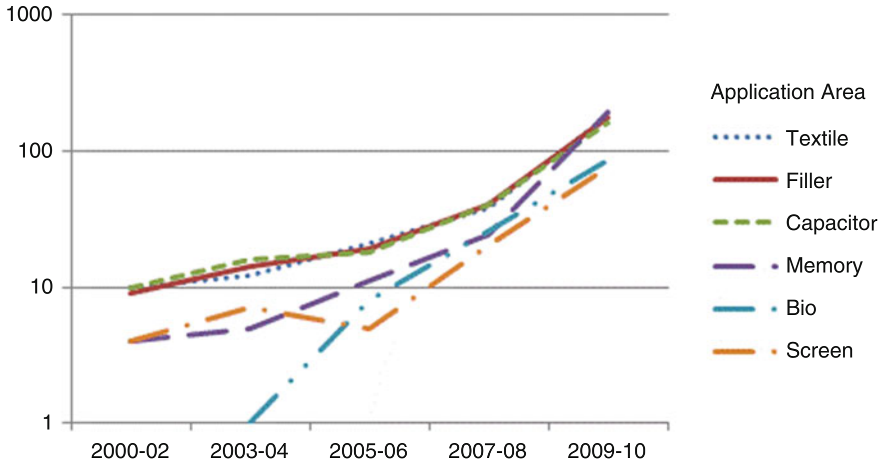


**Fig. 9.5** Graphene patent activity by application area, 2000–2010. *Y* axis = log scaled patent counts (*Source:* Analysis of 633 patents)

From 2000 to 2010, materials, filler, and capacitor application areas all grew at the same logarithmic rate (Fig. 9.5). The memory area grew at a slower rate between the first two periods, at a faster rate in the middle of the decade, and at an even faster rate in the last period. The screen area moved upward between the first and second periods, back downward in the third period, then upward again until the end of the decade. The bio area, which is the smallest in terms of patent counts, had the latest but relatively steepest growth, especially from the 2003/2004 to periods. Average annual patent growth rates from 2000 to 2008 were 35 % for the textile area, 44 % for the filler area, and 39 % for the capacitor area. During this 8-year period, memory-related patents grew by 63 % while screen-related patents rose by 50 %. In the last 2 years, patents in the memory area experienced a more than 8-fold increase, materials saw a 4.8-fold increase, fillers recorded a 4.3-fold increase, capacitor and screen areas nearly quadrupled, and the bio area more than tripled.

Corporations are most prevalent in the memory area, where they account for 46 % of all patents, and least prevalent in the bio area, accounting for only 31 % of the patents. Figure 9.6 graphs each of the top patent assignees against the application factors presented in Fig. 9.4. Many of the larger electronics companies are active in the battery, memory, detect, and screen application areas. For instance, Samsung maintains a large share of graphene patents referring to the keywords of screen, display, optic, and solar, corroborating other sources of information that indicate Samsung's interest in using graphene for touch screen displays. Besides the large multinationals, there are two SMEs (with fewer than 500 employees) represented in Fig. 9.6. Both firms, Vorbeck and Nanotek Instruments, are US-based and offer two unique characteristics vis-à-vis their larger firm counterparts. Vorbeck's patents appear to cover the full spectrum of the six application factors;

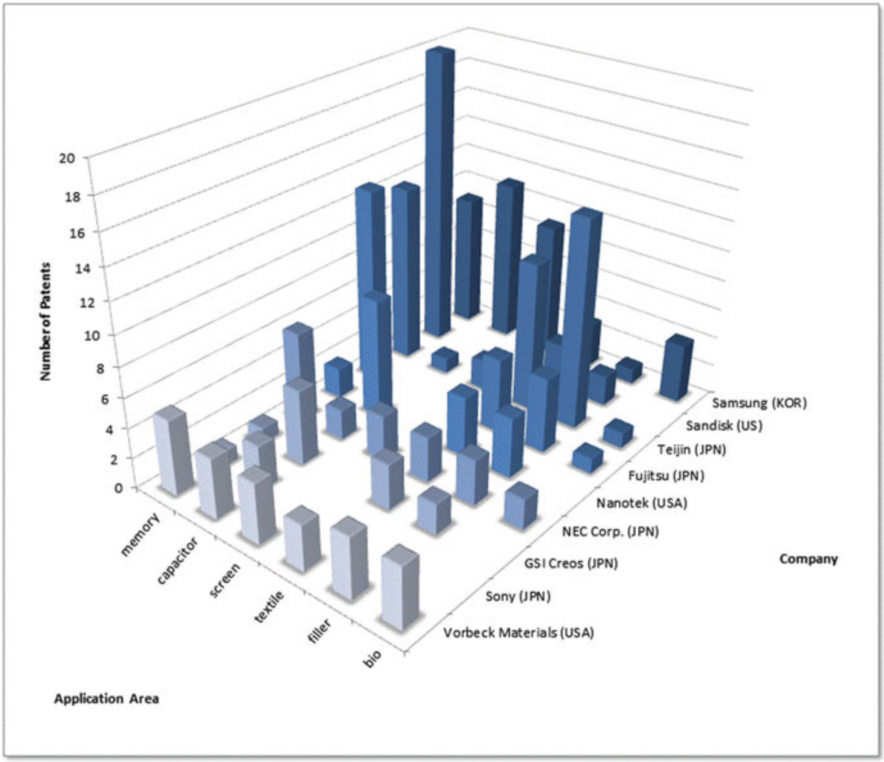


**Fig. 9.6** Graphene application areas in patents of top company assignees, 2000–2010 (*Source:* Analysis of 633 graphene patents)

the company was the first firm to offer graphene-based conductive electronic inks on the market (Rogers 2011). Nanotek Instrument's graphene patents, on the other hand, focus more exclusively in the coating and battery application areas. The finding that smaller firms that patent do so with relatively high intensity is consistent with Brouwer and Kleinknecht (1999) who suggest that once small firms overcome the initial threshold barriers to patenting, they often actively patent to compensate for their lower market power relative to larger firms.

The US has the largest number of patents across all six graphene application areas, but is particularly strong in the memory area. Japan has the second largest number of patents in all six graphene application areas, with particular concentration in fillers. China's patents tend to be in materials, fillers, and capacitors and there is little patent application activity in the other three areas. Korea's patents are most prominent in the capacitor, memory, and screen areas. Germany and the UK have the greatest concentration of patents in the capacitor and filler areas and (for Germany) the memory area.

## 9.5 Conclusions

This research has shown that corporate interest in graphene discovery and exploitation has grown rapidly in leading countries over the past decade. We have used publication and patent counts, with a focus on those authored by or assigned to companies, to understand how corporate activity is unfolding in the graphene domain. Graphene research and commercialization are both still at early stages. In the US, as in other key countries, policy has sought to foster concurrent processes of research and commercialization in the nanotechnology domain, which includes graphene.

Our examination of early corporate trajectories for graphene leads to three major observations. First, the discovery-to-application cycle for graphene appears to be accelerated, particularly when compared with earlier discoveries such as fullerene. Even though the emergence of graphene is relatively recent, we do see an upsurge of early corporate activities by large and small firms. Second, there has been rapid globalization, with companies in the US, Europe, Japan, South Korea, and other developed economies engaged in early graphene activities. Significantly, companies in China are now also beginning to enter the graphene domain, building on the expansion of Chinese nanotechnology research capability. Yet, strength in science alone does not guarantee commercial exploitation: the UK, which is a research pioneer in graphene, has a level of corporate patenting slightly ahead of Canada and Germany but significantly lower than in the US, Japan, and South Korea. Third, we see a rapid widening of the potential application funnel for graphene. Corporate patenting trends signal that companies are interested in exploiting the features of graphene in multiple diverse areas including transistors, electronic memory and circuits, capacitors, displays, solar cells, batteries, coatings, advanced materials, sensors, and biodevices. Although graphene was touted early on as a silicon replacement in semiconductors, initial applications are occurring elsewhere, including in electronic inks and additives to resins and coatings. Our analysis highlighted six emerging application areas: displays/screen, memory chips, biomedical related, batteries/fuel cells, coatings and inks, and materials. However, growth patterns differed across these application areas. The display/screen area exhibited the most pronounced double-boom growth pattern, the memory area extended upward more consistently, and the biomedical area demonstrated steep and late growth patterns.

In examining corporate engagement in graphene, we sought to understand how early corporate activity patterns related to broader research and invention trends. In traditional innovation models, a lag between research publication and patenting is consistent with the linear model. This is less so with more recent innovation models stressing concurrent launch, open innovation, and strategic intellectual property management. In the latter case, publication may come after patenting. There are points at which one might also expect an overlap between publication and commercialization, producing a concurrent pattern as research takes place while technological applications are being patented. In our empirical analysis, taking a highly aggregated global view, we found some linearity in that increased activity in general publication output preceded growth in patenting. There is a propulsive effect from the discoveries which subsequently led to the Nobel Prize award, as publications and then patents quickly began to grow. Graphene patents exhibited an upswing about 4 years after the upswing in graphene research publications. This lag time is apparent for the total set of graphene publications and patents for universities and public laboratories as well as corporations. However, differing patterns were observed when we adopted a more granular look at the corporate sector, which currently holds about 35 % of the graphene patents. There is evidence of a double boom in corporate activity, with an initial period of growth of corporate patents early in the decade followed by a lesser rate of growth in the middle of the decade, and resurgence in corporate patenting growth from 2005 to 2010. These changes are relative to what is observed in the dramatic rise in the number of academic publications (and also corporate publications) since 2004. We observed different trajectories by country, with Japan's corporate activity going through more of a pronounced double boom than that of the US. The output of Japanese corporate patents and publications rose quickly but then declined – perhaps signaling Japanese corporate agility in sensing and engaging in new domains, and also subsequent strategic decisions to draw back for a while. But there are also signs of sectoral shifts. In the US, early entry by chemical companies was followed by a decline in activity, then a subsequent wave of corporate activity particularly in the US information technology and electronics industries. In addition, in the first double boom, there was evidence of concurrent development, with corporate activity occurring in parallel with or shortly after academic activity. This was especially true in Japan, where more than half of its corporations had entered the graphene domain through publications or patents by 2004.

It is to be emphasized again that we are still in the initial phases of graphene commercialization. Nonetheless, the early trajectory of graphene research and patenting reflects the fast pace of growth and change that is seen today in many areas of science-based innovation. Although it is premature to judge the ultimate applications and outcomes of graphene, there does appear to be a short time lag between research discovery and corporate patenting. The emergence of a wide potential application funnel confirms that graphene has general purpose characteristics and may well have pervasive impacts. Yet, the double-booth fluctuations in corporate activities suggest that it may be more difficult than initially anticipated to successfully embed graphene into commercial applications in certain sectors. Policies to encourage applied research and development partnerships, the scaling-up of production and manufacturing, the availability of finance and other assistance for enterprise innovation, and the assessment of potential health and environment risks are likely to be of ongoing help in supporting companies to successfully and responsibly commercialize graphene.

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## References

Abernathy W, Utterback J (1978) Patterns of industrial innovation. Technol Rev 80(7):40–47

Brouwer E, Kleinknecht A (1999) Innovative output, and a firm's propensity to patent: an exploration of CIS micro data. Res Policy 28(6):615–624

Cockburn I, Henderson R, Stern S (1999) The diffusion of science driven drug discovery: organizational change in pharmaceutical research. NBER Working Paper 7359. Cambridge, MA

Cohen W, Levinthal D (1989) Absorptive capacity: a new perspective on learning and innovation. Adm Sci Q 35(1):128–152

Cohen W, Nelson R, Walsh J (2000) Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or not). NBER Working Paper 7552, Cambridge, MA

Cohen SS, Di Minin A, Motoyama Y, Palmberg C (2009) The persistence of home bias for important r&d in wireless telecom and automobiles. Rev Policy Res 26(1/2):55–76. doi:10.1111/j.1541-1338.2008.00369.x

Edquist C (ed) (1997) Systems of innovation. Technologies, institutions and organizations. Pinter Publisher, London/Washington

Grupp H (2000) Learning in a science-driven market: the case of lasers. Ind Corp Change 9 (1):143–172

Helfat CE, Lieberman MB (2002) The birth of capabilities: market entry and the importance of pre-history. Ind Corp Change 11(4):725–760

Hobday M (2005) Firm-level innovation models: perspectives on research in developed and developing countries. TASM 17(2):121–146

Hoppe H (2000) Second-mover advantages in the strategic adoption of new technology under uncertainty. Int J Ind Organ 18(2):315–338. doi:10.1016/S0167-7187(98)00020-4

Hoppe H (2002) The timing of new technology adoption: theoretical models and empirical evidence. Manch Sch 70(1):56–76. doi:10.1111/1467-9957.00283

ITRS (2010) International Technology Roadmap for Semiconductors 2010 Update Overview. http://www.itrs.net/Links/2010ITRS/2010Update/ToPost/2010_Update_Overview.pdf. Accessed 14 Apr 2011

Katila R, Ahuja G (2002) Something old, something new: a longitudinal study of search behavior and new product introduction. Acad Manage J 456:1183–1194

Kogut B, Kulatilaka N (2001) Capabilities as real options. Organ Sci 12(6):744–758

Lavie D, Stettner U, Tushman ML (2010) Exploration and exploitation within and across organizations. Acad Manage Ann 4:109–155

Lieberman MB, Montgomery DB (1988) First-mover advantages. Strateg Manage J 9:41–58

Lieberman MB, Montgomery DB (1998) First-mover (dis)advantages: retrospective and link with the resource-based view. Strateg Manage J 19:1111–1125

Liebowitz SJ, Margolis SE (1995) Are network externalities a new source of market failure? Res Law Econ 7:1–22

Lundvall BÁ (ed) (1992) National systems of innovation. Towards a theory of innovation and interactive learning. Pinter Publisher, London

Malerba F (2005) Sectoral systems: how and why innovation differs across sectors. In: Fagerberg J, Mowery D, Nelson R (eds) Oxford handbook of innovation. Oxford University Press, Oxford

March JG (1991) Exploration and exploitation in organizational learning. Organ Sci 2:71–87

Mowery D (2011) Nanotechnology and the U.S. national innovation system: continuity and change. J Technol Transfer. doi:10.1007/s10961-011-9210-2

Nelson RR, Winter S (1982) An evolutionary theory of economic change. Harvard University Press, Cambridge, MA

Nobelprize.org (2011) The Nobel Prize in Physics 2010. Nobelprize.org. 2 Sep 2011 http://www.nobelprize.org/nobel_prizes/physics/laureates/2010/

Pavitt K (1984) Sectoral patterns of technical change: towards a taxonomy and a theory. Res Policy 13(6):343–373. doi:10.1016/0048-7333(84)90018-0

Porter ME (1990) The competitive advantage of nations. Free Press, New York

Porter AL, Youtie J, Shapira P, Schoeneck D (2008) Refining search terms for nanotechnology. J Nanoparticle Res 10(5):715–728

Pries F, Guild P (2011) Commercializing inventions resulting from university research: analyzing the impact of technology characteristics on subsequent business models. Technovation 31 (4):151–160. doi:10.1016/j.technovation.2010.05.002

Rogers EM (2003) Diffusion of innovations, 5th edn. Free Press, New York

Rogers D (2011) Graphene is beginning to revolutionise the market for plastic electronics. Plast Electron 3(6):57–61

Rothaermel FT, Alexandre MT (2009) Ambidexterity in technology sourcing: the moderating role of absorptive capacity. Organ Sci 20:759–780

Schinwald A, Murphy FA, Jones A, MacNee W, Donaldson K (2012) Graphene-based nanoplatelets: a new risk to the respiratory system as a consequence of their unusual aerodynamic properties. ACS Nano 6(1):736–746. doi:10.1021/nn204229f

Schmoch U (2007) Double-boom cycles and the comeback of science-push and market-pull. Res Policy 36(7):1000–1015

Segal M (2009) Selling graphene by the ton. Nat Nanotechnol 4:612–614

Shapira P, Youtie J, Mohapatra S (2003) Linking research production and development outcomes at the regional level. Res Evaluat 12(1):105–116

Shapira P, Youtie J, Kay L (2011) National innovation systems and the globalization of nanotechnology innovation. J Technol Transfer. doi:10.1007/s10961-011-9212-0

Takeuchi H, Nonaka I (1986) The new product development game. Harv Bus Rev 64:137–146

Teece DJ (1986) Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Res Policy 15(6):285–305

Tuppura A, Hurmelinna-Laukkanen P, Puumalainen K, Jantunen A (2010) The influence of appropriability conditions on the firm's entry timing orientation. J High Technol Manage Res 21:97–107

Van Noorden R (2011) Chemistry: the trials of new carbon. Nature 469(7328):14–6. Nature Publishing Group. doi:10.1038/469014a

# Part III
# Country Foresight Studies

# Chapter 10
# Foresight in Russia: Implications for Policy Making

**Alexander Sokolov**

## 10.1 Introduction

The development of the science and technology (S&T) sector and the National Innovation System (NIS) in general has been facing new challenges during the last decade. Acceleration of S&T pace, shortening of the innovation cycle, increasing investment in S&T require better grounded and more informed policies towards science, technology and innovation (STI).

The complexity of the problem grows with a higher dispersed development of new knowledge (see Metcalfe 2002) and unpredictability of markets. Emergent disruptive innovations (not necessarily based on new technologies) create a base for new markets and disrupt whole big industries (see Christensen 1997).

S&T is increasingly considered as an integral part of economics, which both provides new background for development and reflects emerging problems. It requires extracting the dispersed knowledge about the demand from the economy and society and supply provided by S&T.

Policy makers consider Grand (global) Challenges as one of the cornerstones for modern STI policies, which have been addressed by many policy documents issued by national authorities and international organizations (see European Commission 2009 and the OECD innovation strategy (OECD 2010, p. 216)).

The experience of forward looking activities shows that the knowledge of future social and economic trends and general perception of the future supply from S&T is not able per se to provide a comprehensive anticipation of key changes in existing industries and emergence of new ones. Numerous examples of disruptive innovations (see Christensen 2004) provide evidence of a necessity to have a closer

A. Sokolov (✉)
Institute for Statistical Studies and Economics of Knowledge, National Research University – Higher School of Economics (HSE), Myasnitskaya st., 20, 101000 Moscow, Russia
e-mail: sokolov@hse.ru

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look to particular problems related to Grand Challenges and investigate how S&T can contribute to resolving these problems.

Among the key issues for future oriented technology assessment (FTA) and S&T Foresight in particular there is the elaboration of practical instruments targeted at the identification of key barriers to overcome, which are related to particular markets, products and relevant technologies needed for their manufacturing (see Weber et al. 2011). The major questions to be answered in this respect are as follows: 'Why the problem has not been resolved yet?' and 'Which particular S&T results can help to resolve the problem?'

The role of Foresight in STI policy making and its development have been intensively discussed in literature. The progress along the five phases of Foresight (see Georghiou et al. 2008, pp. 15–16) demonstrates its transformation from a support tool to a powerful instrument of priority setting and policy formulation.

This process fully refers to Russia and reflects both increasing complexity of policy instruments and gradual shift of the national Foresight practices upwards the observed evolution of forward looking activities.

## 10.2 S&T Foresight in Russia: Major Phases of Development

The first attempts of forecasting future trends of S&T in Russia can be traced back to the State Programme of S&T Development in the USSR of late 1980s. It was mostly aimed at quantitative assessments of indicators related to the future long-term plans for the Soviet S&T. That exercise demonstrated how risky the business of forecasting the future was. The disintegration of the Soviet Union transformed the whole Russian S&T system and made the forecasts irrelevant.

Later, during 1990s and early 2000s, the forward looking activities were mostly focused on identification of S&T areas to be supported under the condition of an abrupt fall of R&D funding. They did not have a solid methodological ground and were based on the "technology push" approach applied via surveys of leading researchers. Thus members of the Russian Academy of Sciences in 1991 indicated 80 prospective research problems to be addressed by the government. In 1995, a survey of few hundred experts was used to produce the first list of national S&T priorities and critical technologies, which was then approved by the Government Commission on S&T Policy.

Later on – in 1999 – the list passed a large-scale expert examination, which showed that Russia had been losing its leading positions in several important S&T areas and competitive advantages in commercial application of technologies.

These results were a basis for reconsidering national S&T priorities. The next revised list of national S&T priorities and critical technologies was approved by Russian President in 2002, although its practical use was very limited because – due to the same "technology push" approach – it covered almost all areas of S&T. At the same time there were adopted "Basic Policies of the Russian Federation in the Sphere of S&T Development for the Period up to 2010 and beyond". This document has become an important element of Russia's social and economic development strategy, with its goals of innovation-based economic development, creation of an effective national innovation system and making S&T one of Russia's greatest priorities.

First fully-fledged Foresight activities in Russia based on internationally adopted methodological bases started in 2004. That period was marked with a steady economic growths and a demand for new S&T policies aimed at revitalization of the Russian NIS on a new basis.

The revision of S&T priorities[1] was carried out in 2003–2005 during a period of sustained economic growth and great improvement of the state government system. It was initiated by the President and sponsored by the Ministry of Education and Science. One of the main objectives was to create an analytical background for defining budgeting priorities and forming the Federal S&T Programme "Research and Development in Priority Areas of Science and Technology," as well as for other federal and sectoral goal-oriented programmes, eventually resulting in greater efficiency of public funds invested into S&T.

The Russian Government initiated activities aimed at a longer-term innovation development. There were first attempts of building strategies of innovation development (like the "Strategy of innovation development: 2015" published by the Ministry of Education and Science and a number of innovation based sectoral and regional strategies). Building and implementing the strategies have stimulated demand for new types of instruments, and Foresight in particular. The first step was a revision of S&T priorities with respect to real demand from the national economy. The revised list of critical technologies was based on series of expert panels and wide consultation with all relevant government agencies, academies of sciences, businesses, largest research institutions and universities. The list of S&T priorities – approved by the Russian President in 2006 – was, for the first time in Russia, used as a basis for structuring the National S&T Programme and for initiating a set of large scale innovation projects (with participation of private businesses). As a follow-up of this initiative, it was decided to revise the lists of S&T priorities on a regular basis (every 4 years).

The large-scale ***national S&T Foresight*** activities started on the initiative of the Ministry of Education and Science of the Russian Federation in 2007. The goals of the study were to identify key areas of research that can bring the most substantial benefits in the longer term future (up to 2025), to assess potential demand for innovation in major sectors of economy, and to understand which policy instruments could be most relevant to promote innovation activities. It included a big Delphi exercise (see Sokolov 2009) with participation of over 2,000 experts from all fields of S&T representing the largest R&D units, universities and companies from 40 Russian regions.

A particular attention was paid to the efficiency of STI policy measures, among which the experts gave highest priorities to creation of innovation infrastructure, training of personnel and stimulating business expenditure on R&D and innovation.

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[1] For details see Sokolov 2006.

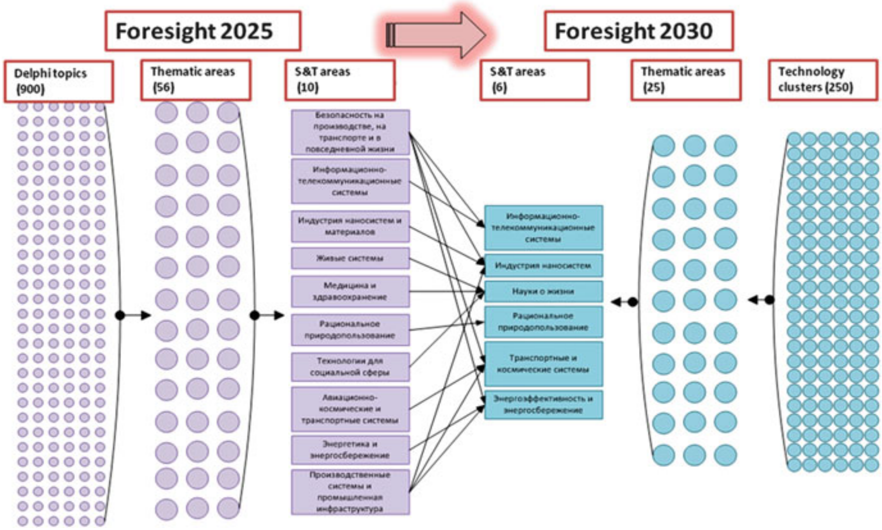


**Fig. 10.1** National S&T Foresight: a connection between first and second cycles

The ***second cycle of the national S&T Foresight*** started in 2009. It was aimed to a more detailed analysis of future trends in S&T and innovation for key application areas, e.g. with respect to the global financial and economic crisis (see Fig. 10.1).

One of key issues for the policy-making considered within that cycle was related to the identification of the most promising complex clusters for public-private partnership, which could be implemented within the actions called “the most important innovation projects” of the Federal goal-oriented programme “Research and development in the S&T priority areas”. The expert analysis of Delphi results resulted in identification of the areas of potential practical large-scale intervention from the government and businesses.

For each thematic area there have been identified promising innovation clusters. Some of them are mentioned in the Table 10.1.

After several years of steady economic growth (although still based on high oil and gas prices) the discussions of long-term prospects of the Russian economy had become more intensive. Key stakeholders (government, research community, and business) agreed that there were no alternatives to innovation development (with a permanent shift towards the higher added value end of the value chain) to provide a sustainable economic growth. The increasing S&T investment during the 2000s had not brought a visible output. Russia had the stable low level of innovation activities of industrial enterprises (around 9–11 % of total – compared to 50–70 % in leading economies). The country’s share of publications in Web of Science journals has been permanently decreasing as well as the citation indices. The effect of priority setting was rather limited because most of enterprises still preferred to buy key-turn technologies rather than invest in R&D; therefore the gap between R&D and innovation became a key issue for policy-makers.

**Table 10.1** Potential technology based innovation clusters

| Thematic area | Promising innovation clusters |
|---|---|
| ICT | Intellectual navigation and control systems |
| | Computer element base |
| | Bio-information technologies |
| Nanosystems and materials | Membranes and catalysts |
| | Biocompatible materials, polymers, crystals |
| Living systems | Integration of bio-, nano- and information technologies |
| | Biosensors, biomedicine |
| | Cell, biocatalyst and biosynthetic technologies |
| Medicine and health | Preventive medicine |
| | Optimization of medical services |
| Rational use of nature | Creation of complex information resources |
| | Forecast and assessment of admissible use of biological resources |
| Energy | Energy saving systems |
| | Energy generation from organic fuels |
| Aerospace and transport systems | Materials for aerospace |
| Safety and security | Fire safety |
| | Safety at transport and public areas |
| Industrial systems and infrastructure | Materials for industrial production |

A more systemic work on identification of long-term S&T priorities S&T for Russia started in 2011 – within the ***third cycle of National S&T Foresight.*** It directly addressed the key challenges for S&T and innovation policies including both supply and demand sides:

- Increasing efficiency of budget R&D funding;
- Development of human resources;
- Fostering innovation in public sector and building relevant infrastructure;
- Initiating innovation in the government;
- Creation of innovation friendly environment for business;
- Bridging the gap between business, R&D and state;
- Integrating innovation into the strategies for sectors of economy;
- Supporting social innovation;
- Localization of innovation, e.g. via building “territorial innovation clusters”.

In parallel, the Government initiated the development of the national Strategy 2020. It was developed during 2011 by 21 expert groups, one of which was devoted to challenges for S&T and innovation policy in Russia (see Gokhberg and Kuznetsova 2011). The results of this group to a large extent were used as a basis for the new presidential term of Vladimir Putin, and many of them were included to the set of President’s edicts of May 2012 identifying key policies related to S&T and innovation for the next 5–8 years.

Russia, being a developed economy with educated population and high GDP per capita level on the global scale faces a number of serious constraints hampering innovation. The most serious of them have a systemic nature and can be overcome only within a cross-sectoral (or whole-of-government in terms of the OECD innovation strategy – OECD 2010) S&T and innovation policies. The low global competitiveness of the Russian economy is aggravated by a number of institutional factors (Gokhberg 2010):

- Unfavorable climate for entrepreneurship and innovations;
- Counter-innovative institutions;
- Sectoral disbalance (focus on raw materials export, import of equipment, "traditional high-tech");
- Domination of vertical organisation of manufacturing and technologic linkages;
- Consumption level depends on the income from raw resources and does not depend on labour effectiveness;
- Enhanced paternalistic approach of public policy, "ignoration" of creative class.

The transition to a new S&T policy required a number of approaches towards priority setting. The selection of priority R&D areas and the scale of relevant budget support should take into account their overall potential impact on economy and society. Such an approach required shift from thematic priorities to socioeconomic objectives related to Grand Challenges and the problems to be emerging in the mid- and long-term future.

There have been discussed a number of key challenges for the S&T and innovation policies that arise under such circumstances, among which concentration of funding on particular institutions and/or research teams; ensuring availability of basic resources of people, money, infrastructure and institutions renewing themselves; building framework conditions for innovation (IP rights, human resources, regulation and few others); proper governance et al are worthwhile mentioning.

The latest STI policy initiatives in Russia reflect a shift towards bridging some of the above mentioned gaps. The Concept of long-term social and economic development of Russia[2] approved by the Russian Government in 2011 considers innovation as a key source of sustainable economic growth for the 10 years ahead. It describes the key goals of socio-economic development, major strategies to achieve the goals, forms and mechanisms of partnership between the state, business and society and key relevant tasks of public STI policies.

A number of latest policy initiatives related to S&T and innovation in Russia were focused on different aspects and dimensions of the National Innovation System.

Regular efforts are aimed at identification of priority areas for STI, including the above mentioned list of national critical technologies.[3] There were also five sectors

[2] http://www.economy.gov.ru/minec/activity/sections/fcp/rasp_2008_n1662_red_08.08.2009.

[3] The last revision of the National S&T Priority Areas and the list of National Critical Technologies was developed within the National S&T Foresight and were approved by the President RF in July 2011 (http://news.kremlin.ru/ref_notes/988).

identified to be a subject for priority technology modernization (Energy efficiency; Nuclear technologies; Space communication technologies; Medicine; Strategic information technologies).

Several policy instruments aimed at bridging S&T and businesses have been introduced. The most important of them are strategies for sectors of economy envisaging complex development of R&D and innovation; technology platforms that become fora for continuing dialogue between research institutions, universities and businesses resulting in articulation of demand for R&D from the economy; and government grants for enterprises that engage universities and research units in development of innovative products and services.

Another set of instruments is aimed at forcing state-owned companies to develop programmes of innovation development (with a strong accent on R&D cooperation with universities and research institution); and stimulation of budget procurements of innovative goods and services.

On the supply side research programmes funded from federal budget (goal-oriented S&T programmes "Research and development in priority S&T areas: 2007–2013" and "Human resources for science and education for innovative Russia: 2009–2013"), a programme of support to the National research universities and National research centres as well as the State programme for development of science and technology.

The regional issue is reflected in the recent initiative on support to territorial innovation clusters and a number of strategies for regional development that include R&D and innovation as an integral component.

## 10.3 S&T Foresight in Russia: A Response to the Demand from Policy Development

Increasing complexity of STI landscape requires more elaborated anticipatory tools. As a reflection to this demand, Russian S&T Foresight activities during the last decade have been increasingly integrating to the process of STI policy making. There is a clear trend of ascending along the four stages of different attitudes to the future identified by Hasan Ozbekhan (see Godet and Durance 2011, pp. 16–17): from passive through reactive and pre-active towards the proactive one.

The revised S&T priorities and critical technologies provided a starting point for the ongoing national S&T Foresight exercise with a horizon of 2030, which addresses the most promising technology areas while drawing on a number of sector-specific studies. Several hundred experts for each area identified prospective technological clusters with the highest expected social and economic return. The clusters were studied in terms of the following issues:

- R&D in Russia compared to the world best in the field;
- Major impact;

- Resources necessary to provide competitiveness in particular clusters, including personnel, R&D expenditure, fixed assets etc.;
- Feasibility of implementing major innovative projects in the next 15 years;
- Potential market size.

The S&T Foresight study will identify the most important trends of S&T development by 2030 as well as emerging and rapidly growing S&T areas. Analysis of the future prospects of the most promising innovative clusters vis-à-vis the Grand Challenges allows pinpointing those segments of the high-technology markets where Russia can expect to successfully strengthen its competitive advantages.

The Foresight results have led to proposing a number of large-scale innovation projects to be funded as part of public-private partnership programmes, allowed identifying key areas of research to be financed by the Federal goal-oriented programme "Research and development in priority S&T areas: 2007–2013", provided a basis for formulating measures to build S&T capacities (funding, human resources, etc.) and for analysing potential S&T policy instruments to be introduced. Another result is a set of research fields that were identified by groups of top level Russian and international experts for priority funding within the future National S&T programmes. The criteria for selection of research fields were constructed in a way to focus research efforts on the areas with the highest promise of return and potential contribution to build capacities for future innovation development. In parallel, there were identified Russian and global leaders in particular fields, key infrastructure required for the accelerated development. For each area there were given benchmarks of Russian leaders compared to the global ones.

In the key areas singled out, S&T policy intervention focused on restructuring the public R&D sector, introducing mechanisms to evaluate research, monitoring and evaluating S&T and innovation policy implementation, elaborating efficient, result-oriented mechanisms of R&D funding including planning of basic research, and building institutions to support R&D and innovation.

The Foresight will cover a wide range of activities aimed at promoting innovation in Russia and concentrating resources on the most promising S&T areas with respect to particular market segments and innovative products and services. The Foresight study covers all areas of S&T and a number of sectors where new technologies can be expected to have the greatest effect (Fig. 10.2).

The major principles of the emerging Foresight system include integrating Foresight into the S&T policy agenda and equipping policy-makers with practical instruments to facilitate innovation development in Russia. In other words, the new system should follow the fully-fledged Foresight approach.

The Foresight programme contains several major components:

- Foresight of key areas of future basic research;
- Macroeconomic scenarios and modelling of principal macroeconomic indicators;
- Development of complex models to forecast indicators of S&T, innovation and educational development;

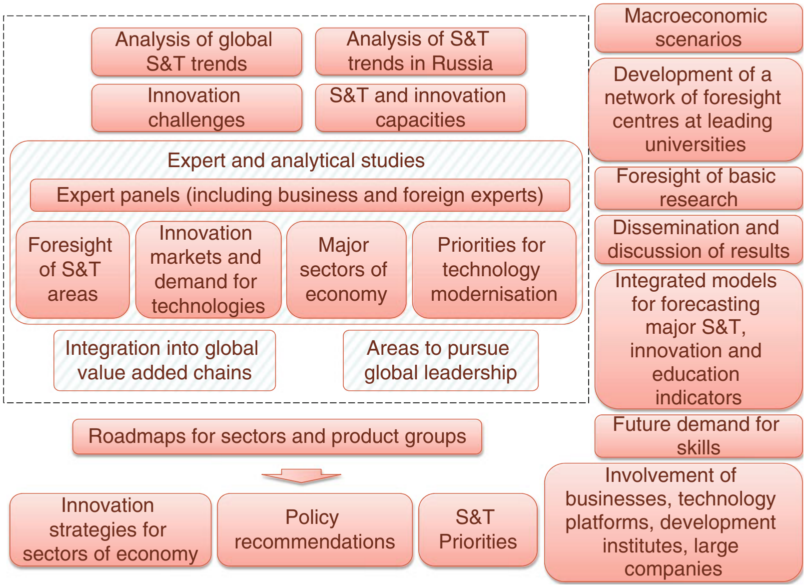


**Fig. 10.2** National system of S&T Foresight

- Foresight of future demand for S&T related competences and a skilled workforce in S&T and high-tech sectors;
- Development of a series of roadmaps for key sectors of the economy and the most promising groups of products and services;
- Development of a complex S&T and innovation Foresight system.

The methodological basis for the above-mentioned activities includes a wide range of qualitative and quantitative methods: horizon scanning, bibliometric and patent analysis, statistical models, expert surveys, literature reviews and many others.

It will be important not only to identify the key challenges facing the Russian national innovation system but also to assess global trends of S&T development and, if necessary, to revise the national S&T and innovation capacities to promote the technological modernisation of the Russian economy.

The Foresight directly addresses principal instruments of S&T policy. The two of them that were initiated by the Government Commission on High-Technology and Innovation are of particular importance: creation of technology platforms and elaboration of "compulsory" programmes of innovation development in the largest Russian companies fully or partly owned by the state. The main goal of these initiatives is encouraging business to innovate and bridge the gaps between industrial enterprises, research units and universities. It is supposed that facilitating the dialogue between S&T and businesses can lead to closer cooperation and the formulation of a national research agenda better tailored to the real needs of the economy.

Each technology platform (of the 30 approved by the above mentioned Government Commission) is required to develop and implement a set of strategic documents, including a technology roadmap and a research agenda, and is expected to incorporate Foresight results in the process. These strategic documents will provide the basis for adjusting the national R&D effort to the needs of businesses and will be used for identifying promising research projects, which are to be funded through federal programmes and supported through innovation-oriented public procurement practices. The implementation phase has to be both bases on the plans ensued from the roadmap and become a source of further Foresight studies at the more detailed level.

The programmes of innovation development that the largest state-owned companies were required to develop also envisaged Foresight-related activities. The companies' programmes are supposed to represent a corporate vision of innovation activities with a 10–15 year time horizon. The ambitious goal is to increase competitiveness in local and global markets and improve economic performance according to key indicators within this time frame by means of technological modernisation and radically increasing R&D efforts (e.g., via closer collaboration with Russian universities and other R&D organisations in particular).

The newly designed S&T and innovation policy instruments in Russia include Foresight tools as an integral part of their approach. The largest state-owned companies are required to include Foresight activities into their programmes of innovation. Every technology platform has to develop a vision and a roadmap indicating the main technology-related milestones, barriers and risks.

Leading Russian universities have established a network of Foresight centres to build new capacities. This process is supported by the federal programme for the development of universities' innovation infrastructure. The network will also monitor technology trends in particular areas and support a more systemic involvement of private businesses in Foresight. As of 2012 the network combined six 'nodes' and over 200 organisations (universities research units and companies) engaged in their activities.

The S&T Foresight studies provide a solid background for future intervention to formulation and implementation of STI policies. The expert analysis of future prospects of applications of R&D in particular sectors gives a possibility to assess importance of relevant R&D fields, level of research compared to global leaders and a potential cumulative effect to be achieved in the future (see an example of such assessment in Fig. 10.3).

Another application of Foresight results is identification of the research areas to be addressed with relevant policy instruments (see Fig. 10.4). The areas with a significant expected cumulative effect and a high benchmark of international standing of Russian R&D might be considered as key priorities for direct project funding in the framework of public-private partnership. For the promising areas with less developed R&D there is required public support to relevant basic and/or precompetitive research. The areas with high-level R&D and limited market expectations need to be analyses with respect to stimulation of demand. The rest of areas could be a subject of more careful analysis in order to look for potential emerging fields that could generate disruptive innovation in the future.

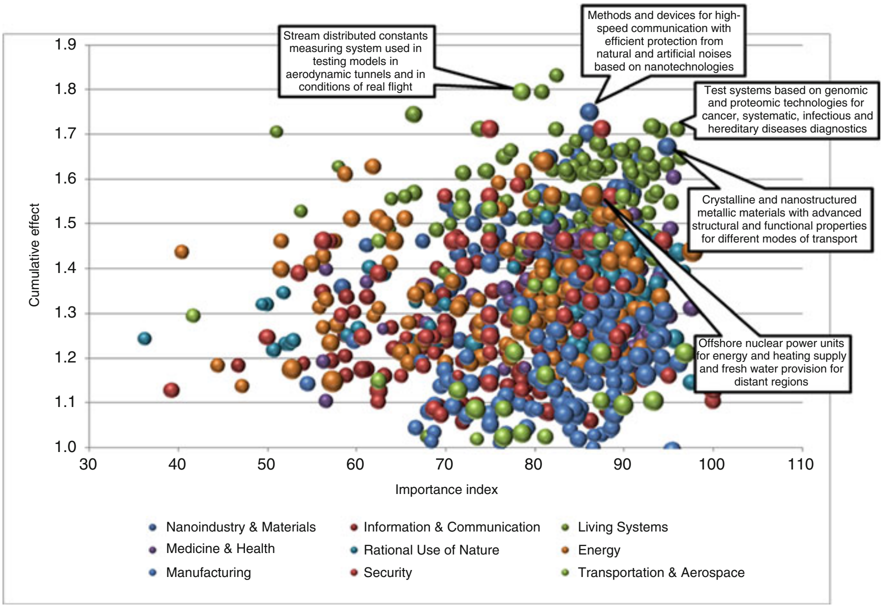


**Fig. 10.3** Identification of promising innovation clusters (size of bubbles reflects the level of R&D in Russia)

The Foresight studies in Russia are now more application driven. They provide an assessment of future S&T impact as a means for better grounded long-term social and economic planning and budgeting, e.g. at the sectoral and regional levels. One of the key approaches in this respect is related to the identification of large-scale promising innovation projects aimed at development of new products on the basis of complex “technology packages” (e.g. potential “marrying” of domestic and imported technologies). Analysis of S&T areas – vis-à-vis the challenges they are able to respond – provides a more detailed and comprehensive picture to be addresses by S&T policies.

It allows achieving several major goals:

- Identification of the most prospective for Russia in the long run areas of S&T and their implementation providing for competitive advantages;
- Identification of areas for potential large scale innovation projects;
- Assessment of future demand for key S&T related resources (basic and applied research, HRST and their skills et al);
- Integration with the formulation of national S&T and innovation policies (technology platforms, programmes of innovation development, government S&T programmes et al).

A number of new features of the S&T Foresight have been introduced during the last cycle. They cover new methodological approaches, which are now more oriented on analysis of future markets and much wider coverage of the sectors of

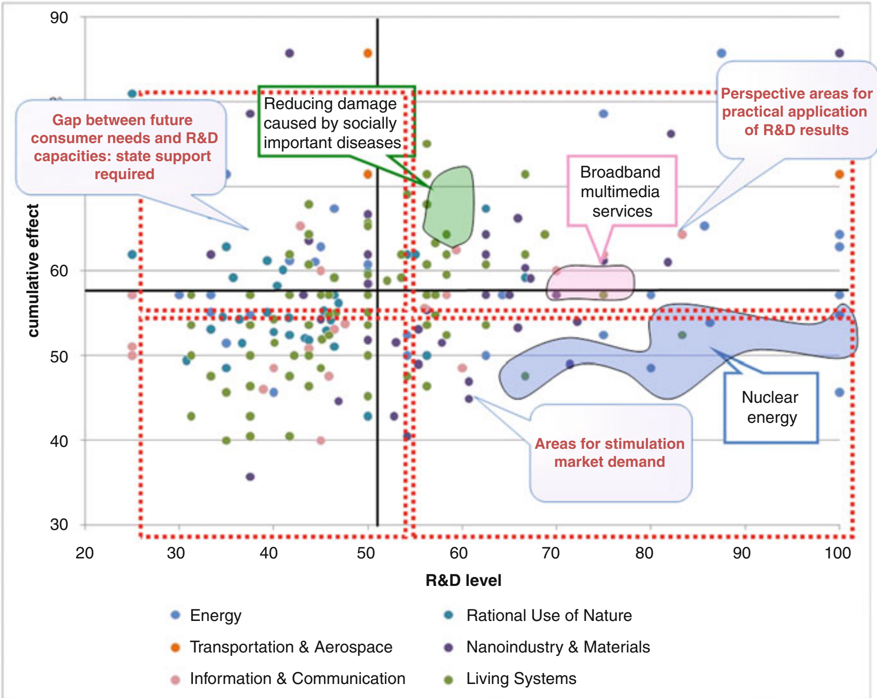


**Fig. 10.4** Use of the results of S&T Foresight studies for selection of policy instruments with respect to particular research areas

the national economy (see Fig. 10.5) as well as on the integration in policy design at a broader scale (providing input for sectoral and macroeconomic policies). This new approached envisages building a sustainable participants' networks based on permanent expert panels and the Foresight centres at leading universities with more active engagement of businesses on the basis of technology platforms, individual companies and business associations.

## 10.4 Methodologies

Addressing new policy issues required involvement of new methods and practical instrument into the practices of S&T Foresight in Russia (see Fig. 10.6). This process follows the global development of FTA methodologies including analysis of global challenges (Boden et al. 2010; Cagnin et al. 2011). Within the last Russian S&T Foresight new techniques for monitoring global technological and socio-economic trends and their detailed analysis with respect to promising research areas were developed (see Sokolov and Chulok 2012). There were also new approaches used in combining qualitative and quantitative methods to assess future

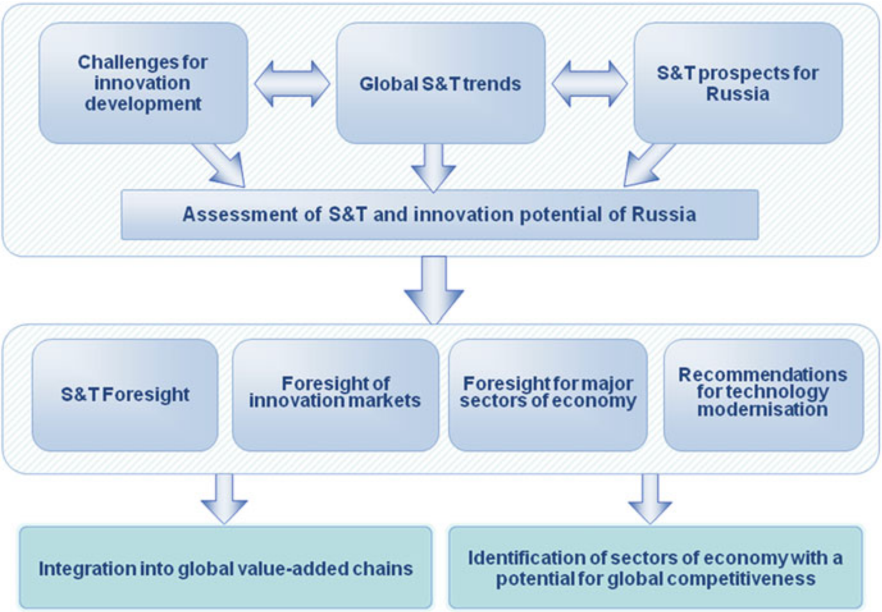


**Fig. 10.5** Integration of S&T Foresight to policy design

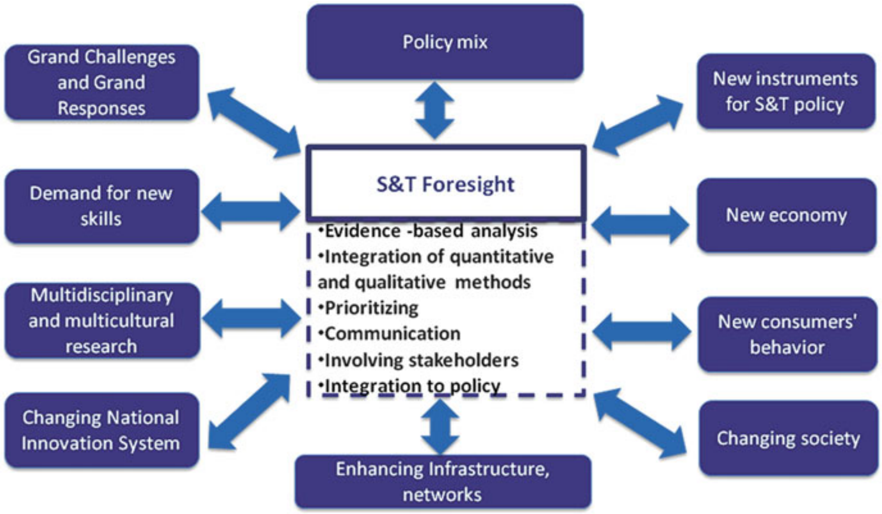


**Fig. 10.6** S&T Foresight in Russia: a methodological background

trends (see Haegeman et al. 2012). The above mentioned practices of identification of research priorities and critical technologies were to a large extent based on the new approaches (Georghiou and Cassingena Harper 2011; European Commission 2006).

During the last decade increasing attention in Foresight studies has been paid to development of methodologies aimed at assessment of future markets (see, for example, Malanowski and Zweck 2007). This issue along with the identification of key consumer properties to be demanded in the future and relevant technologies that can provide these properties was also one of the key subjects in the Russian S&T Foresight. Among the instruments for analysis of linkages between future markets and technologies the most intensively developing one was roadmapping (see Karasev et al. 2011).

## 10.5 Conclusions

The intervention of Foresight to policy making in STI has become a visible trend during the last years in Russia. The results of forward looking activities are used in various dimensions: from priority setting in budget funded R&D programmes to building S&T and innovation strategies for large companies and regions.

Most of already achieved and anticipated outputs of the Russian Foresight studies are related with several key issues: sustaining existing research capacities and building new ones; articulating demand from industries to the national R&D sector; bridging the gaps between S&T and the business sector; and developing detailed long-term plans (roadmaps) of innovation development for companies.

Foresight studies accumulate expert knowledge and help to anticipate future prospects of particular S&T areas (research and technological breakthroughs and S&T based innovation products), highlight strengths and weaknesses of Russian S&T vis-à-vis global competitors. On the other hand, the demand side benefits from Foresight with better understanding of emerging markets and relevant risks, barriers and limitations Russia can face in the future.

Combination of knowledge of anticipated demand and supply trends provides a background for assessment of national competitive advantages and building complex strategy based on future scenarios, identification of strategic forks and technological priorities for particular sectors of economy.

At the same time, there are emerging new challenges related to the fast changes in S&T and socio-economic environment that bring to the Foresight agenda new tasks.

The full-scale integration of Foresight to policy making requires resolving, among others, the following problems:

- Creation of a system of expert network that would be able to provide – on the one hand – the best available expertise in particular fields of science and/or application areas (including foreign researches, knowledgeable business representatives and key stakeholders) and – on the other hand – to deal with interdisciplinary issues;
- Finding a proper balance between the support of 'traditional' areas and emerging fields with potentially high economic and social return;
- Provision of quality assurance via regular monitoring and evaluation of Foresight studies;
- Coordination of different types of priorities (macro-, mission-oriented, thematic et al).

There is still a need for a stronger focus on policy agenda and a better 'grounded' approach (articulation of business demand, roadmapping for promising areas, evidence-based studies, integrated forecasting S&T, innovation and education indicators, etc.). The problems to be addressed in this area include diminishing uncertainties and managing future risks in design and implementation of strategies for social and economic development, correct identification of priorities. New instruments have to be introduced (a combination of qualitative and quantitative methods, weak signals and wild cards, horizon scanning et al).

The above mentioned and other directions of increasing Foresight output have to find their place in the nearest future.

## References

Boden M, Cagnin C, Carabias V, Haegeman K, Konnola T (2010) Facing the future: time for the EU to meet global challenges, EUR 24364 EN, Publication Office of the EU, Luxembourg

Cagnin C, Amanatidou E, Keenan M (2011) Orienting towards effects of resource concentration on grand challenges and the roles that FTA can play. Paper presented at the fourth international conference on future-oriented technology analysis (FTA), Seville

Christensen C (1997) The innovator's dilemma: when new technologies cause great firms to fail. Harvard Press, Boston

Christensen CM, Anthony SD, Roth EA (2004) Seeing what's next. Using the theories of innovation to predict industry change. Harvard Business School Press, Boston

European Commission (2006) Emerging science and technology priorities in public research policies in EU, US and Japan. European Commission, Brussels

European Commission (2009) Policy mixes for R&D in Europe. UNU-MERIT, Maastricht

Georghiou L, Cassingena Harper J, Keenan M, Miles I, Popper R (eds) (2008) The handbook of technology foresight: concepts and practice. Edward Elgar Publishing, Cornwall

Georghiou L, Cassingena Harper J (2011) From priority-setting to articulation of demand: Foresight for research and innovation policy and strategy. Futures 43(3):243–251. Special issue: future-oriented technology analysis

Godet M, Durance P (2011) Strategic Foresight for corporate and regional development. DUNOD – UNESCO – Fondation Prospective et Innovation, Paris

Gokhberg L (2010) Principles for a new-generation innovation policy. Baltic Rim Econ Bimonthly Rev 3:17

Gokhberg L, Kuznetsova T (2011) Strategy-2020. New outlines of Russian innovation policy. Foresight 5(4):8–30 (in Russian)
Haegeman K, Scapolo F, Ricci A, Marinelli E, Sokolov A (2012) Quantitative and qualitative approaches in FTA: from combination to integration?. Technol Forecast Soc Change 80(3): 386–397
Karasev O, Rudnik P, Sokolov A (2011) Emerging technology-related markets in Russia: the case of nanotechnology. J East West Bus 17(2–3):101–119
Malanowski N, Zweck A (2007) Bridging the gap between Foresight and market research: integrating methods to assess the economic potential of nanotechnology. Technol Forecast Soc Change 74:1805–1822
Metcalfe JS (2002) Knowledge of growth and the growth of knowledge. J Evol Econ 12:3–15
OECD (2010) The OECD innovation strategy. Getting a head start on tomorrow. OECD, Paris
Sokolov A (2006) Identification of National S&T priority areas with respect to the promotion of innovation and economic growth: the case of Russia. In: Crangle RD (ed) Bulgarian integration into Europe and NATO, NATO security through science series E: human and societal dynamics. IOS Press, pp 92–109
Sokolov A (2009) Future of S&T: Delphi survey results. Foresight 3(11):40–59 (in Russian)
Sokolov A, Chulok A (2012) Russian science and technology Foresight – 2030: key features and first results. Foresight 6(1):12–24 (in Russian)
Weber M, Cassingena Harper J, Konnola T, Carabias Barcelo V (2011) Building FTA capacities for systemic and structural transformations: new FTA systems for anticipatory action in a fast-changing world. Paper presented at the fourth international Seville conference on future-oriented technology analysis, Seville, 12–13 May 2011

# Chapter 11
# Foresight in Germany: Implications for Policy Making

**Kerstin Cuhls**

## 11.1 The Start

Until the 1990s Germany was not very active in foresight (Irvine and Martin 1989). However, due to economic and other reasons those responsible at the German Federal Ministry for Science and Technology (BMFT, later BMBF) changed their minds. At the time of unification many of Germany's problem areas became apparent. The need for a rational process to set priorities and to concentrate the financial support was felt. Non-financial support was becoming increasingly important. Therefore, various sides expressed the desire to identify the technologies and scientific fields which will have the greatest impact on economic competitiveness and social welfare. 'Emerging technologies' became increasingly science-based (Grupp 1992) and nowadays the education system must provide and support a high intellectual capacity to educate future personnel.

It was a new approach for a German ministry to look into the future on a long-term basis. In this respect, the first two projects were therefore regarded as "risky". In the beginning they earned harsh criticism, but later on became widely accepted by those who were able to make use of them. It was considered a political question whether state bodies should give more emphasis to direct intervention in research matters (e. g. by financing specific R&D projects from industry) or to more indirect support (e. g. tax reductions for R&D projects or subsidies to those companies hiring new scientific and technical staff).

Nevertheless, there were good reasons for starting such activities on a national level: Science and technology shifted towards longer-term future orientation and new policy strategies. New methods should be tested and used to identify 'emerging' technologies and developments of science and technology, as well as

K. Cuhls (✉)
Fraunhofer Institute for Systems and Innovation Research, Breslauer Str. 48, 76139 Karlsruhe, Germany
e-mail: kerstin.cuhls@isi.fraunhofer.de

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their general impacts. This was regarded as insufficient so the new concepts in German foresight also took the economy, society, the environment and other impacts into account. There is always the danger of confusing technology policy with technology planning in the sense of socialist planning, the kind of socialism which had just been overturned in Germany by the unification (concerning the difference between foresight and planning, see Cuhls 2003). The term ‘foresight’ is used in the sense of ‘outlook’ in the German context. This does not have the same connotation as ‘prediction’ which would be closer to ‘forecast’ (Cuhls 2003).

This case study of foresight in Germany shows a series of national foresight activities, commencing in the 1990s and leading up to the present day. The examples are: a foresight exercise called ‘Technology at the Beginning of the Twenty-First Century’, three Delphi processes, the first national ‘programme’ called ‘Futur’ and the BMBF Foresight Process from 2007 to 2009. They were all assumed to induce new paths in the topic portfolio of the Federal German Ministry for Education and Research and direct these paths with new policy approaches.

The methods applied as well as the strategic implementation into national policy and companies’ strategic planning still need to be improved. Various methods of technology foresight have been available for a long time. Holistic approaches are applied to gain an overview, but are not specific enough to give details. Thus, a combination of approaches on the macro, meso and micro level are needed. The organisation of the foresight process may also vary – as it does in all cases mentioned above. The most relevant methods used in enterprises, which can also be important for national foresight, and their effectiveness differ (Grupp 1996, p. 74, own projects experiences). More emphasis was placed on the combination of qualitative-quantitative methods, not only the quantifiable part of future directions. The BMFT at first decided not to use one single approach but a broader range of studies in order to have a fundamental basis to make choices and to combine data.

The methods applied in Germany for longer-term foresight all fulfil the following functions, which are defined as the major classification for purposes of foresight by Irvine and Martin (1989, p. 30 f.): (1). Direction-setting, (2). Determining priorities, (3). Anticipatory Intelligence, (4). Consensus-generation,[1] (5). Advocacy, (6). Communication and Education. Public and private institutions can make use of these foresight studies (Cuhls 1998; Cuhls et al. 2002a), they are available to the public. All Foresight processes fulfilled more and more the six functions for policy-making that recently emerged in the Foresight debate (informing policy, facilitating policy implementation, embedding participation, supporting policy definition and reconfiguring policy structures, as well as the symbolic function, see the ForLearn Guide). However, their effects and impacts are only known in a few cases. In this paper, the relation between the processes and their impact on policy making is discussed.

[1] There is a new understanding of this function: foresight is more important to find out *if* there is a consensus or the potential for conflicts than to *create* a consensus.

## 11.2 The Different Projects and Programmes

### *11.2.1 Technology at the Beginning of the Twenty-First Century*

Technology at the Beginning of the Twenty-First Century, abridged T 21, (Grupp 1993, 1994) was a BMFT-financed project and started in 1992. In the Federal Republic, BMFT, since 1994 Federal Ministry for Education and Research (BMBF), is assisted by several so-called 'Projektträger' (programme operating agencies), mostly located within the national laboratories. Representatives from these 'programme operators' set up a task group and worked face to face on an assessment of critical technologies for the Federal Republic of Germany. The Fraunhofer Institute for Systems and Innovation Research (ISI), which took the overall responsibility for this task, was asked to devise a comparatively new methodology based on technology lists and *relevance trees* (for details see Grupp 1993, 1994).

There were many very different results: the growing interdisciplinarity in technological development, first discussions by the programme operators in different workshops about who can make use of the new knowledge generated and the establishment of new methodologies which may help to make 'better' and more effective decisions about the support of R&D projects. Furthermore, the co-ordination and communication about these new technologies by the programme operators is facilitated. This project had a long-lasting effect. For the first time, the BMBF moved to the interdisciplinary field of "Nanotechnology", and later on made the decision to fund huge programmes in Germany – as well as in all industrial countries.

### *11.2.2 The First Comprehensive German Study on the Development of Science and Technology (Delphi '93)*

The Delphi method is well known and under permanent improvement (Rowe et al. 1991; Häder and Häder 1995; Special Issue Rowe and Wright 2011) whereby in most cases a "questionnaire" with statements is the medium of interaction. Meanwhile, the communication effect of Delphi studies and therefore the value of the process as such is also acknowledged. (Cuhls 1998; Cuhls et al. 2002a)

In the first German Delphi study (Cuhls 1993), the Fraunhofer Institute for Systems and Innovation Research (ISI) collaborated with the Japanese National Institute of Science and Technology Policy (NISTEP). The German Delphi Team took the 1,150 topics in 16 fields prepared for the Japanese fifth survey and translated them into German (BMFT 1993; Cuhls et al. 1996). The assessment criteria were the same as in Japan. For results see Cuhls and Kuwahara 1994. The main conclusion was that Delphi inquiries on science and technology should always be undertaken with an international panel, which includes people from several countries and continents although for many topics no extreme discrepancies in the results were found, only results which were at the same time congruent and diverging.

### *11.2.3 The Mini Delphi(s)*

The Mini Delphi approach was a test to develop the Delphi method further, to meet some criticism from the first German Delphi survey and to gain more detailed data about some of the internationally problematic areas such as Life Sciences and the Future of the Health System or Problems of the Environment with potential contributions from Photovoltaics, Superconductivity, Cognitive Systems and Artificial Intelligence, Nanotechnology and Microsystems Technology, Cancer Treatment and Research, Brain Research, Waste Processing and Recycling or Climate Research and Technology. The Mini Delphi was more oriented towards the identification and assessment of technical solutions for current or *emerging problem fields* which were identified as the most important in the previous Delphi survey. They were therefore more demand-, needs- and problem-oriented than the previous study. The whole procedure of the survey was conducted parallel to that in Japan. The co-operation partners again were ISI on behalf of the BMBF in Germany, and NISTEP in Japan (Cuhls et al. 1995).

### *11.2.4 The Second Comprehensive German Study on the Development of Science and Technology (Delphi '98)*

As foresight gained momentum in Germany and most of the restraints mentioned above still remained, it was obvious that Germany needed further concepts to develop the necessary degree of effectiveness to make innovative leaps. Especially for research programmes or companies' strategies, information about the future is required as a basis for general decisions. Therefore, German foresight activities were supposed to provide more information about the future, informing also those actors who are not able to gain this knowledge alone (e.g. small and medium-sized companies, research institutes, 'the public'). At this stage, they did not intend to influence policy making directly by implementation activities but more indirectly by providing information that could be used in different ways. Thus, the BMBF financed and carried out a new foresight activity in 1997 (Cuhls et al. 2002a; Cuhls et al. 1998; Cuhls and Blind 1999; see also Cuhls 2008).

In Germany, many companies started to analyse the dataset for their own purposes. The great advantage of a Delphi process is: everyone can make his/her own analysis of the study – depending on individual needs and questions about the future. Therefore, the data were provided to whoever wished to use them (Cuhls et al. 1998, or online at www.isi.fraunhofer.de/P/Projektbeschreibungen/Cu-delphi.html/ access until 2007). Some examples of using the data were already introduced in the reports or the follow-up newsletter 'Zukunft nachgefragt' (The future in question, BMBF eds. 1999–2003). Thus everyone was able to make his or her own analysis – using Delphi '98 as working material, not a picture of the future itself.

### *11.2.5 Futur*

In 1999, the BMBF decided to organise a foresight process in order to counter the criticism that only experts were involved in previous foresight activities, and to open up the German national foresight processes for a greater variety of participants. This forerunner version of Futur put special emphasis on the use of the internet as a platform to discuss the different topics. The kick-off meeting took place at a conference in June 1999. The process started by focussing on two areas, 'Mobility and Communication' and 'Health and Quality of Life'. The Ministry expected that it would be sufficient to provide a platform and some input on the topics to encourage any interested party to participate in the discussions. This approach failed because too few people knew about the process, and the questions to be discussed were not well defined. Furthermore, the methodology and objectives were unclear. BMBF decided to re-start the process.

In spring 2001, 'Futur – The German Research Dialogue' was launched (for details see Cuhls 2004). The procedure was more BMBF-oriented and relied on a wider process, using a variety of methods and instruments such as focus groups, conferences, online votes and scenario writing. The first phase of this 'new' Futur ran until the beginning of 2003. It was evaluated by an international expert panel in autumn and winter 2002 (Georghiou 2004 or Cuhls and Georghiou 2004).

The results of this first phase of the Futur process consisted of so-called 'Lead Vision Papers' describing a broader field important for the future, research necessary in this field, including a scenario to illustrate and visualise the things to come (Gaßner and Steinmüller 2003). The outcomes were supposed to be implemented directly by the BMBF. As Futur was regarded as an interesting new tool by the Ministry, the second phase of the Futur process was started in early 2003, with slightly changed procedures and methods. This second phase of Futur finished by March 2005 and after another international evaluation (Salo et al. 2005), the third phase of Futur ended (Hafner and Cuhls 2004 or Cuhls et al. 2004) and although it was originally intended to run Futur as a continuous activity, it was terminated in 2005.

### 11.2.6 The BMBF Foresight Process Cycle I

"The BMBF Foresight Process", subtitled "Implementation and Further Development of a Foresight Process", started by assessing present-day science and technology and was broadened to look into the future over the next 10–15 years – and even further. It took into account the developments at the national as well as international level. In the process, 14 established future fields were developed in detail. They were derived from the German Hightech Strategy. In these fields, future topics were identified, re-clustered and assessed via a set of criteria. Seven *new cross-cutting fields* were arrived at by clustering the most important issues from the established fields. They are rooted in science and technology but have major impacts on society and the economy as well.

The process was conducted by a consortium led by ISI. The process linked both foresight and monitoring in its integrated approach (Cuhls et al. 2009). In 2009, two reports (Cuhls et al. 2009a, b, c) were published and presentations and strategic bilateral talks, later strategic dialogues in BMBF started to implement the different results.

While the implementation of previous future themes is still running, a new foresight process (cycle II) is starting in spring 2012. This time, its starting point is the demand-side and – among other tasks – identifies "needs" that can be addressed by science, technology and education. In a second large workpackage, some of the Future Fields of the first cycle are updated.

## 11.3 Rationales and Objectives

The common ground of all rationales and objectives in German foresight activities is that they provide information about things to come in order to have a better base for decision-making and priority-setting. Nevertheless, the rationales and objectives in the different projects changed, in Futur even broadened.

In the first national project, the **Technology at the Beginning of the Twenty-First Century**, the objectives were rather modest and adequate for a 'project'. The main motive was to complement economic growth criteria by the idea of growth using intelligent new technologies. Secondly, learning from Japanese and US sources, a stricter and more transparent methodology for listing and assessing technologies should be tested. The approach also aimed to mobilise the in-house expertise of German research administrators for foresight purposes.

The rationale behind the **first German Delphi study** was to discover more about future science and technology, to determine the time horizon and to test the Delphi methodology. In order to keep the project costs modest, the Japanese Delphi topics were translated. If the final results were to prove very similar, it was expected that in the future, the German government could adopt the Japanese results. If not, it was intended to conduct a German Delphi every 5 years (to update), and also to start a communication process about the future. A side effect of the project was to gain insights into Japanese visions about the future and scientific solutions or even products developed in Japan.

The detailed objective of the Delphi investigation was to find out the following: the degree of *importance* the experts assigned to the topics, the *time of realisation* between 1995 and 2020, major *constraints on realisation* or reasons for non-realisation, the *precision of time determination* and the *necessity to co-operate internationally* in pursuing technology progress.

The results were published as a BMBF report to provide the information to all interested persons and organisations. It was not intended to make use of the data for 'strategic planning' in BMBF in the field of science and technology. The German constitution says 'Science shall be free.' Therefore, planning from the side of the state would not be accepted – and the 5-year-plans of the GDR, which was regarded as exceptionally unsuccessful, had just been abandoned. Companies who utilised the Delphi Report especially acknowledged this and asked the BMFT to continue with similar foresight activities because they gained a lot about of insight into what others think about future subjects.

This was why **Japanese-German Mini Delphi studies** were conducted only for methodological improvements. New aspects of these studies were: they started from the demand side (obvious demand), they were performed in strict co-operation with Japan to keep the questionnaire equivalent but asking different questions, and they had a more complicated survey design, to conduct the same study concurrently and analysing the results in a joint workshop.

The **second comprehensive German Delphi '98** was started specifically at the request of industry because the information about future science and technology was regarded as very valuable for strategic planning. The second aim in 1996 was to make the different experts in the system aware of the future, think long-term, consider their views seriously and create a certain commitment for actions in the different fields (see the 5 Cs of Martin 1995). The foresight initiative was to provide answers to a set of critical key questions, e.g. "In what areas of innovation can significant advances be expected to take place during the next 30 years?" "What impacts can these significant advances be expected to have on economic development?" or "How can technological innovation contribute to the solution of ecological problems?" These questions were 'translated' into Delphi criteria to assess the topics.

At this time, an even more strategic use was contemplated in BMBF but not planned in detail. This was – in the end – not realised due to parliamentary elections and a change in government. Therefore, the objectives to inform companies, research organisations and whoever was interested in the future, were reached, but the chance of doing more strategic priority-setting inside BMBF was missed (for details see Cuhls et al. 2002a).

As this was criticised and as the objectives for foresight increased, in the meantime, **Futur** had already started with a new and ambitious set of objectives, principles and a kind of 'hidden agenda' (to have an impact on the internal organisation of BMBF). Officially, Futur,[2] as started in 2001, aimed to introduce new perspectives into the existing research agenda of BMBF by adding to the traditional mechanisms for agenda-setting and prioritisation. The conventional decision-making process is characterised by a closed and rather opaque interaction between research institutions, industry, project operating agencies and ministerial bureaucrats in charge of research funding. Strategically oriented officers within the ministry were increasingly concerned about the risk of missing important new issues of the funding agenda, if this were solely based on traditional mechanisms driven by the actors involved.

Futur (Cuhls et al. 2004 or Hafner and Cuhls 2004) was oriented towards the identification and inclusion of societal needs in future research agendas and served as a means of priority-setting for future innovation-oriented research policies. Interdisciplinary, problem-oriented 'Lead Visions' *(Leitvisionen*) were the major outcomes of the process which should reflect the demand for research and be translated into publicly funded research programmes or projects. *Participation* of a broader audience in various kinds of activities and the combination of different creativity, communication and analytical tools are additional characteristics of the process. The objectives broadened in the second phase of Futur starting in early 2003. It was additionally intended to start public discussions in so-called 'Future Dialogues' (*Zukunftsdialoge*), but the first tests were not very successful and the decision to continue the dialogues about more topics was not taken.

The process was *open to results*, which means that it was performed independently of current funding programmes or 'hot' topics within the Ministry and it had no thematic restrictions. At the same time, even if the process was broad and diverse, it had to be *result-oriented* towards the generation of a usable output for the Ministry (Cuhls 2003 and Cuhls et al. 2002b). The process was not only supposed to give input to the Ministry, but also to promote *awareness-raising* and future-oriented thinking in society (Banthien et al. 2004). To achieve this, all Futur outcomes were to be designed to be '*understood by everybody*'.

Although the main objectives were met during the process, there were too many principles and objectives to be met and communicated, which made the process very complicated – this is one result[3] of the second Futur evaluation performed by an international evaluation panel (Salo et. al. 2005). It recommended a concentration on certain objectives and clarification if the process should only be directed towards the BMBF or also towards other actors in the innovation system. In that case, the objectives and methodology used need to be changed accordingly. A simplification of the complicated process would be helpful.

Concerning the principles of Futur, interdisciplinarity was met sufficiently and provoked problems inside the policy making of BMBF because some of the topics

[2] The objectives of the forerunner Futur started in 2000 were unclear, therefore, they are not mentioned here.

[3] The results of the evaluation are not published, only a short summary is available from BMBF. Therefore, these assessments are the author's more general findings.

identified were not within the responsibility of BMBF, leading to implementation problems. More problematic was the need-orientation, which for example was not reflected by a proper methodological approach. The questions remained: What is society’’s demand on the future? And what or who is this society? What is the role, a Ministry for Education, Science and Technology can play beyond providing information and financially supporting projects and programmes?

Tensions occurred between being open to any result at the outset and, on the other hand, focusing on real policy making by applying the BMBF Lead Visions and filtering out topics outside the BMBF responsibility. Additional tension was felt between the declared principle of participation of new actors and participants’ lack of knowledge. The meaning of ‘participation’ also had to be communicated, because it was obvious that the general public was not involved and the number of participants did not increase compared to the previous studies (Cuhls et al. 2004). For greater awareness-raising, the public relations activities were also regarded as insufficient. This was a matter of resources, but also of timely decisions in BMBF.

In the **BMBF Foresight Process Cycle I**, the objectives were defined by the BMBF when launching the call for tenders: Objective 1 is to identify new focuses in research and technology that the BMBF must address. Objective 2 is to define interdisciplinary topics and areas, that require broader attention and are to be tackled by various departments and groups of actors. The fields thus determined have to be addressed by different partners in the innovation system (strategic partnerships) over a longer period of time (objective 3), and measures should be devised to promote the fields in question (objective 4). BMBF was the clear addressee for this foresight – it was not performed for the public or the companies in the country.

In order to achieve objectives 1 and 2, the *foresight approach* applied well-known search strategies as well as other methods from innovation research and international foresight activities alongside new, creative methods. The themes to be investigated at the national and international level were further developed by experts, taking into account existing forward-looking road-mapping and strategy processes from the public and private sector.

One of the findings here is that it proved difficult to fulfil the task of just describing in very detail those new fields, already well-known and derived from the German Hightech Strategy. In these cases, many stakeholders, even lobbies are already active and it was difficult to provide the BMBF with “new” findings and detail the topics in an adequate granularity. The situation was different for the new Future Fields (*Human-technology cooperation, Deciphering ageing, Sustainable living spaces, ProductionConsumption 2.0, Modelling and simulation, Time research*, *Energy solutions* with a) *Energy concert* and b) *Energy from the environment*) where even the formulation was a political decision. On the other hand, there was broad interest because up to that time, nobody had claimed “responsibility” so that the administration did not have to position itself against these topics. Nevertheless, as there were no adequate organisational structures, implementing these new fields turned out to be rather difficult.

## 11.4 Policy Effects and Limits of Policy Making

New future fields can only be realised if there are advocates and if action is taken to that end. Public policy makers but also private actors can take the initiative. As all fields are different, new challenges for science, technology and innovation policy will arise. This was the major result of an international workshop held in early October 2008 during the BMBF Foresight Process. The workshop provided a platform for generating ideas for recommendations concerning policies and research alliances (objectives 3 and 4) to be further elaborated in the years to come. The workshop took place in Hamburg and gathered international and German experts with experience in promoting new or cross-cutting issues. The purpose of the workshop was to discuss what kinds of measures are successful in implementing new or cross-cutting topics, along the lines of examples from the past outside of the BMBF Foresight Process. The guiding questions were therefore:

- How can future issues and topics with a time horizon of 10–15 years and longer be rapidly and efficiently absorbed into an existing innovation system?
- How do organisations or companies in other countries deal with cross-cutting issues and future topics with a time horizon of 10–15 years and beyond?

It was obvious that new approaches in innovation policy are necessary to implement and realise new cross-cutting fields of the future. The approaches vary and need to take into account the different stakeholder groups involved. But the “how to” is often still the open question that is answered in an experimental way. In the last phase of the BMBF Foresight Process, the actors of the current innovation system were identified and potential actor groups, who could further foster the different topics or fields, were named. This was an integral part of the process (see objectives) and in some cases helped the actors “to find each other” – but in the end this was only partly used.

When reviewing all foresight activities in Germany it becomes apparent that opening foresight processes to different experts as well as the general public is a new feature of foresight, therefore according to Georghiou (see Miles et al. 2008, p. 15 f.) even a new generation of foresight – and for Germany a change in policy. In the second cycle of the BMBF Foresight, this kind of actor analysis is not conducted. Science and technology policy will not only be based on the recommendations of scientists and other experts, but also take into account the opinions of those who will apply these in the future.

The German national research system consists of ministries like the BMBF and others (e.g. agriculture, environment, construction) which provide funds for science and technology. Universities are free in their choice of research topics and are funded by the federal states (*Länder*). Max Planck Institutes, the Fraunhofer Society and the Leibniz institutes work in the area between the basic-science-oriented universities and the private enterprises with their more applied research. The Delphi studies investigated basic research as well as applied research and therefore included persons from all these institutions. Their participation as such already had an impact, as they were required to reflect on their future projects. Regarding Futur, the attempt was made to bring together the different actors in the system directly and to also include those who are normally not heard. But it was not possible to directly involve more people than in the previous study.

When the different approaches are analysed in general, it must be stated that no direct use of the data can be noted in the **T 21**, however, BMBF used them as an information source for different purposes (e.g., calls, programmes, new projects etc.). A more direct impact of the workshops were annual meetings of the programme operating agencies, which previously had no direct links or institutionalised contacts. A few years ago, they even established a formal network with regular meetings.

Concerning **Delphi '93**, there were many possibilities to use the huge amount of Delphi data for individual purposes. The initial result of the survey as well as the Mini-Delphi and the **Delphi '98** was a large volume of data which is the base for further analysis and discussion. The Delphi '98 data were also made available on the internet. The data do not have one addressee but are provided to all interested parties: companies use them as an input for their strategic planning and as additional information about their future framework conditions, ministries to re-evaluate or pre-evaluate their research agenda, research institutions or associations for strategic thinking or evaluation (e.g. the Fraunhofer Society made use of the data during its systems evaluation, Cuhls et al. 2002a), or the general public and the media for information and transparency about what is going on in research and technology.

One practical example is to draw up scenarios or roadmaps from the data which are more application-oriented, e. g. the house of the future (see, for instance Grupp 1995, p. 85). Many stakeholders in the German innovation system analysed the data for their purposes.

The national government (federal level) was supposed to be the main 'user' of all Delphi studies in Germany. The results of the surveys already contributed to decisions such as the orientation of the education and research system, as well as to strategic talks between industry and large research organisations. BMBF made no strategic use of both comprehensive studies as the timing before general elections was inopportune. The regional administrations (*Länder*) are also interested in the results; they tried to analyse and interpret the data from their point of view (Cuhls et al. 2002a; Blind et al. 1997; Schmoch et al. 1995).

A follow-up project was a European effort in the field of biotechnology in food and food processing which was conducted on behalf of the European Commission and compared the opinions of producers, consumers and other stakeholders of five European countries in more detail. The results were especially interesting because in this conflicting area, no consensus between the different opinion groups could be observed. This evidently shows that foresight can also be used to identify the cases in which there is consensus and in which conflict potentials are especially high (Menrad et al. 1999). This provides information at an early stage where the policy making actors can position themselves.

The impact on German society is also linked to the widely discussed results in the media, leading to interesting debates on the desirability of specific technologies. This was especially intense in the run-up to the year 2000. There were times when the ISI server almost broke down because too many people accessed the Delphi dataset. This can also give indications for policy-making.

The data and responses of a Delphi process serve to provide an intimation of future developments, thus allowing a structured communication process about the future. The fact that some areas of the future are already being contemplated today gains time to slow or halt evidently false developments, or to start or accelerate necessary innovations. Thus, Delphi studies provide no immutable picture of the future, but instead offer a basis of information for the decision of what has to be done, not done or even what has to be actively stopped today. How the future will actually develop depends on the decisions made today. Therefore, the actual development can differ greatly from today's assessments. It also depends on those decision-makers who have the power to shape the future on the basis of foresight results. In policy making, mainly the framework conditions for the new developments can be shaped – actively or haphazardly.

**Futur** addressed a different audience than previous studies. Although there seems to be a learning impact on all participants, these were not the major clients. Futur was conducted on behalf of the BMBF which it directly involved, and the Lead Visions specifically addressed the BMBF. Therefore, an impact should be expected mainly here, but it is difficult to confirm a direct impact. The implementation of programmes and projects, as well as the corresponding budget allocation, does not, strictly speaking, belong to the Futur process as such. It is, however, the responsibility of the BMBF, which means that there the outcomes of the Lead Visions were translated into the policy making process for funding research projects and activities. In general, interdisciplinary project teams were established within the Ministry to manage the implementation of the Lead Visions from the first phase.

The four Lead Visions 'Understanding Thought Processes', 'Living in a Networked World', 'Healthy and Vital throughout Life by Prevention' and 'Creating Open Access to Tomorrow's World of Learning', which were developed and adapted during the first phase of the Futur process, have undergone different stages of implementation by the Ministry. The details of the procedure of implementation differed for the four different Lead Visions (Dietz 2004; Cuhls et al. 2004), e.g. for the Lead Vision 'Understanding Thought Processes', the BMBF project team elaborated a detailed concept of implementation together with different BMBF divisions. In autumn 2003, a first call for proposals was launched to establish centres for computational neuroscience. Two centres started their work in autumn 2004, two others followed at the beginning of 2005. The funding amounted to a total of € 5 m per year for a period of 5 years. A brain research network (Bernstein Centres) was planned to be supported with € 34 m.

The Lead Vision 'Living in a Networked World' led to the development of an implementation strategy by a high ranking expert group working for the BMBF sub-directorate 'Information and Communication Technology'. It was decided to give priority to the topic of heightened IT security. Later on, the following projects started: Applications in cars (network on wheels, embedded systems), mobile internet and next generation internet, human machine interface, especially service robotics, smart web, augmented reality. Funding in 2004 amounted to € 7.9 m, while € 64 m were allocated to later projects in 2005–2007.

The implementation of the third Lead Vision 'Healthy and Vital throughout Life by Prevention' started with a BMBF project team involving health research, educational aspects, biotechnology and innovative workplace development. A call for proposals was formulated by the division Health Research, based on a further expert workshop. Before the call was launched, it was discussed and accepted by the national Health Research Council. First projects started at the end of 2004. The total budget planned amounts to € 5 m per year. The recommendations for the fourth Lead Vision 'Creating Open Access to Tomorrow's World of Learning' were found to be difficult to implement. Budgetary restrictions prompted the BMBF to decide not to implement the Lead Vision (Cuhls et al. 2004).

In BMBF, the Lead Visions and the whole Futur process were not easily accepted. Usually, the divisions are responsible for their own topics and working in an interdisciplinary fashion with other departments causes more work, does not fit the budgets and may threaten the 'own' budget. In an attempt to increase acceptance, persons from the BMBF divisions (*Fachreferate*) and the programme operating agencies (*Projektträger*) were directly involved, especially by providing them with separate workshops and information but resistance remained. Doubts were also voiced whether the topics of the Lead Visions were really new to BMBF or would have been supported anyway, if at a later date.

A priority-setting fund *(Priorisierungsfond)* was established by the BMBF to implement the Lead Visions that were transferred to research projects in 2004. This fund contained € 10 m, and was planned to be expanded to € 25 m per year. The sum seems to be high at first sight, but in comparison to the large programmes it is not very high. The divisions were reluctant to apply for this money (in competition), because the money was only provided for a limited period of time at the start of the projects. The division would later be responsible for paying the money out of their own budget.

The effects of the relatively large Futur programme are different from the previous foresights because the addressees and the concept are different. Although the figures for implementation sound high, the direct impact can be rated as relatively modest. There is no direct measurable impact for the previous Delphi surveys. But when the companies' strategic planning and the activities started with the data are taken into account, the impact (or better: input-output relation) of the Delphi surveys seems to be even higher, as it was a much more resource-saving foresight process (including all publications Delphi '98 cost less than € 750.000,-). Companies are relatively critical about Futur,[4] because their own output (learning or influencing research programmes was an expected effect) is modest and no 'data' or 'facts' about the future are derived from the process. However, in the long run, many of the topics and visions that were discussed but were not formulated into

[4] This was often stated in the surveys which were performed during the monitoring of the process and at the end of Futur to provide the evaluation panel with data.

final Lead Visions have nevertheless become topics of discussion in BMBF and are on the agenda for concrete policy making, e.g. the demographic change which was at first played down ("interesting for our health insurance system, not for science and technology..." quotation from a BMBF participant).

**BMBF Foresight Process:** The results of the BMBF Foresight Process were presented at a conference in Bonn in the presence of the Undersecretary of State, high-ranking persons, decision-makers and interested experts. Two hundred persons participated in this conference held at the former parliament building. Part of the conference was organized into so-called "topic islands" where the new fields were presented and discussed by experts from different disciplines. All topic islands had a different agenda, and the participants were free to choose where they wanted to go. The discussions were very animated.

Talks in BMBF revealed strong interest in the new fields so that follow-up activities were launched. The first of such activities were "follow-up workshops" to bring together different BMBF departments and enable them to exchange views. In 2010, the BMBF started strategic dialogues as an opportunity for looking into the new future fields of the BMBF Foresight Process from different perspectives. This is necessary, on the one hand, for the further development of content and, on the other hand, to ensure that important aspects are included in the integration and translation of results into funding policy at an early stage.

The interdisciplinary new fields were presented in every specific department of the BMBF to make other divisions aware of cooperation potentials and to discuss further activities. With specific divisions, bi- or trilateral talks took place to convince these divisions to go on fostering the specific topics. Some workshops took place to deepen the discussion. A follow-up project was the so-called "Strategic Dialogues" bringing together responsible BMBF people with other actors of the innovation system. The Strategic Dialogues were based on selected fields from the BMBF Foresight and from different internal interests of BMBF.

Another direct policy result is the foundation of a new division (*Referat 524* – Department 524) at the BMBF in June 2010, which has been named *"Demografischer Wandel; Mensch-Technik-Interaktion"* (Demographic Change; Human-Technology Cooperation).

The BMBF Foresight Process in particular showed there are interesting topics that could contribute to the solution of basic problems in the country or meet some of the grand challenges that we are facing. However, it is not easy to directly implement policy measures to foster these fields or topics. It was clear from the beginning that the actors of the specific innovation system need to be motivated to engage and that in every case, different approaches would be necessary (already mentioned in the reports, see Cuhls et al. 2009a, b, c). But in spite of this need most of the topics are now, in 2012, still "in the pipeline" and have not really began to improve.

Some topics like the Human-Technology Cooperation and ProductionConsumption 2.0 gained specific momentum due to current developments. Others are regarded as very important, additional papers are written, but they remain on the list of the unsolved problems (e.g. time research). In the context of the discussion on trajectories, Schienstock seems to be quite right when he says: “The distinction between a new technological paradigm and national trajectories provides a useful approach to study both path creation and path dependency within an overall framework. It is important to mention that a new national growth path develops more or less independently from the existing technological regime through the transformation of a new paradigm into a national trajectory. Furthermore, the existing institutional setting does not channel a new growth path, but institutional renewal has to take place together with the creation of a new technological trajectory“ (Schienstock 2011, p. 71).

Therefore, in the next Foresight cycle, which has demand-orientation at its centre and as the starting point, it will be similarly difficult to implement topics into clear policy-making. It is clear that only those topics which can be accepted by and incorporated into the innovation system in an institutionalised way as well as the policy making system will be supported.

## 11.5 Conclusions and Outlook

Looking at foresight in Germany during the last 20 years, after much initial skepticism, it has even become a kind of fashion to apply foresight. However, the tendency to use foresight for everything to do with priorities and to try to meet too many objectives with one foresight project or programme has also emerged. This became especially obvious in the Futur programme, in which the input-output relation became more and more imbalanced. With time, even the distinction between foresight activities in support of priority-setting and general public relations activities (i.e., public awareness, acceptance of science) became blurred. Both kinds of activities may be needed; but pursuing them simultaneously through mixed instruments (e.g., organization of large conferences, participatory generation of new ideas) requires considerable management activities and seems to appear confusing to the participants.

The process of generating new topics, which was at the forefront of the Delphi method, was originally part of Futur, but the filtering process allowed only more general, well-known topics to ‘survive’. Generating new themes is necessary, and maybe requires a complementary process, focusing not only on science and technology but on society-driven topics, in particular. Even in the international context, there are no straightforward approaches for articulating the implications of ‘societal demand’, therefore such a process may also call for new methodologies. In Futur, they were not developed, the BMBF Foresight Cycle II is a new attempt to develop such methods.

The methods of Futur were not new, but their combination was an innovation. Some instruments served their purpose, others did not or even served different ones (like the conferences) under the heading of Futur. Therefore, the BMBF Foresight Process combined the methods in a way that served the purpose of identifying future fields – in this case for BMBF – but at the cost of less participation. People could only participate in an online survey, most other methodologies asked for expert opinions.

The interlinking of methods and results was often a challenge. Mainly using papers for the transfer frequently resulted in the loss of interesting aspects, perspectives and details. This remains a challenge to be solved in German foresight. What can be unequivocally stated is that applying only ‘soft’ methods like workshops or focus groups is by now regarded as problematic. Industry and BMBF demand ‘harder’ results (facts, figures, indicators) about the future with which they can work, although it is generally accepted that the future cannot be foreseen.

In the Delphi processes, the addressee of foresight in Germany was unclear. It emerged that there is a broad range of addressees, which made the use of the results more self-organized and arbitrary than intended. On the other hand, the concentration on the only addressee BMBF means that the Ministry needs to be more directly involved and the process needs to meet its requirements better than at present. The other possibility is to once again broaden a foresight process in Germany, focusing not only on BMBF but also on other ministries or even more on industry. This is a decision that has to be made by those who finance the process.

The major crucial point in the national Foresight programmes in general is expectation management. In the German foresight projects, the expectations rose with every process. Only the BMBF Foresight Process of 2007 – 2009 was very reluctant to evoke expectation. Therefore, nobody was too disappointed and it was possible to communicate and implement the positive results. In the German Futur, the expectations were extremely high – and that led to disappointment on the side of the participants because they expected to be able to influence directly German policy-making. This sounds naive but for those who are not familiar with innovation systems the announcements of Futur sound logical.

On the other hand, the expectations of BMBF itself in Futur were too high and manifold: Many managers expected detailed analysis with ready to use decision points – but the process provided only normative scenarios and Lead Visions with short descriptions. The money from the strategic fund to implement the topic and develop a concrete programme was only available for a short period of time (5 years). This made the divisions in BMBF quite sceptical because after they had just started a topic, they would then need to finance it from their general budget. The third major negative experience is that the topics themselves are not really new but very broad, general, easy to understand and consensus-oriented. Here, we close the vicious circle: Those were exactly the criteria selecting the themes for the Lead Visions – of course they must be “boring”.

This was the reason why the BMBF Foresight Process of 2007–2009 worked much more reluctantly (we even called it “under cover”), informing the stakeholders in BMBF formally but without involving them too much during the process in order not to evoke the feeling of “we advice ourselves”. In the end, it was more difficult to explain the new future fields to the responsible persons in BMBF – bilateral talks and presentations were necessary.

The outcomes of a foresight activity are often interesting to different stakeholders in the system. But the question remains how to convince these people to go ahead and realize what they regard as "interesting". For this realization, leaving the old trajectories, starting something new and even investing money would be necessary. "Path Dependency and Path Creation cannot be conceptualized as a rational decision-making process; it involves vested interests and power games. The path creation period is a period of trial-and-error experimentation and confrontation between the forces of change and those of persistence, but also between different groups of modernizers, because it is widely undetermined in which direction a new path develops. The development of a new path, therefore, has to be conceived of as a 'contested terrain'" (Schienstock 2011, pp. 70–71). To change the trajectories in a ministry like the BMBF therefore seems to be pointless. Nevertheless, the attempts are necessary – and looking longer term ahead is one of the possibilities to make policy makers aware and in the long run change something, even if it is only possible step by step.

The future is shaped by looking into the future and asking questions about what to do – or not to do. We all make that decision – and act or desist from action. This is more than a self-fulfilling prophecy. We tried to make German policy more proactive to support this aspect of shaping the future. And it is hoped that foresight will help to shape a (somewhat) better future. For these reasons, there is a need for foresight. Although the methodological combinations and concepts may change, foresight in Germany will continue and even broaden. The new BMBF Foresight Cycle II is only one programme.

## References

Banthien H, Cuhls K, Ludewig N (2004) Introduction to Futur – the German research dialogue. About the Futur process. In: Cuhls K, Jaspers M (eds) Participatory priority setting for research and innovation policy. IRB, Stuttgart, pp 5–23

Blind K, Grupp, H, Schmoch U (1997) Zukunftsorientierung der Wirtschafts- und Innovationsstrukturen Nordrhein-Westfalens, Karlsruhe

Bundesministerium für Forschung und Technologie (BMFT) (ed) (1993) Deutscher Delphi-Bericht zur Entwicklung von Wissenschaft und Technik, Bonn

BMBF (eds) Zukunft nachgefragt (The future in question). Newsletter published by ISI/BMBF 1999–2003 several issues

BMBF Hightech Strategy: new version can be found here: http://www.bmbf.de/en/index.php. (access 24/3/2013), old fields in archive

Cuhls K (1998) Technikvorausschau in Japan. Ein Rückblick auf 30 Jahre Delphi-Expertenbefragungen [Foresight in Japan. Hindsight on 30 years of Delphi expert surveys]. Physica, Heidelberg

Cuhls K (2003) From forecasting to Foresight processes – new participative Foresight activities in Germany, Cuhls K, Salo A (Guest Editors). Journal of Forecasting, 22(Special Issue):93–111

Cuhls K (2004) Futur – Foresight for priority-setting in Germany. Int J Foresight Innov Policy 1(3/4) Inderscience:183–194

Cuhls K (2008) The handbook of technology Foresight, concepts and practice. In: Georghiou L et al (eds) Foresight in Germany, PRIME series on research and innovation policy. Edward Elgar, Cheltenham, pp 131–152

Cuhls K, Blind K (1999) The German Foresight study '98 on the global development of science and technology. In: Kocaoglu DF, Anderson TR (eds) Technology and innovation management, PICMET '99, Portland,pp 577–582

Cuhls K, Georghiou L (2004) Evaluating a participative Foresight process: Futur – the German research dialogue. Res Eval 13(3):143–153

Cuhls K, Kuwahara T (1994) Outlook for Japanese and German future technologym, comparing technology forecast surveys. Physica, Heidelberg

Cuhls K, Breiner S, Grupp H (1995) Delphi-Bericht 1995 zur Entwicklung von Wissenschaft und Technik – Mini-Delphi -, [Delphi report 1995 on the development of science and technology]. Karlsruhe (same as brochure of BMBF, Bonn 1996)

Cuhls K, Uhlhorn C, Grupp H (1996) Foresight in science and technology – future challenges of the German S&T system. In: Meyer-Krahmer F, Krull W (eds) Cartermill guide for science and technology. Cartermill, London, pp 63–81

Cuhls K, Blind K, Grupp H (eds) (1998) Delphi '98 Umfrage. Zukunft nachgefragt. Studie zur globalen Entwicklung von Wissenschaft und Technik [Delphi '98 survey. Study on the global development of science and technology] Karlsruhe, www.isi.fraunhofer.de/P/Projektbeschreibungen/Cu-delphi.htm

Cuhls K, Blind K, Grupp H (2002a) Innovations for our future Delphi '98: new Foresight on science and technology. Technology Innovation and Policy, vol 13, Series of the Fraunhofer institute for systems and innovation research. Physica, Heidelberg

Cuhls K, Ludewig N, Kuhlmann S (2002b) Futur. The German research dialogue. Information document for the evaluation panel. Fraunhofer ISI, Karlsruhe (unpublished)

Cuhls K, Hafner S, Rainfurth C (2004) FUTUR – the German research dialog, information document for the evaluation panel. Karlsruhe (unpublished)

Cuhls K, Beyer-Kutzner A, Bode O, Ganz W, Warnke P (2009a) The BMBF Foresight process. Technol Forecast Soc Change 76(2009):1187–1197

Cuhls K, Ganz W, Warnke P (eds) (2009b) Foresight-Prozess im Auftrag des BMBF. Etablierte Zukunftsfelder und ihre Zukunftsthemen. IRB, Karlsruhe/Stuttgart (Original in German), www.isi.fraunhofer.de/bmbf-foresight.php

Cuhls K, Ganz W, Warnke P (eds) (2009c) Foresight-Prozess im Auftrag des BMBF. Zukunftsfelder neuen Zuschnitts, IRB (Original in German), Karlsruhe/Stuttgart, www.isi.fraunhofer.de/bmbf-foresight.php

Cuhls K, Ganz W,Warnke P (eds) (2009d) Foresight process – On behalf of the German Federal Ministry of Education and Research (BMBF), Report, New Future Fields; Karlsruhe/Stuttgart (English version), www.isi.fraunhofer.de/bmbf-foresight.php

Dietz V (2004) The German Foresight process Futur: implementation of results in research funding. In: Cuhls K, Jaspers M (eds) Participatory priority setting for research and innovation policy. concepts, tools and implementation in Foresight processes. Proceedings of an international expert workshop in Berlin. IRB, Stuttgart, Dec 2002, pp 104–110

Federal German Ministry for Research and Technology/Bundesministerium für Forschung und Technologie (BMFT) (ed) (1993) Deutscher Delphi-Bericht zur Entwicklung von Wissenschaft und Technik. Bonn

Federal German Ministry for Research and Technology/Bundesministerium für Forschung und Technologie (BMFT) (ed) (1998–2001) *Zukunft nachgefragt*, Newsletter no. 1–8 edited by ISI, Karlsruhe

ForLearn Guide http://forlearn.jrc.ec.europa.eu/guide/1_why-foresight/functions.htm. Accessed 4 Aug 2008

Gaßner R, Steinmüller K (2003) Szenarien, die Geschichten erzählen. Narrative normative Szenarien in der Praxis. Wechselwirkung und Zukünfte 2 p. 52–56

Georghiou L (2004) Evaluation of Futur: intermediate results. In: Cuhls K, Jaspers M (eds) Participatory priority setting for research and innovation policy. Concepts, tools and implementation in Foresight processes. Proceedings of an international expert workshop in Berlin. IRB, Stuttgart, Dec 2002, pp 18–23

German Hightech Strategy http://www.hightech-strategie.de/. Accessed 21 June 2012

Grupp H (1992) Dynamics of science-based innovation. Springer, Heidelberg/New York

Grupp H (ed) (1993) Technologie am Beginn des 21. Jahrhunderts. Physica, Heidelberg (2nd edition 1995)

Grupp H (1994) Technology at the beginning of the 21st century. Technol Anal Strateg Manage 6:379–409

Grupp H (1996) Foresight in science and technology: selected methodologies and recent activities in Germany. In: Science Technology Industry (STI) review no 17. OECD, Paris, pp 71–99

Häder M, Häder S (1995) Delphi und Kognitionspsychologie: Ein Zugang zur theoretischen Fundierung der Delphi-Methode. ZUMA-Nachrichten 37 p 8–34

Hafner S, Cuhls K (2004) Futur – the German research dialogue. Paper to be presented at the EU-US scientific seminar on new technology Foresight, forecasting & assessment methods (Future-oriented technology analysis: FTA), Seville, May 2004

Irvine J, Martin BR (1989) Research Foresight: Creating the Future, Netherlands Ministry of Education and Science, Zoetermeer

Martin BR (1995) Foresight in science and technology. Technol Anal Strateg Manage 7 (2):139–168

Menrad K, Agrafiotis D, Enzing C, Lemkow L, Terragni F (1999) Future impacts of biotechnology on agriculture food production and food processing. Physica (Technology, Innovation, and Policy 10), Heidelberg

Miles I, Cassingena Harper J, Georghiou L, Keenan M, Popper R (2008) The many faces of Foresight. In: Georghiou L et al (eds) The handbook of technology Foresight concepts and practice, PRIME series on research and innovation policy. Edward Elgar, Cheltenham, pp 3–23

Rowe G, Wright G (eds) (2011) The Delphi technique: past, present, and future prospects – introduction to the special issue. Technol Forecast Soc Change 78(9): 1487–1720

Rowe G, Wright G, Bolger F (1991) Delphi – a reevaluation of research and theory. Technol Forecast Soc Change 39:238–251

Salo A et al (2005) Evaluation report on Futur – The German research dialogue. Helsinki/Karlsruhe (unpublished, summary available from BMBF)

Schienstock G (2011) Path dependency and path creation: continuity vs fundamental change in national economies. J Futures Stud 15(4):63–76

Schmoch U, Laube T, Grupp H (1995) Der Wirtschafts- und Forschungsstandort Baden-Württemberg – Potentiale und Perspektiven. In: ifo studien zur strukturforschung 19/I, München

# Chapter 12
# Implementing Foresight Study Results in Policy Action and Measures: EU Experiences

**Jennifer Cassingena Harper**

## 12.1 Introduction

The effectiveness of a foresight exercise is primarily assessed in relation to the extent to which it results in the outputs which were agreed upon at the start by the sponsors/clients and implementing team. These usually have to be produced by the end of the foresight exercise. In time the deeper success of the foresight action may be assessed in the medium to long-term outcomes and impact(s) it generates, in particular through the broadening of policy perspectives and options by encouraging participants to think the unthinkable. More significantly long-term impacts can relate to the extent to which an exercise facilitates processes of major transition, disruption and/or paradigm shift, by stimulating the need for a more fundamental re-thinking and re-alignment of policies, and restructuring of implementing frameworks and networks (Havas et al. 2007). There is often a dual tension between the need for timeliness and immediacy in delivering formal outputs and the uncertainty surrounding informal outputs in terms of where, when and how these arise during the foresight activity and beyond, and whether these can be taken up and addressed. This can itself have an influence on how a foresight activity is conducted. As a result, the activity may become overly focused on the completion of set deliverables within certain timeframes, such as organising a fixed number of meetings and producing a number of publications, and the process benefits may not be sufficiently addressed, recorded and appreciated.

The long-term benefits and impacts of the foresight process in terms of enhanced learning and unlearning, foresight embedding, creative thinking, realignment of power and interests, often escape the formal evaluation process at the end of the exercise, since they are informal outputs and their effects may surface later. There is thus a level of uncertainty and complexity in the implementation of foresight results

J. Cassingena Harper (✉)
Malta Council for Science and Technology, Bighi, Kalkara CSP 12, Malta
e-mail: jennifer.harper@gov.mt

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into policy and action due to the fact that these tend to take place at different levels and different times (FORLEARN 2005–2007). This depends primarily on the receptiveness of the policy context (JRC IPTS et al. 2001) and the key players. Practice demonstrates this in a number of cases, with foresight evaluation indicating, on the one hand that the process has not lead to direct policy impacts, whilst acknowledging that indirect effects on policy have taken place and that a reservoir of policy options has been created and could be tapped in future when the time is ripe (Georghiou et al. 2004).

Whilst the essence of foresight remains the same (namely a participatory vision-setting exercise), the nature of foresight has been undergoing significant change in recent years to embrace a broad spectrum of activities. There has been a shift from more large-scale programmes often employing complex phasing, and a range of methods and resources, to small individual exercises, involving a series of expert meetings and workshops, falling more into the broader category of forward-looking activity. This is due to a growing interest of policy makers in designing more robust evidence-based forward-looking policies. This has stimulated a response on the part of foresight practitioners to embed foresight in ongoing strategy development processes, where the policy maker may not be entirely convinced of the effectiveness of foresight processes but is keen to experiment by including a foresight workshop/process. Another factor is the need in key areas of strategic policy making to link foresight more closely to policy making by endeavouring to engage the key players directly in the exercise at the outset to provide formative shaping and steering of the process and/or at the end to endorse and take forward the results. In this situation, foresight sponsors and practitioners recognise the need and advantage of adapting foresight to a new policy context where the influential players have limited time to spare but their attention even for a short activity can render more useful results than a long-running, resource-intensive activity. These experiments in engaging with key players can take the form of 24-h success scenario workshops where the time commitment of key players is low but the policy insights, networking and results generated, can be high. Such workshops are still resource-intensive since they require careful preparation in terms of approach, design and content and in terms of follow-up work.

It is interesting to consider the varied effectiveness of these activities in terms of whether, how and why they may translate foresight results into policy action and measures. In this paper, we explore experiences generated through a selection of EU forward-looking activities, with a view to identifying where these have proven effective, and why and how these processes have evolved over time to address a range of policy rationales, contexts and players. The embedding of foresight thinking and approaches in a range of EU strategic initiatives, programmes and measures highlights a growing recognition of the utility of the approach even when the results do not prove entirely satisfactory or lead to unexpected policy directions. The setting up of the European Forum on Forward-Looking Activities (EFFLA) and the confirmation of a strong role for foresight in the new European programme, Horizon 2020, to address the grand societal challenges, highlight a level of ongoing commitment to foresight approaches at European level. The paper starts by identifying different types of outputs, outcomes and impacts that can be generated through foresight and analysing their translation into policy action in the emerging EU policy context and European experiences with transformation processes.

## 12.2 Distinguishing Between Foresight Outputs, Outcomes and Impacts

Foresight exercises are primarily undertaken to fulfill a number of policy-related functions. In the FORLEARN Mutual Learning exercise (Da Costa et al. 2008), the following set of key functions were identified:

- "Informing policy by supplying of anticipatory "intelligence" on the dynamics of change, future challenges and options as an input to policy conceptualisation and design.
- Facilitating policy implementation by building and supporting networks of stakeholders with a common awareness of the current situation, of the challenges to come and of desired visions of the future.
- Embedding participation in policy-making by facilitating the participation of different stakeholders in the policy-making process, thereby improving its transparency and legitimacy.
- Supporting policy definition by jointly translating outcomes from the collective process into specific options for policy definition and implementation.
- Reconfiguring the policy system in a way that makes it more apt to address long-term challenges.
- Symbolic function by indicating to the public that policy is based on evidence and developed through transparent processes"

In this analysis, the implementation of results linked through these functions is addressed with the main emphasis on the growing concern with the use of foresight to reconfigure the policy system to address long-term societal challenges, since this is emerging as a priority function at European level. The translation of results into policy action and measures is often considered as the ultimate goal of a foresight exercise which can often prove difficult to implement due to hidden barriers in the local context. Indeed, the extent to which foresight impacts relate to effective policy changes, is becoming a key measure for assessing the success of the exercise. Inclarity over the client's expectations with regards to outputs, outcomes and impacts, can often result in disappointment, especially if the client has particular priorities which are not communicated to those implementing the exercise. On the other hand, over-specification of deliverables and expected results can reduce the space for creativity and exploration and the opportunity to generate unforeseen results. Thus some discussion of expected results, indicating client priorities in terms of outcomes, impacts and outputs would be useful, in determining where more effort needs to be focused. In distinguishing between outputs, outcomes and

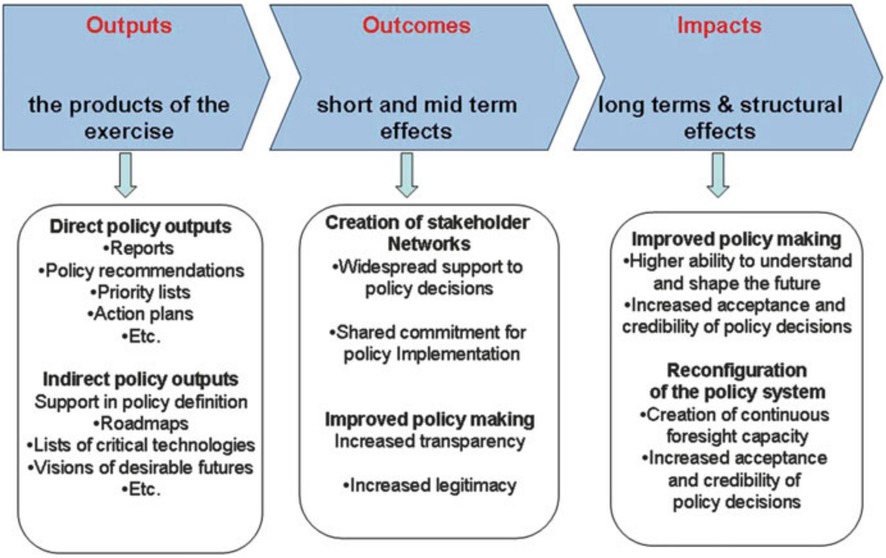



**Diagram 12.1** Foresight outputs, outcomes and impacts (FORLEARN http://www.foresight-platform.eu/community/foresightguide/foresight-for-policy-makers/functions-of-foresight-for-policy-making)

impacts, the timeline of when different types of results can be expected to materialize (Diagram 12.1 above) highlights the fact that reconfiguring the policy system and the setting up of an ongoing foresight capacity are impacts which can be expected to take place in the long-term.

The client and implementing team usually agree in advance on the outputs or products of the exercise, since these are tangible products which include reports, action plans, workshops and networks and more indirect outputs such as roadmaps and visions. The expectation is that these products are delivered at the end of the exercise and mark the successful completion of the exercise. While the outcomes relate more to the process of foresight embedding and the shared commitment to policy implementation, impacts are created when an output interacts with the economy, society or culture and when outputs result in a roadmap for action and the adoption of concrete policy measures. Thus outcomes and impacts tend to be more informal, intangible and unforeseen, deriving from the foresight process and going beyond the expectations of the exercise (Havas et al. 2010) or changing from the expected direction. Long-term impacts relate to re-alignment of the system, including the introduction of a disruption factor, inducing a major change in mindset, policy approach or new strategic direction.

Based on a review of foresight practice at national and European level, it is possible to identify a number of pitfalls which prevent implementation of results into action. A key concern is when the client/sponsor is not satisfied with the quality and/or general thrust of the proposed recommendations. This can be due to the fact that results are poorly communicated to the client/sponsor and that insufficient communication is maintained with the sponsors throughout the exercise. Results can fail to be implemented by policy makers if the foresight activity is poorly perceived and does not achieve sufficient profile, or if timeframes for policy implementation are not properly thought out and key deadlines for policy decisions are missed. Another factor is when those managing the foresight process are not sufficiently in tune with policy processes and/or make incorrect assumptions that certain recommendations are feasible. Alternatively the exercise may focus too much on formal outputs and neglect the process and engagement of a sufficient range of stakeholders to drive effective implementation. Foresight results can often be hampered by a delay factor due to the fact that the time for a new strategic direction has yet to come and in this case implementation may happen over a longer timeframe. Indeed new ideas and approaches from a foresight exercise can end up in a reservoir, eventually to be implemented, when the time is right.

Based on this review, it is possible to identify a number of key success factors in ensuring that foresight results are implemented in policy action. Firstly it is important to ground and attune the exercise to the particular context since there may be specific unforeseen pitfalls to watch out for. It is imperative to understand the client's expectations and not to overstep the remit. In order to translate results into action, it is important to synchronise and engage with the policy cycle, keeping to timeframes and delivering results on time and in the format required. Where possible, long reports need to be substituted or complemented by clear concise documents, outlining policy options. More attention needs to be given to the actors rather than the tools and to build the networking and teamwork to ensure success. An effective communication plan is a sine qua non for keeping sponsors and clients updated, handling the media and for engaging with stakeholders, understanding what they expect and speaking their language. Special efforts need to be reserved for key players who influence decision-making. This highlights the need to put in place a team which brings together all the required skills and expertise and which is well-networked with the stakeholders. Each context throws up different ways of ensuring success but not all good practices are easily transferable. In the next section, our focus turns to the European policy context and the growing concern with addressing grand societal challenges approach which is creating a new impetus for attuning the foresight tools and for reconfiguring the research and innovation policy system.

## 12.3 European Policy Context and Grand Societal Challenges

The European Union supports foresight activity at different levels and to address different rationales including, providing support for national, regional and local foresight exercises; and the organisation of EU level foresight to inform EU policies and promote the harmonisation of member state policies. The EU investments in foresight take different forms. The EU draws on and works with foresight units and experts in member states and worldwide, and sets up and organises where necessary, expert groups, projects, studies, conferences and workshops. These activities reflect a strong emphasis on support to European policy and capacity-building in developing tools and skills at European and national level, using a combination of qualitative and quantitative approaches and horizon scanning.

Over the last decade the European Union has sponsored a range of foresight studies using different instruments and addressing different objectives. During the accession phase of the EU-12, foresight was used as an instrument of transition to support the accession of new Member States with the aim of building R&I intensity, capacity and performance. EU-sponsored regional and city foresight addressed local territorial concerns as well as cross-border cooperation. Of particular note is the Fifth Framework Programme project, FOREN (Foresight for Regional Development), a high impact project, which produced a regional guide which was adapted in many European countries and regions. FOREN together with the Regional Foresight Expert Group and the recent DG Regio Cities exercise have had important impacts in influencing policy and action at different levels. These actions have resulted generally in increases in national R&I spend contributing to new actions and measures, at regional and city level, have enhanced governance processes and lead to more effective regional and city programmes.

The more strategic of EU foresight studies have been assigned to high level expert groups addressing particular themes, including regional foresight, the role of universities, key technologies and converging technologies, the EU in the World, as well as sectoral exercises including agriculture, environment and climate change, cities among others. Foresight projects have been supported since 2000 through the EU Framework Programme, initially the STRATA Programme in the Fifth Framework Programme (FP5) which sponsored foresight projects in accession countries. More recently, foresight is being used in a more strategic and embedded way in a number of EU initiatives, including the Joint Programming Initiatives, in developing the strategic research agendas and at project level in the Seventh Framework Programme (FP7). A number of blue skies projects were also sponsored to promote European level cooperation in horizon scanning, the identification of weak signals and wild cards, and the use of foresight to address grand challenges.

The latter coincided with a major watermark in EU research and innovation policy, namely the shift from a primarily thematic and disciplinary approach to research and innovation investments reflected in Framework Programmes up to and including, to a certain extent, the Sixth Framework Programme (FP6), to a more strategic grand challenge approach, inspired by the ERA Rationales Expert Group Report (2008) and confirmed at the Swedish Presidency Lund Conference. Although not a foresight study, the ERA Rationales Expert Group Report identified a way forward, by outlining a "rationale" for a European Research Area that has a clear purpose which is meaningful to Europe's citizens and political leaders and relevant to its key actors. While there is a pressing need to improve the effectiveness of the public research system, the ultimate justification of the resources and commitment needed to achieve this lies in increasing the value of the contribution that public and private sector research makes, and is seen to make, to Europe's economic, social and environmental goals' (ERA Rationales Expert Group Report 2008).

"The central means to achieve this is to engage the research system in Europe's response to a series of Grand Challenges which depend upon research but which also involve actions to ensure innovation and the development of markets and/or public service environments." This shift has not only influenced FP7 and the design of the next programme Horizon 2020, but it has also lead several European and international organisations[1] to adopt the Grand Challenge approach, in particular the International Council of Scientific Unions, the European Science Foundation and NordForsk (Keenan et al. 2012; European Science Foundation 2010; NIRPA 2012). There is also evidence that a number of member states have implemented the societal challenge approach in their national research and innovation strategies and programmes (Cunningham and Karakasidou 2010).

## 12.4 Europe's Experience in Implementing Transformations

In recent years, the European Commission has invested in various forward-looking activities which have had the ambition to bring about major transformations in the European research and innovation landscape. These have included the design of a post-Lisbon agenda, aimed at making Europe more competitive globally, the re-thinking of the European Research Area rationales, with a view to reducing fragmentation, the shift to the Grand Societall Challenges approach which started in FP7 and will become more evident in H2020 involving wide consultation processes and the Europe 2020 Strategy with the launch of the European Innovation Flagship initiative and the European Innovation Partnerships. Indeed, the EU2020 drive has emerged as a key policy development and transition, synchronising policy efforts at European and national levels across a range of key challenges and sectors.

The drive to gear research and innovation to address grand societal challenges reflects a more ambitious commitment to bringing about societal transformations by design (Weber et al. 2012). In essence this is a shift towards generating longer-term impacts in society, economy and governance processes. The use of foresight to address societal challenges is in itself highly challenging for those designing and implementing the exercise, since the process for generating such impacts is more complex and risky. This is due to the increasingly dynamic and fast-changing European and global policy context, which is becoming more prone to crisis, sudden change and disruption. The lack of preparedness of governance systems to anticipate and cope with a combination of natural and man-made crises, has prompted institutional responses at national, European and international levels (Amanatidou et al. 2012; Konnola et al. 2012; van Rij 2010). There is evidence of more investment in horizon scanning facilities for early detection of significant emerging trends and drivers, in particular weak signals and wild cards and their use in foresight/forward-looking activity.

[1] International Council of Scientific Unions, the European Science Foundation and NordForsk.

Weber et al. (2012) distinguish between four types of transformations or disruptions which foresight activity has to contend with in different ways. Foresight activity has traditionally contributed to ongoing processes of transformation. This is the case with the EU FP5 STRATA projects such as eFORESEE (Cassingena Harper and Georghiou 2005) and FORETECH which supported transition processes in accession countries. These projects generated important impacts in terms of stimulating capacity-building in research and innovation and in related policy and strategy development. They also lead to follow-up foresight activity particularly in Malta and Romania in the education and other sectors, indicating a level of foresight embedding.[2] What emerged strongly from the Malta foresight exercise is that an important function of foresight is that it flags hidden barriers in the national system, which are preventing transformation and progress. The informal unforeseen benefits of the exercise happened in an unplanned way but could be designed in a more deliberate way in future exercises (Cassingena Harper 2002). The limits of effectiveness of the exercise related to the fact that key players could not participate fully in the exercise except through one-to-one interviews, and this to some extent affected the take-up of the recommendations in a more systematic way. Over time the success of the exercise can be assessed based on the fact that foresight has become more embedded in policy development and that the learning generated has developed into an ongoing masters programme at University.

In a more mature policy context, foresight activity can be geared into a more ambitious mode, namely to deliberately stimulate transformation by design through gradual transition or policy shocks. In this mode, foresight is used to explore future scenarios for transforming the current system by identifying a range of emerging trends and drivers. A European foresight exercise of this type which has proven particularly effective is the SCAR (Standing Committee on Agricultural Research) which has recently completed its third exercise. In 2005 in response to dramatic changes in the agenda for agricultural research which required that agricultural practices and production processes be set in a much wider context of achieving sustainability, the new SCAR as part of its remit to engage in "strategic discussions on the agricultural research agenda in Europe in the long term (FP7 and beyond)", decided to adopt foresight as one of its priorities. In 2006, SCAR launched the first foresight exercise to develop scenarios for European agriculture in a 20-year perspective as basis for identifying priority research needs for the medium and long term (SCAR FFRAF Report 2007). The results of this exercise and the scenarios generated were discussed in two successive conferences held with a wide range of stakeholders in 2007 in Stockholm and Brussels. These discussions led SCAR to establish a Foresight Monitoring Mechanism aiming at providing early signals and warnings about emerging and new problems at regular intervals.

[2] These have been documented in a number of publications including the European Foresight Platform Briefs.

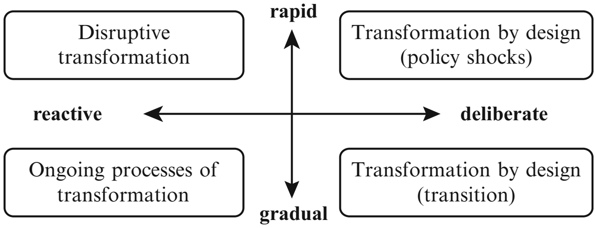
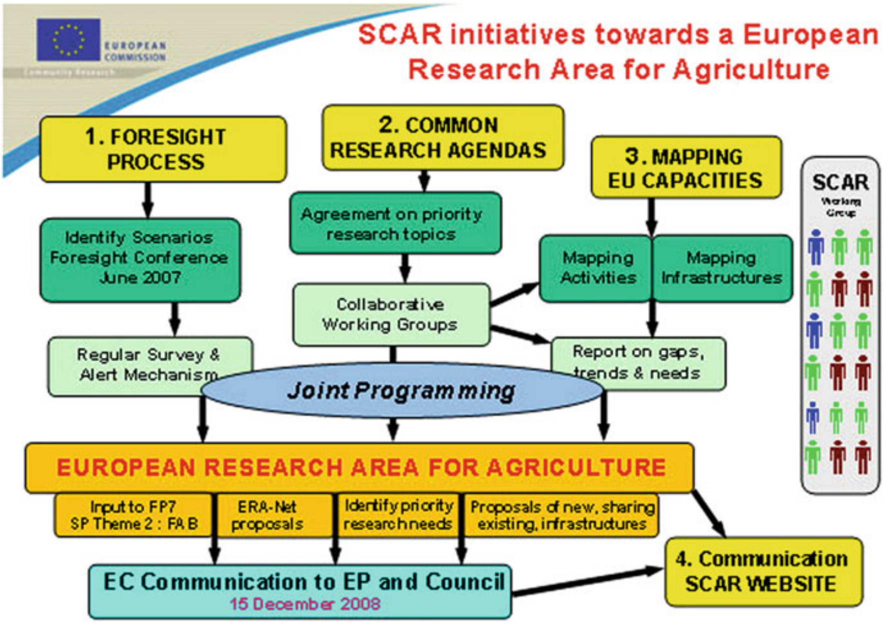



**Fig. 12.1** Identified types of transformations




Two follow-up foresight exercises were also carried out by SCAR as well as a joint foresight workshop conducted in 2009 as part of the EU Blue Skies Project, Farhorizon, which provided an input to the ongoing work to develop a Joint Programming Initiative in this area (see Diagram 12.1 Scar initiatives towards a European Research Area for Agriculture). The Farhorizon project was aimed at developing foresight methodology, in particular the success scenario approach, in real situations bringing together key players to address a grand societal challenge and inform the the development of the related European research agenda. “The “Success Scenario Approach” is an action-based approach, which helps to generate a shared vision among senior stakeholders of what success in the area would look like, specified in terms of goals and indicators, which provide the starting point for developing a road-map to get there. The purpose of having such a vision of success is to set a ‘stretch target’ for all the stakeholders” (EFP 176 2010).

The Farhorizon SCAR workshop focused on “Application of Breakthrough Technologies to Adaptation to Climate Change in Agriculture” and brought together 26 experts from the agricultural research and associated policy and user domains with specialists from outside to explore a foresight vision of the contributions that breakthrough technologies could make. The significance of the success scenario approach in this policy context is that it is being applied to a situation where key policy makers from different domains and at different levels of policy making, European and national, need to agree on and commit to a transition. In terms of implementation of results into policy action, it is difficult to determine the precise impact of this workshop since it formed part of a number of related foresight activities which in turn contributed to helping the "research communities to become one of the first to engage realistically with the Joint Programming Initiative and to position itself for further opportunities within the Innovation Union framework" (EFP 176 2010).

European foresight experiences in the agriculture research area reflect a growing pragmatism in the tendency to tailor and adapt foresight approaches more directly to the needs of the policy context, the key players and the stakeholders. This has led to a more strategic and structured use of foresight methods in ongoing forward-looking policy processes to suit the specific ambitions, needs, resources and targeted results of the exercise. This more utilitarian approach has proven effective and has been emulated in other sectors where agenda-setting is required, for example the preparation of the priorities to be addressed through the Environment and Climate change challenge in Horizon 2020. It is also increasingly embedded in FP7 calls for proposals in the marine, information and communications technologies sector as well as in the development of the strategic research agendas in the Joint Programming Initiatives.

## 12.5 Conclusion

This paper has reviewed a range of European foresight experiences and the conclusion is that foresight exercises achieve benefits derived from the process to a degree at least comparable with any benefits deriving from their more formal outputs. In the first wave of European exercises in the 1990s this was a common finding both in the official reports and in initial evaluations. The effectiveness of EU strategic foresight activity and in particular the role of the expert groups in setting European vision and policy and the strategic, long-term research agenda demonstrate a clear impact. Key insights and messages are often picked up from one expert group to the next and from one policy domain to another, creating significant spin-off effects. The rupture/disruption approaches picked up by the first SCAR foresight group were to become a popular theme in other European exercises, while the grand challenge approach flagged by the ERA Rationales group has been taken up in the design of Horizon 2020.

Transformation by design using policy shocks is being increasingly implemented at European and national level through the use of horizon scanning and detection of wild cards and weak signals of major disruptions underway or on the horizon. The FP7 Blue Skies projects iKnow and SESTI focused on refining the tools for identifying wilds cards and weak signals as well as reflecting on their significance in relation to addressing European grand societal challenges. These projects highlighted the need for an ongoing facility at European level to map and detect signals and to understand and analyse the cross-impacts of such trends and drivers and their potential impacts in the European and global context. The setting up of a centralised foresight and scanning facility with the Joint Research Centre central offices in Brussels and the setting up of the European Forum on Forward-looking Activities is a significant step in confirming the utility of these investments.

## References

Amanatidou E, Butter M, Carabias V, Konnola T, Leis M, Saritas O, Schaper-Rinkel P, van Rij V (2012) On concepts and methods in horizon scanning: lessons from initiating policy dialogues on emerging issues. Sci Public Policy 39(2):208–221

Cassingena Harper J (2002) The relevance of EU regional foresight experiences for small candidate countries. Paper prepared for EU HLG on Regional Foresight, April 2002

Cassingena Harper J, Georghiou L (2005) The targeted and unforeseen impacts of foresight on innovation policy: the eFORESEE Malta case study. Int J Foresight Innov Policy 2(1):84–103

Cunningham P, Karakasidou A (2010) Innovation and societal challenges, Pro Inno Europe thematic report no 1

Da Costa O, Warnke P, Cagnin C, Scapolo F (2008) The impact of foresight on policy-making: insights from the FORLEARN mutual learning process. TASM 20(3):369–387

European Commission (2008) 'Challenging Europe's Research – Rationales for the European Research Area (ERA)', report of the ERA Expert Group, EUR 23326 EN. Luxembourg: office for Official Publications of the European Communities. http://ec.europa.eu/research/era/pdf/eg7-era-rationales-final-report_en.pdf. Accessed 15 Dec 2011

European Science Foundation (2010) Contribution to developing voluntary guidelines on framework conditions for joint programming in research – foresight activities. European Science Foundation, Strasbourg, 28 June 2010

FORLEARN. http://forlearn.jrc.ec.europa.eu/guide/8_mutual/index.htm

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.nih.gov.hu/english/technology-foresight/evaluation-of-the-080519. Accessed 22 july 2012

Havas A, Schartinger D, Weber M (2007) Experiences and practices of technology foresight in the European region. UNIDO Technology Foresight Summit. https://www.unido.org/foresight/rwp/dokums_pres/tf_panels_weber_havas_202.pdf. Accessed 22 july 2012

Havas A, Schartinger D, Weber M (2010) The impact of foresight on innovation policy-making: recent experiences and future perspectives. Res Eval 19(2):91–104, SSRN: http://ssrn.com/abstract=1633021, March 8

JRC-IPTS et al (eds) (2001) FOREN foresight for regional development guide. http://forlearn.jrc.ec.europa.eu/guide/7_references/foren.htm. Accessed 22 july 2012

Keenan M, Cutler P, Marks J, Meylan R, Smith C, Koivisto E (2012) Orienting international science co-operation to meet global grand challenges. Sci Public Policy 39:166–177

Konnola T, Salo A, Cagnin C, Carabias V, Vilkkumaa E (2012) Facing the future: scanning, synthesizing and sense-making in horizon scanning. Sci Public Policy 39(2):222–231

Nordic Network for International Research Policy Analysis (2012) Final report. http://forinn.no/file.axd?file=2012%2f3%2fNIRPA+slutrapport+final+light.pdf. Accessed 22 july 2012

SCAR (2007) FFRAF report: foresighting food, rural and agri-futures. EU commission – Standing Committee on Agricultural Research (SCAR). http://ec.europa.eu/research/agriculture/scar/pdf/foresighting_food_rural_and_agri_futures.pdf. Accessed 22 july 2012

Van Rij V (2010) Joint horizon scanning: identifying common strategic choices and questions for knowledge. Sci Public Policy 37:7–18

Weber KM, Cassingena Harper J, Konnola T, Carabias Barcelo V (2012) Coping with a fast-changing world: towards new systems of future-oriented technology analysis. Sci Public Policy 39(2):153–165

# Part IV
# Foresight Studies: Instrument for Innovation Policy?

# Chapter 13
# Challenges for Science and Innovation Policy

**Luke Georghiou**

## 13.1 Introduction

Faced with difficult economic and social times, science and innovation are caught between the blades of supply and demand: while the demand for solutions to socio-economic challenges has never been greater, highly stressed public finances find it increasingly difficult to provide the investment necessary for them to deliver. Against this background it is ever more important that both the research system and the innovation system, as well as the links between them, should operate with the greatest possible effectiveness. Each faces a series of challenges. For the research system to deliver on the agenda of impact requires hard consideration of how scarce resources should be deployed across institutions, fields and over time. Here at least the boundaries are well understood but for the innovation system this is not the case. We need a better understanding of how the full gamut of public policies impacts upon innovation and what forms of governance are needed to bring them to bear. We also need a new stress on the systemic character which means a shift away from a focus on institutions and towards an engagement with the mobility or flows which represent the dynamic character of an effective innovation ecosystem. In this chapter, these dimensions of research and innovation systems are explored and conclusions are drawn about future needs and directions.

## 13.2 The Fundamentals for a Research System

A research system, and in particular the mode and consequences of its distribution of resources can be characterised by its position on three key dimensions:

L. Georghiou (✉)
Manchester Institute of Innovation Research, Manchester Business School,
University of Manchester, Booth Street West, Manchester M15 6PB, UK
e-mail: luke.georghiou@mbs.ac.uk

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- Selectivity: Which fields to support and how much focus to give priorities?
- Concentration: Which institutions or research teams to support and how concentrated should funding be on the best performers? and
- Sustainability: Are the basic resources of people, money, infrastructure and institutions renewing themselves?[1]

We may consider each of these in turn.

### 13.2.1 Selectivity

It is difficult today to imagine a complete research system operating without any priorities but this, at least in name, was until the 1980s the sole approach operating in most bodies funding research in universities and other organisations pursuing longer term agendas. Termed 'curiosity-driven' research at that time, and more aptly 'investigator-driven' today, this form of funding is driven by the internal dynamics of science, focusing resources upon what applicants consider is most promising. Given the unpredictable nature of science few would argue that this approach does not have an important place and it survives in 'responsive mode' organisations such as the European Research Council and many national funding bodies. What is different is that for most funders it is now only a part of their portfolio. The remaining funding is typically reserved in some way under priority headings. The justification for this may be internal to science, for example based upon concepts such as achieving a critical mass of activity or driven by quality judgements of national capability in a field. More often though, the priorities relate to external drivers, such as relevance to socioeconomic goals. It could be argued that the investigator-driven system reflects hidden priorities. For example in the distant past, UK research councils allocated funding between fields according to 'proposal pressure'. Basically this distributed funds between disciplinary committees on the basis of the proportion of total requests they accounted for. Since the equation was driven by the population of researchers in a field it served to reinforce historical judgements and made it very difficult to adapt to major shifts in the balance of scientific promise. With or without this formula, historical inertia tended to dominate allocations.

It is perhaps not a coincidence that the revival of foresight approaches in the early 1990s coincided with the need to adjust the balance of funding in the direction of the rapidly emerging promise of life sciences. However, the more common demand made upon the foresight community is for guidance on how to align S&T priorities with socio-economic priorities. We can follow these developments using the example of European Union research funding programmes. At this level two aspects of this type of demand are currently evident, one of which is framed at

[1] This framework was articulated as part of the FP7 ERAPRISM project http://www.eraprism.eu.

top down and the other at bottom up level. Representing the top-down approach is a desire to identify societal or grand challenges which can provide not only a focus for interdisciplinary research efforts but also a bridge to innovation and to wider political and public engagement with research. At the other end of the scale is another task which forms a regular demand for foresight, the identification of key technologies likely to have a pervasive role. Each task has particular problems.

Looking first at the identification of challenges, the starting position is not a clean sheet. From the first introduction of the notion of grand challenges to the European debate by the ERA Rationales Group (Georghiou et al. 2008) a set of challenges has dominated debate, these being energy, resource, personal and food security, sustainability, and the ageing population and health. Several of these have emerged as Joint Programming Initiatives (in which Member States of the EU combine and coordinate national resources with further input from the European Commission) and subsequently have emerged as the structuring feature of a large part of the next cycle of European research and innovation funding, the Horizon 2020 programme. The difficulty has been to move on from these headlines in two ways, one being to articulate the challenges in such a way that research can address them effectively and the other to search for gaps and unidentified challenges. The perceived lack of anticipation of the financial crisis has created a desire not to be caught out again and even resulted in an institutionalised approach with the foundation of the European Forum for Forward-Looking Activities (EFFLA), a high-level advisory panel with the remit of scanning foresight and related activities and reporting possible disruptions to the Commission.

Further illustrating this dual function, a group convened by the European Science Foundation was asked to suggest approaches to identification of both types of challenges (ESF 2010). The recommendations are summarised on Fig. 13.1. The task of identifying new challenges is particularly difficult. The influence of headlines and fashion should not be underestimated – pandemics, global warming, financial stability, scarcity of vulnerability of supply for rare metals and minerals are all real challenges but have received very different levels of political and media attention at different points in the last decade.

A key issue in considering priorities is that of granularity – at what level may a challenge be translated into an actionable problem that can be addressed by research and innovation? We will argue that the generic challenge statement is too broad and that a single targeted programme is too narrow but it is necessary to explore how the two may be connected? Public recognition of a grand challenge is normally at the highest level of aggregation – climate change, energy or food security, migration and so on. If the public are to be assured that the research is focused upon these issues it is essential to maintain traceability to this level but headings at this level of granularity do not lend themselves to specific or measurable action. A first step is to articulate the challenge into its key components – for example climate change will have elements of measurement and prediction, of mitigation and of adaptation and could be addressed across a range of sectors such as agriculture, land use, transport and energy.

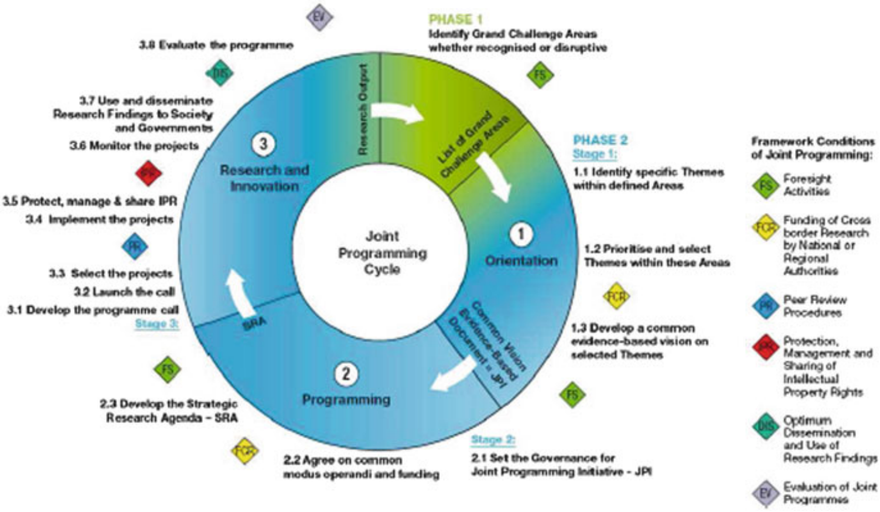


**Fig. 13.1** Joint programming cycle: steps proposed by the ESF

### *13.2.2 Aligning Not Selecting*

Given that resources for research are finite there will be some pressure to support the allocation of funds between challenges. By their nature it is unlikely that grand challenges will be in a position where a formal selection process is applied to competing proposals. A more realistic model is that actions which are brought to the required level of maturity and have sufficient support will be taken forward first, thus creating the risk that new and unforeseen challenges will be difficult to support if flexibility of funding is reduced by commitments already made. In reality, grand challenges are unlikely to be funded from a single source. It is more likely that they will involve alignment or redeployment of existing resources as well as attracting additional investment.

### *13.2.3 Prioritising Key Technologies*

If we turn now to key technologies, we find once more that granularity is an issue. It is almost a truism to say that every country has prioritised biotechnology, information and communication technologies and nanotechnology. Large amounts of research can be classified or even re-classified under these headings but they do not relate to the specific needs of the sectors or other opportunities that a country or region may be seeking. So again it is necessary to drop one or even two levels in the classification. While in this case the taxonomy is probably technological the links to application areas remain very important.

It is an artificial assumption that a full choice set and full information about technological or socio-economic potential will be there to allow rational selection. To begin with, Interdependency is often overlooked. Generic elements such as mathematics may not be easily linked to specific applications but without them the area may not be able to move forward. A technology is often associated with particular institutions or companies hence bringing their relationships and influence into the picture. There are several methodologies available for making choices but these generally begin after the crucial step – the formulation of the list which is to be prioritised.

One further difficulty with the practice of prioritisation is the strong aversion most panels have to the identification of negative priorities or "posteriorities" – the areas which should be downgraded or deleted. Any such exercise is generally fraught with controversy – a recent attempt by a UK research council to stop growth of its investment in certain areas led to a highly publicised funeral procession for science outside Parliament by members of the affected community. During the long period of growth of research funding this problem was largely side-stepped by simply growing the priority areas faster (Georghiou and Cassingena Harper 2011, pp. 246–247) but in a time of economic constraint this may no longer be an option. The resources may be needed for new more productive investments.

If we aggregate the selectivity decisions made at institutional, regional or national level, the debate intersects with that of specialisation. We need to distinguish here between scientific specialisation and industrial specialisation. Both are driven by a logic of clustering – the idea in the first case being that sufficient numbers of researchers are present to cover the necessary range of related fields within the specialisation and able for example to justify associated capital equipment. The argument may be that a country or region cannot afford to cover all fields. It raises an interesting side issue – this being what is the minimum level of cover that should be given to a low-priority field in order that it could be regenerated if circumstances change in the future.

For industrial specialisation the challenge is more complex as one sector may still require a wide range of fields to support it but within those fields specific competences could be needed. For example a specialisation in nuclear power technology creates demands across nuclear physics, radiochemistry, materials, computation, medicine and more.

### *13.2.4 Concentration*

The level of concentration in a research system reflects the degree to which research resources or outputs are distributed within a system. It is a frequent state to be found in science that such indicators are unequally distributed, normally on a logarithmic scale. Figure 13.2 shows a typical pattern, the distribution of citations to the top 100 papers in the breakthrough area of graphene research.

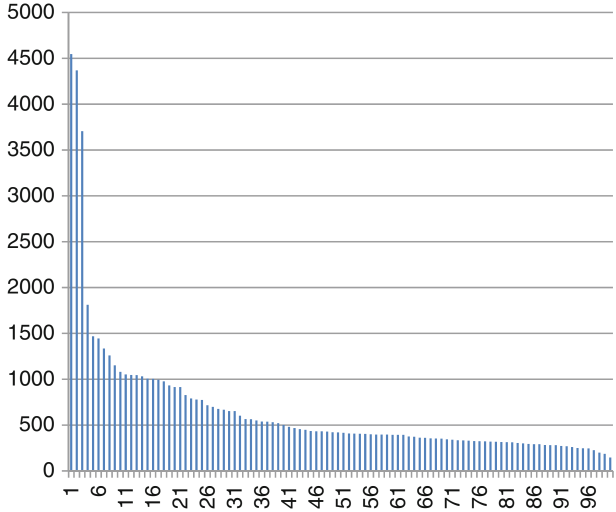


**Fig. 13.2** Distribution of citations to papers in graphene (Source: Google Scholar October 2011 using Harzing Publish or Perish)

A more recent phenomenon is the pursuit of concentration as a specific policy objective. This normally is effected through a competitive process. By making research grants larger and longer-lasting a trend to concentration is established. Several funding bodies (for example the European Research Council and the Wellcome Trust) operate on an elite funding model which gives such rewards to a small number of the top echelon of researchers. Another form of concentration comes about when institutions are merged to create centres of excellence.

The consequences of these changes are manifested at several levels. At the individual level, the increasing focus on track record creates barriers to entry and may inhibit the development of the next generation of researchers if not backed up by explicit measures to compensate. This effect could currently be disguised by a backlog of senior researchers as most schemes are relatively recent. At regional level the normal case that in any geographical unit the incidence of research funding is highly unequal in its distribution. In the ERC case the decision to allocate purely according to criteria of quality means that entire countries may be excluded. The phenomenon of unequal distribution is not confined to Europe. California accounts for one fifth of US R&D, the top 20 states 85 % and the bottom 20, 4 %. However, in Europe the New Member States (principally in Eastern Europe and known as the EU12) have been making it increasingly clear that they are not getting a ‘fair share’ from European programmes either quantitatively or qualitatively.

It is likely that these arguments have two drivers. The first is the belief that proximity to R&D leads to socio-economic benefits. A distinction should be made here between basic and applied research. Applied research is clearly linked to a providing a user or customer with a solution and in principle can be sourced from anywhere. The private and not-for-profit research and technology organisations

(RTOs) are major performers in this sector. Despite some signs of internationalisation by organisations such as the Fraunhofer Gesellschaft, such trade remains to a large extent within national borders. For basic research, at first sight the location should not matter since results are freely available. In practice though very little such research is funded across borders and even countries that fund little of it themselves seek to get a larger share of European funding. Why should this be the case? The answer lies in the nature of the benefits beyond the freely available publications (which are mainly addressed to a fairly narrow peer group). The socioeconomic benefits are more likely to be manifested as externalities resulting from the ability of research to produce highly trained people and of the cumulative expertise of researchers that can be applied to solve problems. The labour market effect in turn may attract inward investment from technology-intensive firms, or lead to entrepreneurial knowledge-based start-ups. Both of these effects have a spatial nature and hence incentivise countries or regions to maximise their share. It is, however, unlikely that such benefits can be realised effectively without addressing wider framework conditions – a topic we shall return to later.

The second driver comes from the arithmetic of research funding. Scientific communities in low R&D intensity regions are more dependent upon external sources of finance and hence place higher priority upon securing a share even if their capability to do so is less than their counterparts in research intensive regions.

It is useful to explore further the linkage between the proximity argument and concentration. The former as we have noted rests on idea that access to knowledge and absorptive capacity are dependent upon active engagement in R&D. R&D capability is often taken as a proxy for quality in other dimensions of activity – for example the widespread belief that leading research universities are also the best place to study. Where they have a choice, students largely follow this logic.

Does this mean that we should disperse R&D activity as far as possible to give an equitable opportunity to each region to access such benefits? There is a counter-argument to this view, which is that research is performed more effectively in institutions with a critical mass of activity. While widely used in the literature, the term critical mass is not always well-defined. Opponents of the argument often argue that empirical studies appear to show that the critical size of a research group is quite small (no more than 10 except for some highly capital intensive areas). (see Johnston 1994; Bonaccorsi and Dairaio 2007; von Tunzelmann et al. 2003 for arguments around this issue). 333 From this they conclude that large institutions or regional concentrations are not beneficial overall.

There is an important counter to this argument. There has been a substantial trend towards interdisciplinary research, driven for example by the convergence between biological and physical sciences. This interdisciplinarity is often at the core of responding to an industrial or societal problem. The advantage then passes to institutions which have multiple research groups at a high quality level and also have the capability to configure these groups to work on such problems. Critical mass then becomes defined as much by economies of scope as by economies of scale.

### 13.2.5 Sustainability

The third key dimension of a research system is its sustainability – its ability to thrive and grow over an extended period of time. In turn, this dimension can be considered in terms of three key factors: funding, people and infrastructure

#### 13.2.5.1 Funding

The issues of selectivity and concentration have already been discussed above but funding may also be considered in terms of the mechanisms and criteria used to allocate it. We may focus on one particular issue – the distribution between institutional and competitive funding. The first term refers to funds that are given to research institutions in a block to cover the costs of fulfilling their mission but without specific conditionality at project level. The second refers to funds that are allocated on the basis of competing proposals, normally by some form of peer review with modifications if wider criteria such as socioeconomic relevance are applied. Institutional funding can also be competitive and even peer reviewed (for example the UK's Research Excellence Framework formerly known as the Research Assessment exercise) but the judgement is much broader and does usually have the much lower success rates of fully competitive funding. In other cases institutional funding can be allocated on a formulaic or historic basis.

Each approach has its strengths and more particularly its weaknesses. Too much block funding favours incumbents and reduces performance incentives and the agility of the system to move into new fields or approaches. Too much competitive funding prevents institutions or research teams from developing strategies and risks hollowing out of laboratories by not supporting equipment and other support that are not easily allocated to a single project. Hence in either case an imbalance threatens sustainability.

#### 13.2.5.2 People

Sustainability also is an issue when considering the people who perform research. Almost 40 % of the human resources in science and technology in the EU are 45 years or older. This is driven by two clusters of countries with low proportions of younger (<34) researchers. One is the remaining unreformed and underinvested countries of Eastern European e.g. Bulgaria and Croatia, while the other is a group of high-tech economies – Germany, Switzerland, Austria, Finland and Sweden.

Without a rebalancing of the demographics of the research system through training or migration, recovery from the economic downturn could be held up by a lack of trained researchers. Cutbacks in R&D during a recession cause an asymmetric effect – it takes 7–9 years to gain skills and 2 years of unemployment to lose them.

#### 13.2.5.3 Infrastructure

The final dimension of sustainability concerns infrastructure, mainly but not exclusively research equipment, as other items such as larger datasets are also relevant here. Several long-term trends are in operation here. Sophistication of the level of equipment needed to remain at the front of research exerts upward price pressure while innovation in equipment means that a given effect (for example resolution of imaging equipment or the speed of sample processing) is falling in some cases dramatically. The net effect has been to make research more capital intensive but also the site of some spectacular gains in productivity. Few areas can surpass genomics where the original human genome project cost $13 billion and today a commercial sequence can be obtained for $5,000.

A further trend is the extension of the range of capital intensity from traditionally intensive areas of Physics and Chemistry to a series of fields that were traditionally less so, including Life sciences, Environmental sciences and Engineering. In many cases this has been driven by a convergence in disciplinary requirements around interdisciplinary collaborations in imaging and other techniques. Technology has also meant that there has been an emergence of highly networked equipment systems not tied to a single location – for example in high performance computing and in astronomy.

Sustaining the level of capital equipment is increasingly challenging, particularly during times of austerity. New strategies have been emerging including a desire by policymakers to increase the degree of sharing of equipment. There is a belief, no doubt with some substance, that research groups accumulate equipment not only to use but also as a symbol of their achievement. This could mean that items are acquired even when there is spare capacity in neighbouring, or at least in reasonably accessible labs. When researchers are cut off from high quality equipment altogether, for example in some small countries, then the motivation to travel to use equipment is greater. Effective sharing of equipment does however require well worked out solutions to deal with cultural, logistical and financial barriers, and will almost certainly result in higher recurrent costs. As already noted there is also a risk of project-related items being acquired without the basic general purpose equipment and maintenance capability needed to keep a laboratory functioning effectively.

## 13.3 Emerging Views of Innovation

In the second part of this chapter we shall consider some elements of innovation policy that have been historically neglected but which have come to the fore in the current debate. Four observations can be made, that there is: a growing understanding of importance of demand side and user innovation; a recognition that innovation is not necessarily R&D based but can come from new configurations of existing technologies and from service, social and organisational innovation; an absorption of the open innovation idea into wider concept of an innovation ecosystem; and an emergence of the concept of broad-based innovation policy.

In this environment we can conceive of innovation policy measures as falling into four main categories: finance, systemic/networking, demand side and framework conditions. Policies involving finance are the longest established and are manifested in a variety of instruments including equity support, grants, loans and fiscal incentives. Systemic and networking policies include the provision of innovation services to improve the capability of firms to innovate but are mostly focused on the interfaces between firms and between firms and universities. The demand side is much less developed but is the area of most policy innovation at present. Approaches include the use of public procurement, of regulation and of standards to incentivise innovation. Possibly the least attention has been given to the framework conditions for innovation, not least because many of these policies, though important for innovation are created for other reasons. We shall examine them in more detail.

### *13.3.1 Framework Conditions for Innovation*

A recent study by the Manchester Institute for Innovation Research for NESTA (Allman et al. 2011) identified six key categories of framework conditions for innovation and explored how to measure them. They were: the public research base, talent, demand, the business environment and competition, entrepreneurship and finance, and infrastructure and services. Taking first the public research base, we have an explicit link to the first part of this chapter but a reminder that the requirement for high quality is increasingly matched with an expectation of socio-economic impact. Hence framework conditions also include the propensity and capabilities to work with firms or to commercialise ideas and intellectual property. Linked to this is a second aspect of framework conditions which can broadly be characterised as the talent available defined as the stock of accumulated experience, skills and abilities that people bring to bear on the production of an output. This is supported by the quality of training and education and the adaptability of the workforce.

We have already noted the existence of demand-side innovation policies but these need to be set in the wider context of demand conditions favourable to innovation. This includes the attitudes of consumers towards innovation. At firm level it is the degree to which firms are engaged with their customers before and during innovation. On the customer side this could be characterised as having a high absorptive capacity for innovation.

Turning to the wider business environment, innovation is significantly affected by the legal framework in which it is set, including the need for a secure and effective intellectual property system. Less easy to measure but equally important is the existence of the social capital and trust that will allow firms to work together in the complexities of innovation. A stable competition environment is needed but at the same time this should create an arena for innovation-based competition to enable creative destruction and creative accumulation. Particularly important for innovative start-ups are the entry and exit conditions for firms so as to allow churn and renewal.

Entrepreneurship conditions embody attitudes to risk and failure. They also imply good access to venture capital at all stages of innovation.

Turning to the infrastructure this can include the well-understood requirement for a well-functioning physical infrastructure in areas such as transport and utilities but the argument also extends to technological infrastructure. This can encompass testing, measurement and standards facilities, and the information infrastructure including broadband availability and speed.

### *13.3.2 The Need for Mobility*

Up to this point we have explored the static conditions that may facilitate innovation but a well functioning innovation ecosystem is based upon dynamics and in particular upon the mobility it exhibits. Four flows are key: for knowledge, people, finance and services.

Mobility of knowledge encapsulates the flows between actors in the innovation system. It links to the propensity to collaborate described above. The 'open innovation' label has been applied to a part of this process. Such access need not be confined to a region or nation – access to knowledge from other countries is also important.

Mobility of people concerns the dynamics of the innovation workforce. It includes the facility with which older people change jobs to reskill themselves. Within the domain of research it also concerns the normally low levels of science-industry mobility of established researchers. Such channels when they do occur are key vectors also for the mobility of knowledge.

Mobility of finance is about the speed and ease with which investment can be channelled into innovative ventures at any stage of their development. It applies equally to de-bureaucratising public finance and to the effectiveness and expertise level of a venture capital system.

Mobility of services completes the quartet, covering in part the activities of some of the infrastructure described in the section on framework conditions with a focus on associated services for innovation including incubators, science parks, digital connectivity, business support, access to equipment for testing etc.

### *13.3.3 Assembling the Ecosystem and Some Policy Failures*

With the institutional components we have described and the flows between them we have the basic functioning of an innovation ecosystem. It should in principle be possible to design policies which build on the relationships and flows that we have

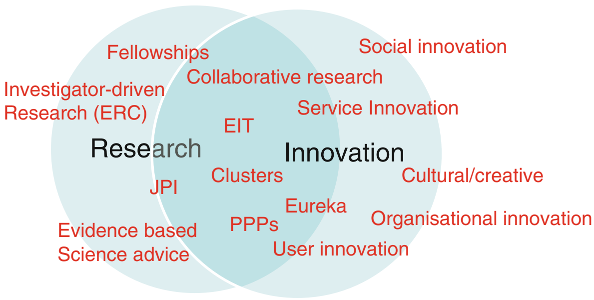


**Fig. 13.3** European policies and measures mapped against research and innovation domains

discussed. Unfortunately we find that it is often not the case – policymakers are more likely to take an element of the system in isolation with the result that they design inappropriate measures. For example there has been an increasing tendency to target small and medium-sized firms (SMEs) while neglecting the fact that well over 90 % of their business is with large firms. Schemes which work with supply chains are more useful than those which pull SMEs away from their markets. In the same vein there is a tendency to keep start-ups alive with successive research grants when they need investment and first customers – procurement based initiatives are far more likely to set them on the path to sustainability and growth as a business.

At a higher level of aggregation there is a tendency to forget that high tech is about technologies and not about sectors. As already noted priorities are usually under the headings of biotechnology etc. but the assumption is that the support will focus only on recognised high tech sectors – in practice advanced technologies may be applied in any sector and innovation is just as likely to found in say the food or construction sectors as in aerospace.

In this chapter we have treated research and innovation sequentially while emphasising the need for linkages where appropriate. However, there is a danger in the current policymaking setting that each will be defined by their overlap with the other while their independent aspects are downplayed. Figure 13.3 illustrates the issue by mapping European support measures and some areas of action onto the spaces occupied by research and innovation respectively. It suggests that more attention is given to the overlap in the Venn diagrams than into the distinctive features. Hence policy may neglect areas such as social innovation which are less clearly connected to research and on the other hand may focus on impact of research at the expense of less connected activities.

## 13.4 Conclusions

In the light of the pressures we have seen upon both the research and innovation systems to deliver, particularly on the socioeconomic agenda, we can reasonably ask the question of whether the governance arrangements that are in place are themselves fit for purpose in meeting these challenges. One fundamental dichotomy is that between coordination and integration (Blind and Georghiou 2010). In the past the cloak of coordination has been used to disguise the fact that joined-up or integrated approaches to research and innovation policies were of a superficial nature. They remained the domain of dedicated agencies and ministries. The engagement with wider socio-economic challenges has made this position untenable. Not only do the challenges fall squarely within the domain of sectoral ministries (often several at a time) but they also require connectivity horizontally across regions and nations and vertically through multiple levels of governance. While achieving these connections is beginning to be recognised as a legitimate policy, we still have no truly effective means of getting political buy-in beyond the rhetorical level to a broad-based innovation policy. It could be that the economic crisis in Europe creates an opportunity for the seismic levels of change in governance that may be required.

To overcome the resistance to a more horizontal and cross-cutting innovation policy, it will be necessary to bypass policy lock-ins and to involve more and other stakeholders, using better mechanisms than are presently employed. Present innovation policies are largely ineffective and could be set aside unless the supply side becomes re-energised by the employment of complementary demand-side approaches.

Governance remains a challenge in itself because the wide base of stakeholders militates against having a specialised ministry or agency that sectoral ministries may see as a rival encroaching upon their domains. It is important to avoid creating another innovation policy silo. A more immediate problem is that innovation policy is often perceived as a branch of research policy, or at least of technology policy. We have already noted the tendency to focus only on the intersection of the two and the risks which that entails.

Going more widely, we have argued for the importance of flows in the innovation ecosystem, with the latter term used advisedly to emphasise interdependencies. There is a strong tendency to focus on institutions when designing policies – hence a failure to transfer knowledge from universities to business in that thought mode must mean that universities need reform rather than that we should understand what incentivises and structures those flows of knowledge. Despite 23 years of talking about national systems of innovation we very rarely address systemic characteristics in policy design. Finally we have spent some time considering framework conditions. These are usually left out of the discussion because they are significant well beyond the domain of innovation and often under the control of governance structures in which innovation is not a prime consideration. For this reason, even though framework conditions potentially have far more influence than explicit policies, they remain harder to change than the supply of technology or the structure of the research system in the dimensions we have enumerated. At the very least there is a need for a concerted effort to improve internationally comparable measurement of these conditions and their relation to innovation performance.

## References

Allman K, Edler J, Georghiou L, Jones B, Miles I, Omidvar O, Ramlogan R, Rigby AJ (2011) Measuring wider framework conditions for successful innovation – a system's review of UK and international innovation data. NESTA, London

Blind K, Georghiou L (2010) Putting innovation at the centre of Europe-suggestions for a European innovation strategy. Intereconomics 45(5):264–286

Bonaccorsi A, Dairaio C (eds) (2007) Universities and strategic knowledge creation – specialisation and performance in Europe, PRIME series on European research policy. Edward Elgar, Cheltenham

European Science Foundation (ESF) (2010) Contribution to developing voluntary guidelines on framework conditions for joint programming in research – Foresight activities. ESF, 28 June 2010

Georghiou L, Cassingena Harper J (2011) From priority-setting to articulation of demand: Foresight for research and innovation policy and strategy. Futures 43(3):243–251, Special Issue: Future-oriented Technology Analysis

Georghiou et al (2008) Challenging Europe's Research: Rationales for the European Research Area (ERA), European Commission Directorate General Research EUR 23326 EN

Johnston R (1994) Effects of resource concentration on research performance. High Educ 28:25–37

von Tunzelmann N, Ranga M, Martin B, Geuna A (2003) The effects of size on research performance: a SPRU review, June 2003. http://www.sussex.ac.uk/spru/documents/geunaost.pdf

# Chapter 14
# Innovation Policy or Policy for Innovation? – In Search of the Optimal Solution for Policy Approach and Organisation

**Dirk Meissner, Vitaly Roud, and Mario Cervantes**

The contribution of innovation to improving societal welfare is without any doubt an important one. Over time, numerous concepts and policies have been developed and implemented all with the aim of building and maintaining the capabilities of market economies – to generate innovation. Although much work has been done to understand the process of how innovation – defined as a new product or a new process – is generated, the underlying motivations for entrepreneurs to seek to innovate has been neglected in the broader research.

Nevertheless from the perspective of policy making, the importance of innovation has been stressed over and over again that the term 'innovation policy' has become a fashionable expression often used by politicians and administrative bodies sometimes without properly delineating the role of government in the process. In some case references are made to improving the framework conditions which are conducive to innovation. But so long as no consideration is made of the underlying motivations of society to develop and accept innovations, policy actions are very likely to remain at interventions at the invention stage rather than the innovation hence ordinary people thus taxpayers will ask for justification of such activities. In practice, the decision to accept innovation is generally with the user and not with a government or similar body although user is not limited to private end user but understood in a broader scope as the 'innovation applying entity or individual'.

So the question is what should governments do about innovation? Should they care about it at all or simply sit back and wait of what comes from the market? Given the high social rates of return associated with innovation, governments have found justification for intervention due to the existence of market failures

D. Meissner (✉) • V. Roud
Institute for Statistical Studies and Economics of Knowledge, National Research University – Higher School of Economics (HSE), Myasnitskaya st., 20, 101000 Moscow, Russia
e-mail: dirk.meissner@gmail.com

M. Cervantes
OECD, Paris, France

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(e.g. spillovers that limit the appropriability of the returns from innovation) or so-called systems failures arising from weakness in innovation systems (e.g. low levels of collaboration between industry and universities). The market and systems failures have justified the development of innovation policies and related measures. The issue however is that although the term "innovation policy" is an often quoted as a way to support innovation there is little understanding of what constitutes an "innovation policy" beyond the stated goal of generating more innovations. Consequently the lack of understanding can be exploited by various actors in the government or the private sector. Any measure supporting innovation in any respect usually receives a warm welcome (Johansson et al. 2007). It often seems sufficient to use the terms "innovation" and "innovation policy" to generate awareness and acceptance. Announcements are certainly necessary, but at some stage action should follow announcement. So long as the term "innovation policy" is not clearly defined and communicated misuse and false expectations are likely to arise as seen in the proliferation of structures and programmes with vague aims of enhancing the rate of innovation.

In contrast a discourse around "policies for innovation" supported by the efficiency considerations encourages the shifts in policy design towards more concentrated and targeted initiatives. Traditional levels of regulation (see Table 14.1), such as particular institutions of national innovation systems (NIS) at the macro level (e.g. Public R&D, Private R&D, Technology markets, Higher Education and others), industries and specific sectors of economic activity, administrative regions, rely more and more heavily on the detailed understanding of existing practices. Limited resources for innovation policy call for the focusing attention on excellence-based approaches, such as supporting specific Technology platforms instead of broad sectoral interventions, or raising/incubation of regional clusters with rich externalities as opposed to pursuing average intensity of regional innovation (Laranja et al. 2008).

If one considers the aggregate country performance as the combination of diversified regions one must consider in detail the variance in regional strengths, weaknesses, competences and potential.

At the same time, large scale actor-based studies (e.g. firm-level or PRI-level surveys, analysis of bibliometric and patenting data on excellence and co-operation in the R&D sector, extended Foresight projects) demonstrate the heterogeneity of the innovation process even within particular sectors and regions. The data not only support the idea of the inefficiency of generic measures aimed towards sectoral/regional averages, but also provides new directions for improvement.

Observations on the particular components of the innovation process highlight the importance of targeted interface management and robust and manageable instruments (e.g. innovation vouchers). Identification of existing types of innovation actors within the NIS (e.g. distinguishing firms targeted at innovation through imitation as opposed to radical innovation development, enterprises that successfully co-operate with public research sector vs. in-house inventors) helps to decompose and reconstruct the actual demand for policy intervention.

Understanding the micro-level behaviour of NIS actors also leaves space for broadening the scope of innovation-related objectives from the sole economic

**Table 14.1** Approaches to policy targeting

| Level | Specialization type/ underlying concepts | Policy substance | Limitations |
|---|---|---|---|
| Macro | National innovation system | Increasing aggregate performance<br>Large scale sectors (Science, Business, Education, etc.) | Weak focus on the underlying mechanics<br>Prevailing concentration of framework conditions improvement as a contrast to specific practices and points of excellence<br>Blurred prioritization and unclear sequencing |
| Meso | Sectoral innovation systems | Support of innovation within specific sectors of economic activity | Focus on industrial sectors and lack of account for technology and business model shifts<br>Isolation of sectors |
| | Regional innovation systems: geographical proximity | Fostering regional innovation performance and development | Assumption that all the regions are innovative; unification of development strategies.<br>Poor linkages in both horizontal and vertical contexts |
| Micro-based | Technology platforms | Optimization of capital, technology and skills flows within identified networks of enterprises | Limited scale of effect<br>Bias towards high-tech sectors |
| | Cluster approaches | Optimizing strategic priorities and competence development<br>Linkage building | Questionable externalities |
| | Smart specialization of regions | Distinguishing regional competitive advantages | Excessive challenge of consensus development and the coordination of particular policies |
| | Functional approach to NIS performance | Identification of NIS bottle-necks based on understanding of its core functions | Theoretical model of NIS is still underdeveloped for strict formal application |
| | Behavior-specific policy instruments | Addressing the heterogeneity, support of specific types of behavior | Weak methodology for identification and evaluation of the essential groups of actors<br>Lack of methodology to link to other levels of analysis |

effects. There is an increasing tendency to expand the foci of policy instruments to increase social benefits at all levels. Thus, the trade-off between “Innovation for Business” and “Innovation for Society” is becoming more and more intense. In some cases, such as widely spreading programs for inclusive innovation, these trends evolve synergistically, providing business with new markets and enabling the participation of specific social groups. In others they struggle – e.g. making the whole topic of intellectual property on media/entertainment and other information-related activities highly debatable. Only the systematic analysis of the actual arrangement of interests of innovative actors within the economy and society, followed by the intelligent targeting can lead to fruitful shifts of the resulting socio-economic "equilibria".

But what does this all mean in reality and everyday life? It's well known that an innovation friendly environment requires more than policy initiatives that aim at research and development and the transfer of knowledge between industry and public research. Most policy initiatives and institutional set-ups in countries do not even allow a policy conducive to innovation since too many parties are involved and to many wishes and ambitions are expected. Besides R&D as a key driver of innovation, other relevant policy fields include migration policy, tax policy, education policy, regulations and standard settings, labor market, family and economic policy to name a few. In practicable terms all policy fields are affected to certain extent by policies supporting innovation. Thus innovation policy is a combination of different policy fields. It follows that by its nature innovation policy would require an appropriate political set-up eventually resulting in one political unit (e.g. ministry) which designs and co-ordinates all measures accordingly. Such a unit would be an outstandingly powerful institution which, in democratic and market based societies, would surely not be accepted by either politicians fearing to loose power, administrative bodies or by society. To overcome such fears some countries have established ministries for innovation or the like with the aim of supporting innovation at national level. However reality shows that such institutions are mainly responsible for research and development done in the public sector and industrial research, and not for innovation in the broad sense.

Also the issue arises about how to design framework conditions and in which regional context (Laranja et al. 2008). R&D and innovation especially is becoming ever more expensive. Assuming that R&D is one of the major drivers of at least radical innovation, the costs for research at early stages are exploding not only because of the costs certain science and research fields cause but because of the fact that so many different sciences hence research fields are interconnected today. That fact forces scientists, researchers and innovators to cooperate more between different fields. However it would be not rationale to assume that such cooperation is cooperation between fields of expertise which can be merged together into one without additional effort and cost. Practice shows that this is a cost intensive undertaking and moreover an undertaking which consumes a substantial amount of time (Lundvall and Borrás 2005).

That might be an effort to bring together very different policy arenas which are affected by innovation and more precisely R&D but it does by no means mirror the reality of how innovation growths. The ambition of pioneering nations is to bring the responsibilities for research, esp. publicly funded research with blue sky ambitions and the more applied oriented forms of research under one roof in one hand. The idea itself is certainly one which everybody will appreciate. But first of all innovation is something which results from more than research activities in any sense and secondly innovation does not stem from national efforts but is the results of entrepreneurs and actors in sub-national geographic regions which are in regular contact with other actors (i.e. suppliers, institutions, and consumers) in other regions (Doloreux and Parto 2005). Increasingly communication technologies, freedom to move and all different aspects of globalisation contribute to an effect which can be considered a "solve a problem" competing with the standard "let's solve a problem together as we know each other". ICT is the driver of co-operation between people from different places in virtual communities. We are only at the starting point of this . . . the last years can be considered the experimental phase whereby virtual collaborations emerged. Following this early people got used to this new form of interaction and technology progressed driving down the costs of virtual and networked collaboration further.

So what does this mean for the national and regional context of research and innovation? *Firstly* it needs to be remembered that efforts towards innovation are undertaken by entrepreneurs and not by societies or nations as a whole. Thus federal or national ministries will be limited in their ability to activate a process that in practice is driven by the regions. Thus innovation policy on national level is likely to remain on a more strategic level. What counts finally is not the naming of a policy field with the respective organisational setting behind but it's far more about the political concepts which will support a nation build of several regions to remain or become strong in innovation. A ministry or related public body which aims at innovation and all the relevant policy areas thus is likely to be an institution which is busy with internal procedures coordinating all relevant policy fields but not having special knowledge of any of the related areas any longer. It turns out that such will create artificial bodies with convincing aims and missions but no real power as the competences needed to design relevant policy measures are likely to be lost over coordination and negotiation procedures internally. Moreover such an institution will be faced with requests from numerous stakeholders and lobby groups especially. Why is this? It's because to design and implement an innovation policy it needs a body responsible and accountable for that.

*Secondly* simply defining a national innovation policy but not naming a responsible to implement such policy is probably a nice political game but certainly not effective and efficient. Thus the according infrastructure needs to be developed and set up. But that is contradictory to the idea of policy which is conducive to innovation, e.g. policy for innovation (Woolthuis et al. 2005). To be effective such a complex policy needs competences and special expertise from so many policy fields. Hence policy for innovation creates different requirements towards policy making and the co-ordination of individual policies.

*Thirdly* it's important to maintain and keep the balance between expertise and work in special fields relevant to innovation and negotiations/co-ordination procedures one the other hand. Policy for innovation thus should follow the overarching aim of supporting and making possible innovation on a national scale but not interfere actively in the design of single policy measures in different fields. Thus it seems appropriate to develop governance mechanisms (e.g. councils) that can represent different stakeholders and have oversight over different policy measures Good governance of innovation requires institutions with the competences to have a systemic views of the overall national system, including its linkages at international level. Such an institution should also have a strong co-ordinating role and bring together the stakeholders from industry, science, policy and administration. Such institution can be kept lean in resources terms but it needs to have decision rights rather than a pure consultative role. Many governance institutions exist in different countries which are either of scientific nature or industrial nature but governance institutions which combine more than the usual research and development policy related aspects are the exception rather than the rule (Kuhlmann 2001).

## 14.1 Consequences

Changing the thinking about innovation seems a logical consequence from increasing efforts by many nations but especially when considering the implications resulting from globalization on science and industry but likely even more important from new communication tools for society which allow the exchange of knowledge, experiences and ideas on a global scale real time. In addition as knowledge and technology remain on their path to become more complex and specialized at the same time it seems logic that work to generate knowledge and technology is shared not by disciplines but by locations increasingly. It is common knowledge that innovators need to and will continue to use competences and capacities. Such competences are likely to grow and prosper at locations which focus on designing policies for innovation rather than innovation policies.

The difference between the two is that innovation policy is more or less policy designed and implemented top down instead of reflecting the nature of innovation which was and still is bottom up. Here policy needs to respond accordingly. Such response does not mean financial support rather it asks for a broader understanding of framework conditions e.g. responding to changing societal developments, needs and requirements. Moreover it became evident recently that even products needed for daily life are increasingly offered and supplied by multinational companies which in turn make use of extensive networks of small and medium sized local suppliers along the value chain in the respective markets. That of course generates employment in certain stages of the value chain but the major share of revenues from such activity is likely to remain with one actor (e.g. MNC) although the physical value is generated but local SMEs (Thite et al. 2012). What counts for the final user (consumer) is the brand name the end-user consumes. National or regional policies aiming at supporting innovation are hence less visible in the respective regional or national context since the final product incorporating innovations is assembled and developed at any place in the world. Thus policy measures aiming at enhancing innovation need to consider economic policy measures increasingly among others. The final consequence is that innovation policy itself is not likely to create sustainable impact but policy for innovation requires a systemic view and respective responses in organization of policy making processes and institutional design. New approaches towards both are hence precondition for an economy to maintain sustainable economic comptetitiveness.

Hence innovation policy needs to respond to numerous challenges. In course of the still progressing globalization of industrial R&D and the tendenzy towards open science the ultimate question arises of how sustainable local factors are which determine the attractivness of innovation hubs for companies but also for public research insitutes and eventually for human resources. A common policy maker perception here is that an open research and science base expressed by the Knowledge and technology transfer (KTT) activities is advantageous for the innovation location. This has been an issue for long time in different fora including the policy arena (Gustafsson and Autio 2011). However given the widespread of KTT discussions and support measures in place along with changing incentive schemes for researchers in public institutions concerns arise that HEI and PRO might run the danger of losing ground in the generation of new knowledge which has more groundbreaking character versus the generation of maginal new knowledge which is more suitable for KTT by public institutions. In this light the academic freedom – which is recognized and applied in most insitutions – receives special attention. Curently a tendecy towards profesional management approaches of HEI and PROs is growing which is by definition rather contradictory to R&D management approaches used in industrial R&D. Although such managment approaches are forced and supported by policy makers in many countries there is no sound management concept theory thus far hence causing an urgent need for balanced management approaches for HEI and PRO considering the varied missions and visions of these institutions.

Countries often consider innovation related policy measures ‚one fits all solutions' for building and maintaining the economic strengths of disadvantaged regions. Numerous national innovation strategies developed and implemented by federal governments mirror this understanding. Still knowledge, technology and innovation are created a local or in some cases regional level hence the issue of the current governance of innovation system is in question with the major concern raised is innovation strategy an issue for a federal government at all (Edquist 2001).

It's widely recognized that education is a crucial precondition for knowledge, technology and innovation generation. Increasingly the outcomes from innovation activities are more complex solutions which in turn requier users education and training to an even larger extend. To support technology and innovation acceptance by society and industrial users governments are confronted with the questions, what role education but also further education play in the whole innovation landscape. Education of users is also in line with the fundamental question of the increasing speed of innovation diffuse and the willingness of societies to accept these developments and related changes at such speed. Moreover it can be assumed that the diffusion speed of innovation will continue to grow in the future since.

Finally governments strongly believe that public support to innovation funding is essential. In many cases this public support is justified by impact analysis' of respective public support programs. However determining the performance of industry in the absence of public support remains a challenge since industry typically claims that it would not have done so without the motivation of public support. Since such public support is available in all countries global firms will rationally seek to take advantage of these support programs globally. One might consider a global co-ordinated approach towards public support of industry in innovation-related issues as a solution but such a potential concept contradicts the principle of competition for investment in innovation activities by countries. Hence public support for industrial innovation activities currently plays a major role and will continue to do so.

This chapter has argued that innovation is covering and partially integrating many different fields; management fields at company level, governance fields in the public sector or eventually policy fields at different levels. In this respect the term ‚innovation policy' has become misleading. Instead, the policy discourse should consider the concept of ‚policy for innovation' as a more appropriate framework with the added benefit of recognising the heterogenity of the process of innovation and its dynamic and systemic nature. In this regard the established concept of national innovation systems needs to be expanded and developed further (Tödtling and Trippl 2005). Broadening the understanding of national innovation systems towards systems innovation includes different dimensions. One dimension is a clearer focus on the origin of innovation, e.g. regions and local innovation networks, another dimension is on the application of innovation by the eventual user and the value added generated. The traditional thinking of supply of input to generate innovation is expanded by the inclusion of the different innovation ecosystems which need to be developed with the help of policy measures or which emerge without policy interventions. Hence a new challenge arises for policy, the question is not how to intervene but if to intervene adding additional complexity to policy making and implementation. Regarding the latter, policy implementation, the overarching innovation governance systems need to be rethought, starting by policy making processes, policy intelligence and organizational setups in a country.

## References

Doloreux D, Parto S (2005) Regional innovation systems: current discourse and unresolved issues. Tech Soc 27:133–153

Edquist C (2001) The systems of innovation approach and innovation policy: an account of the state of the art. In: Lead paper presented at the DRUID conference, Aalborg, 12–15 June 2001, under theme F: ‘National Systems of Innovation, Institutions and Public Policies', Draft of 2001-06-01

Gustafsson R, Autio E (2011) A failure trichotomy in knowledge exploration and exploitation. Res Policy 40:819–831

Johansson B, Karlsson C, Backman M (2007) Innovation policy instruments, CESIS electronic working paper series, paper no.105, Dec 2007

Kuhlmann S (2001) Future governance of innovation policy in Europe – three scenarios. Res Policy 30:953–976

Laranja M, Uyarra E, Flanagan K (2008) Policies for science, technology and innovation: translating rationales into regional policies in a multi-level setting. Res Policy 37:823–835

Lundvall BA, Borrás S (2005) Science, technology and innovation policy. In: Fagerberg J, Mowery DC, Nelson RR (eds) Innovation handbook. Oxford University Press, Oxford, pp 599–631, Chapter 22

Thite M, Wilkinson A, Shah D (2012) Internationalization and HRM strategies across subsidiaries in multinational corporations from emerging economies – a conceptual framework. J World Bus 47:251–258

Tödtling F, Trippl M (2005) One size fits all? Towards a differentiated regional innovation policy approach. Res Policy 34(2005):1203–1219

Woolthuis RK, Lankhuizen M, Gilsing V (2005) A system failure framework for innovation policy design. Technovation 25:609–619

# Chapter 15
# Indicators for Science, Technology and Innovation on the Crossroad to Foresight

**Leonid Gokhberg**

## 15.1 Introduction

Science, technology and innovation (STI) related decision making has developed over the last decade to a more profound level which is in many cases and aspects based on solid data and information which is transformed into indicators. This development was first observed in company STI related decision making, and subsequently governments applied the indicator based approaches in the recent years towards evidence based policy making. However although the demand for robust STI indicators supporting more reliable and profound decision making which has significant impact on future development of companies and economies has risen, e.g. STI related indicators at the micro level of companies and the macro level of economies hence nations, major challenges to identify relevant indicators, provide feasible measurement tools for newly emerging phenomena, ensure indicators' comparability and compatibility as well as assure the quality of the underlying data still take its toll. Moreover the overarching challenge of more or less unclear path dependencies' of indicators puts serious pressures on the validity of indicators.

STI policy and related indicators aim at enabling and supporting the technological progress and development for enhancing and maintaining a nation's international competitiveness and wealth creation. For that purpose research (science) and innovation activities (technology) are regularly supported by public funds. STI policy aims at broad intellectual, social, cultural, environmental and economic impacts hence STI indicators are challenged to display the broad range of missions and expectations towards STI (Donovan 2007).

L. Gokhberg (✉)
Institute for Statistical Studies and Economics of Knowledge, National Research University - Higher School of Economics (HSE), Myasnitskaya st., 20, 101000 Moscow, Russia
e-mail: lgokhberg@hse.ru

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STI is one driver of constant change, and it still comes in different shapes. First of all, STI is expressed in the generation of codified but also of tacit knowledge which stems from either institution internal or external sources. Eventually the outcomes of STI related activities can either be embodied in capital goods and products or disembodied, i.e. included in patents, licenses, utility models or design, R&D activities, or embodied in skilled personnel (Archibugi and Pianta 1996).

Foresight is an established instrument of STI policy but also a tool for corporate strategic management which aims at developing scenarios of potential future development not only of STI at different levels but also in a broader context including societal developments among others. Therefore Foresight is by definition and nature strongly dependent on indicators which comprise information about current and potential future STI related developments. Thus STI indicators and Foresight indicators share numerous common features. Such commonalities are the adequacy of methodological concepts, the reliability of underlying data, the potential to aggregate indicators, and their robustness.

## 15.2 STI Indicators: A General Overview

STI indicators in many cases fulfill the commonly accepted purpose of monitoring institutions' regions' or countries' performance in science, technology and innovation. This implies an ongoing benchmarking or at least comparison of these actors in the STI dimension. Thus defining and interpreting indicators needs a clear and methodologically sound understanding of the processes underlying science, technology and innovation. STI indicators describe special characteristics of the overarching innovation processes (Kleinknecht et al. 2002; Godin 2004). STI indicators can in principle be classified as input, output, process or impact indicators and as lagging, leading and real time indicators considering the time dimension the indicators display. While input indicators like expenditure on research and development and the number of employees in R&D sectors and output indicators like the number of publications, citations or patents are broadly accepted and documented, process indicators referring to the evolution of scientific results, technologies and innovations are barely available (Scharnhorst and Wouters 2006). Impact indicators are even more seldom: given well-known difficulties to measure economic, social, cultural or environmental benefits of STI mostly indirect data have been provided such as percentages of enterprises experiencing certain effects of innovation activities, public attitudes toward STI, scientific literacy or CO2 emissions.

There is consensus that indicators employing economic data are not always adequate for foreseeing future trends in STI. Instead such indicators need to be considered against best practices combining relevant qualitative and quantitative indicators which are eventually of a broader social, environmental, cultural and economic public value (Donovan 2011). Hence the established indicators need to be revised respectively especially since these indicators are often used as

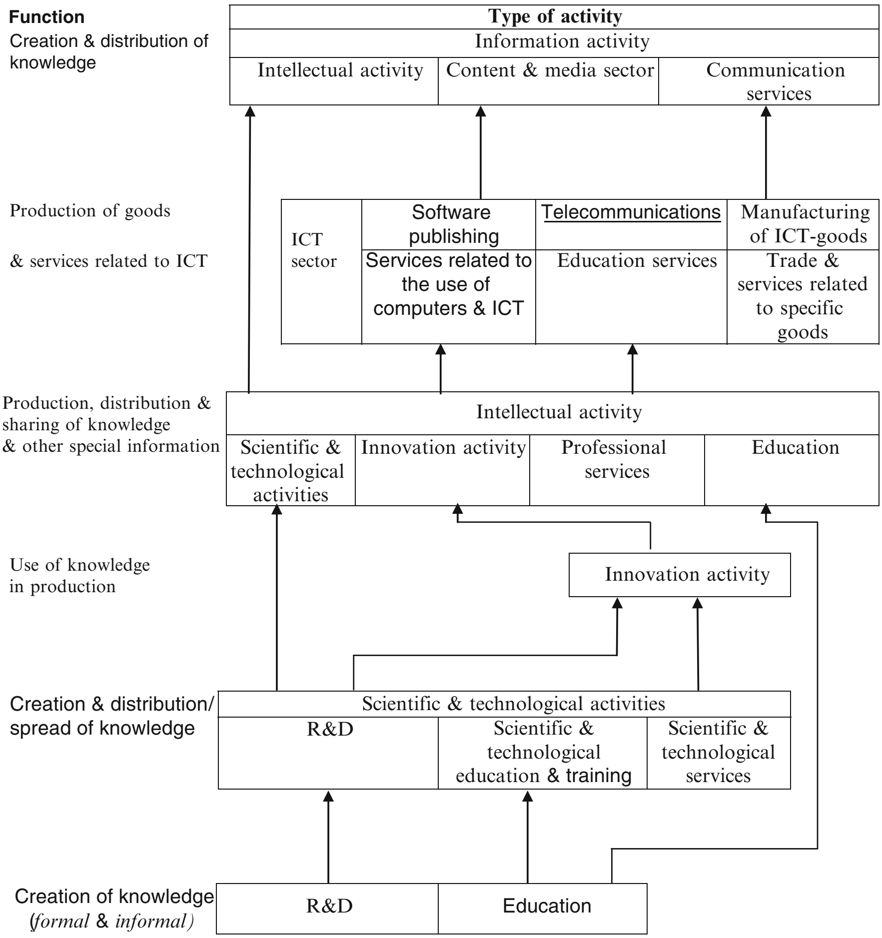


**Fig. 15.1** Classification of economic activities related to knowledge creation, distribution and use (Note. ICT – information and communication technologies) (Source: Gokhberg 2000, 2003, 2012; Gokhberg and Boegh-Nielsen 2007)

'strategic weapons' for evidence-based governments and research funders policy making and implementation, e.g. for the enhancement of financial support. Still indicators are confronted with the challenge to consider the diverging characteristics of all research fields (including the humanities, social sciences, and creative arts) and technology areas (for example, ICT, bio- and nanotechnology) in their own terms.

In general STI indicators are challenged to reflect a broad range of activities related to the creation, distribution and use of knowledge (Fig. 15.1).

Since indicators are used for decision making the quality of indicators eventually strongly determines the validity of the subsequent decisions, namely decisions of long term and strategic nature with a significant and lasting impact. However indicators are confronted with numerous challenges:

- Firstly, there is a serious threat to STI indicators which stems from the unclear definition of the term ‘technology’. In common practice ‘technology’ is understood as a result of creative work which can be based on codified knowledge or implicit tacit knowledge. This creative work spans the combination and reconfiguration of existing knowledge and technical solutions as well as the development of fully new knowledge by different means. Hence the term technology itself has different meanings in different science fields but also in different application fields, e.g. industrial sectors. Thus indicators measuring the technology intensity of industries but also science fields need to account for these differences (Freeman and Soete 2009). In this regard the challenge for designing indicators and collecting data for measuring technology is to distinguish between the different essentials of technology which are not limited to the configuration and composition of technical and knowledge bits and pieces into a new full solution but involves also the process of searching for existing knowledge, building and maintaining absorptive capacity and conversion of the technology into broad application. Here the problem is not only the indicator definition but rather the data collection since data required to describe these tasks and stages of technology components are usually not available.
- Secondly, indicators addressing innovation are sometimes incomplete and even misleading. Related currently available indicators focus primarily on input and output measurements, namely expenditures on R&D and other innovation activities (input), share of new products, process improvements, patents etc (output). However innovation processes also include a broad range of managerial, marketing and commercial activities before the start of innovation projects, complementary to innovation projects, at the stage of market introduction and after sales activities. Such activities however are not properly covered by innovation statistics although they account for a significant share of costs allied to innovation.
- Thirdly, standardised STI indicators barely take account of national and regional circumstances and characteristics. There is longstanding academic and political but also societal discussion about the appropriateness of STI investment. With the exemption of the European Union which articulated the 3 % target (GERD/GDP) under its Lisbon agenda very few countries have made such explicit statement. The reasons are that there is so far no direct evidence of the societal and economic impact of STI investment overall and investment indicators hardly reflect the industrial structure of the economies, e.g. there is a tendency towards misinterpretations if cross national comparisons are made using STI indicators only but not considering the underlying industrial structure and special characteristics of the different economies.

With the emergence of the “evidence-based” policy concept policy evaluation in many different shapes gained ground (Pawson 2002). Accordingly policy making is increasingly based on ex-post and ex-ante (often referred to as ‘backwards looking’ and ‘forward looking’) evaluation. While ex-post evaluation aims at finding evidence for the impact generated by a respective policy measure, ex-ante evaluation is

**Table 15.1** Types of statistical units in science and innovation analysis

| Kind of activity | Statistical unit | Accounting unit |
|---|---|---|
| Research and development: | | |
| Performance | Organisations carrying out R&D | Organisations |
| Financing/funding | Departments (and agencies) providing funding | Departments (agencies) |
| | Government programmes | Departments (agencies) |
| Condition of scientific equipment | Organisations carrying out R&D | Organisations |
| Socio-economic status of researchers | Researchers/ Academic community | Organisations |
| Creation and diffusion of technologies: | | |
| Patent activity | Inventions, utility models, industrial designs | National offices for intellectual property |
| Development of advanced technologies | Organisations developing advanced technologies | Organisations |
| Production of ICT-related goods and services | ICT sector enterprises | Organisations |
| Use of advanced technologies (industrial, energy, ICT, bio, nano etc.) | Enterprises that use advanced technologies | Organisations |
| Technology exports and imports | Enterprises engaged into agreements for technology exchange with foreign countries | Organisations |
| Innovation activity | Enterprises manufacturing goods and services | Organisations |

Source: Gokhberg 2003

more targeted towards potential impact assessment of measures. The latter one is not so commonly widespread in policy making yet since it is an assessment of potential impacts which are still highly uncertain but evidence-based policy more or less considers learning from experience. Collection of data and their systemic and structured composition and aggregation into relevant, feasible, valid and robust indicators remain unmet challenges for many aspects of science, technology and innovation policy. This challenge is reasoned by the complexity STI indicators are expected to describe. The indicators have to take account of the STI activities which are performed by different bodies and institutions. These activities vary in nature including research and development, creation and diffusion of technologies and innovation activities. In course of measuring these activities the statistical units and the accounting units are not necessarily equal as shown in Table 15.1. Consequently a special challenge arises for data collection methods and eventually for indicator composition. Different methodologies are in many cases applied for collecting data, e.g. standardized questionnaires, semi structured interview guidelines and open interviews in some cases each depending on the characteristics, e.g. the nature, of the activity described. R&D related data are mostly financial data expressed in monetary values with the exception of the socio-economic status of researchers. The latter is measured in terms of hierarchical status and position of researchers. Although this seems a solid information base one has to take into account that such status is assigned depending on country and also institution specific criteria, e.g. status expressions are comparable in semantic terms but not necessarily in terms of duties and obligations related to the socio-economic status of researchers. Hence these data are of indicative nature rather than quantitative. Data describing the creation and diffusion of technologies are also mixed data, hence including quantitative and qualitative data. Patent activities and the technology exports and imports are quantitative data whereas the development of advanced technologies production of ICT-related goods and services and the use of advanced technologies (industrial, energy, ICT, bio, nano etc.) are semi quantitative data. Innovation activities are typically measured with quantitative and qualitative data. Usually questionnaires are used containing questions which aim at an assessment of the share of new products and services among many others. Such data are not systematically collected in organizations or due to the often vague nature of innovation rather difficult to provide.

STI indicators can be used for a broad range of applications. These applications include indicators to measure the STI related input, e.g. for comparative STI investment analysis and supply side analysis of research and engineering staff; or STI related output, e.g. technology specialization, the intellectual property position, the global science competitive position and the country innovation performance. Other indicators are used and suitable to describe the status of the knowledge economy development or used for classification of the economy development stage (Table 15.2). Each indicator shows numerous potentials for application but also limitations. In example patent statistics are easy to analyse and are in principle comparable across different patent databases but the underlying motivation and strategies of patent holders are not documented and known. This becomes ever more crucial when analyzing patent statistics. The major weakness of these statistics is the unknown range of application fields protected by a patent, e.g. the broadness of protection expressed in the respective claims. Also it's common knowledge the a significant share of patents are filed for strategic reasons hence the purpose of blocking competitors etc. but not necessarily used actively. Although each indicator shows certain limitations they are suitable to compare different regional and/or national innovation systems.

The majority of STI indicators are of ex post nature, e.g. describing systems and institutions at a given point in time which does not necessarily reflect the current status.

**Table 15.2** STI indicators – application, advantages and limitations

| Type | Indicator | Application | Advantages | Limitations | Level of analysis | Availability | Longitudinal studies |
|---|---|---|---|---|---|---|---|
| **Input** | R&D expenditure | Comparative STI investment analysis | Standardized measuring<br>Terminology established and commonly accepted | Difficulties in counting R&D expenditure at company level and at level of PPP | Country<br>Region[a] | Broad | possible |
| | Research staff | Supply side analysis of research and engineering staff | Indicative assessment of human resources supply possible | Terminology lacking, e.g. some statistics show Full Time Equivalents(FTE) others show headcounts (HC) | Country | Broad (for FTE level) | possible |
| | | | Complements R&D expenditure statistics | Expressed in persons but not in financial terms, raises difficulties for path dependency analysis<br>Quality of staff is not measured | Region[a] | | |
| **Input/ output** | Tertiary graduates | Input indicator for knowledge economy / economy development stage classification | Comparative analysis of national education sector performance | Overall demand and need for tertiary graduates remains vague and unclear | Country | Broad (subject field specific) | possible |
| | | | | In some cases leads to policy measures to increase number of graduates without solid evidence for related skills and competences demand | Region[a] | | |

(continued)

**Table 15.2** (continued)

| Type | Indicator | Application | Advantages | Limitations | Level of analysis | Availability | Longitudinal studies |
|---|---|---|---|---|---|---|---|
| **Output** | Patents | Technology specialization | Broad coverage | Patent statistics do not necessarily show the inventive power of nations | Country | Broad (IPC class specific) | possible |
| | | Intellectual property positions | Standardized databases | Patent behavior of companies is not reflected | | | |
| | | | Comparability of national statistics possible | No correlation between innovation and patent, e.g. patent does not necessarily equal innovation | | | |
| | trademarks | Intellectual property positions | Comparability between countries possible | Assignees /Trademark/ holders protection strategy is unknown | Country | Broad (goods and services class specific) | possible |
| | | | | Trademarks are a relatively new mechanisms in many countries, used for one or 2 decades only – statistics | | | |
| | Publications | Global science competitive position | Broad coverage of peer reviewed publications | Publication behavior varies between institutions and individuals | Country | Broad (subject and field specific) | possible |
| | | | Comparative analysis of countries is possible | Scientists outside established networks face serious challenges entering publication networks (emerging countries) | | | |
| | | | | Publications are one output of science and research only | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Citations | Competitive Science position | Gives indication of the relative position of a country's science base in the world science community | Journal editors often require authors to include references from other papers in the journal they edit on even the reference are not necessarily needed<br>Peer review process in many cases implies to reference leading scholars without need to market own research | Country | Broad(subject and field specific) | possible |
| High tech exports | Country innovation performance | Gives an indication of country's position in global value chain | Neglects industrial structure of countries, export orientation and size of internal market<br>High tech is often assumed future industries but underlying industries (agriculture, raw materials) are not considered | Country | Broad (NACE specific) | possible |

[a]Regional analysis is possible in most countries if data are used from national statistics offices, international organizations in most cases publish only aggregate country level data

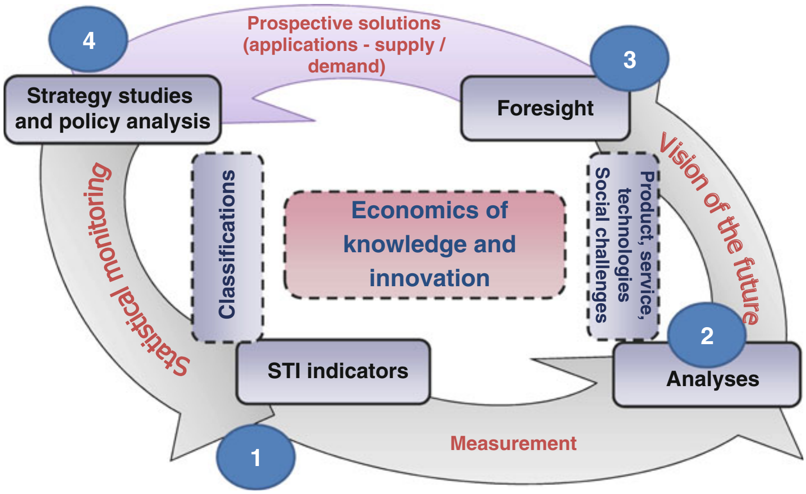


**Fig. 15.2** Indicators – Analysis – Foresight – Strategy – Model (IAFS)

## 15.3 Application of Major STI Indicators in Foresight

Foresight studies are by purpose and nature ex ante oriented studies. As shown STI indicators are mainly of descriptive ex post nature thus at first sight STI indicators do not have much in common with Foresight. However a deeper look into the nature of Foresight reveals that these studies do not consider potential future developments only but take into account the potential and capabilities of the current national and also international STI system to cope with the challenges which inherent in the potential future developments.

A closer look at Foresight and STI indicators reveals that indeed STI indicators appear to be a significant input for Foresight. STI indicators are frequently used in Foresight for SWOT analysis and competitive position analysis. Moreover analysis's of countries, regions or companies are based on STI indicators and often the initiating momentum for Foresight. Foresight in turn results in prospective scenarios which require roadmaps and related strategic responses from decision makers hence strategy studies and policy analysis build on Foresight. These analysis' requires more sophisticated and up to date indicators, namely STI indicators. Eventually a model (**IAFS**) can be constructed which includes four major elements (Fig. 15.2).

1. STI **I**ndicators;
2. **A**nalysis based on STI indicators;
3. **F**oresight based on analysis;
4. **S**trategy studies and policy analysis based on Foresight.

### 15.3.1 STI Indicators

There is a broad range of STI indicators available. With regard to Foresight these indicators can be grouped into the following:

- Analysis of linkages between actors in the National Innovation Systems (NIS)
- Technology specialization – Intellectual Property and Publication analysis
  - Trademarks
  - Patents
  - Publications
- Network analysis
- Sustainability assessment
- Globalization of NIS

(a) Linkages in the NIS

The analysis of linkages between actors in the NIS provides a first impression and overview of the boundaries of science and innovation raising the challenge of the positioning of public research in the innovation value chain, its contribution to short term STI objectives and indications for the resulting capabilities of the national STI system to meet upcoming challenges from a systemic point of view.

Linkages between the actors in NIS are either horizontal or vertical. Horizontal linkages are linkages between actors at the same or similar, e.g. comparable, stage of the innovation value chain while vertical linkages express linkages between different stages of the value chain. In STI terms such linkages are mainly analyzed in research related context hence the linkages between the research communities and the industrial community. Such linkages are especially expected to be of high relevance in countries with a high share of public expenditure on research and especially an industrial structure which is mainly characterized by low- to medium tech industry. An example for such a country is Italy where the government's expenditure on research exceeds the industrial expenditure and the industrial structure is dominated by low to medium tech and a high number of micro- and small enterprises (Abramo et al. 2009). These characteristics need to be taken into account while designing and more important interpreting indicators describing the linkages between the research and the industrial community (Dlouhá et al. 2012).

To define STI indicators for measuring industry-science linkages one has to consider the major outcomes and impacts from science. These are mainly the generation of new scientific information, education and training of skilled graduates, support and enrichment of scientific networks and stimulating interaction; expansion of the capacity for problem-solving (absorptive capacity mainly); design and production of new instrumentation and application of new methodologies and techniques; creation of new firms; and provision of social knowledge (Butcher and Jeffrey 2005). Given this background typical indicators measuring these linkages are:

- Number of university articles in co-authorship with private researchers
- Number and volume of contract research
- Number and size of cooperative research projects
- Joint patents (joint inventorship)
- Industry related training and education courses
- Public service sector related training and education courses
- Spin offs from institutions
- Number and size of joint publicly funded research projects
- External graduate thesis (post graduate level)
- Consulting and advisory services by scientists to public sector and industry

However these indicators can only be interpreted in the light of the overall missions and tasks of the public institutes.

(b) Technology specialization

Technology specialization of countries is measured by an indicator set which is based mainly on intellectual property related information providing a solid base for trend analysis with potentially mid-term impact, e.g. displaying major activities in science and technology fields which are likely to be turned into innovation and remain in markets and application for a certain time. In addition trademark statistics analysis have the potential to display very recent structural changes in industrial activities, namely in the structure of gods and services in demand but also in preferences of society expressed in the choice of words and pictures for trademarks.

Intellectual Property Rights (IPR) are established in the industrial context mainly and the scientific/research community context for long time. Analysis of Intellectual Property (IP) statistics, namely patent and trademark statistics, is considered a suitable means towards the gathering of knowledge and capabilities (Freeman 1982; Hidalgo and Gabaly 2012; Pavitt 1988; Dosi 1988). Using a time series of patent and trademark data Hidalgo and Gabaly find that these data provide a tool for predicting the potential development of patent and trademark application in the future, e.g. predicting trends of application developments (Hidalgo and Gabaly 2012).

The two major forms of IPR are patents and trademarks being the most frequently and effectively used legal tools to protect the results of intellectual work. Patents and trademarks provide the owner a monopoly to use an invention for clearly specified and defined purposes, offer goods and services under a chosen name or logo or a combination of that in case of trademarks, while publications mainly serve the aim of diffusion knowledge at marginal or zero cost. However still publications are protected by means that the generator/producer of knowledge has to be named and mentioned. All three intellectual property types share the common feature that it is in the sole responsibility of the originator/owner to monitor potential infringements of his rights and take countermeasures to protect the intellectual property. While publications, namely scientific publications, describe inventions without clearly specifying applications, patents are clearly focused at applications of technologies, e.g. inventions. Trademarks on the other hand do not necessarily refer to inventions or technologies but have a strong application focus of goods and services regardless the technological and inventive content of the good or services labeled under a trademark.

#### 15.3.1.1 Trademarks

Trademarks in principle play one major role which is to protect the delivery of a product from a provider to a customer. The protection is for the provider of the product which gives him a unique position to be recognized by the customer. The product in questions protected by a trademark can take many forms including services which are not tangible products as well. In this respect trademark based indicators do have a potential to deliver more indicative impressions about ongoing changes in economies. However the pure analysis of the number of trademarks does not allow a reasonable solid interpretation of the innovativeness and creativity of a country’s trademark holder/owner. Moreover it’s reasonable to analyze the fields selected by trademark corresponding to the goods and services classification. Trademark statistics give an indication of the development of especially service based innovation as measured by the number of trademarks. In general trademarks can be considered an indicator providing indication of the use of marketing related instruments not only for innovation but for general purposes.

At more detailed level, namely the analysis of goods and services in clearly described goods and service classes relating more clearly to STI, conclusion of more indicative nature can be drawn for the importance of STI related activities of a country. These more STI related goods and services classes are especially Class 38 Telecommunications, Class 40 Treatment of materials, Class 41 Education; providing of training; entertainment; sporting and cultural activities and Class 42 Scientific and technological services and research and design relating thereto; industrial analysis and research services; design and development of computer hardware and software (WIPO 2011). Recent statistics of Community Trademarks show a significant share of STI related trademarks (CTM) in the respective service classes (Table 15.3). In the overall statistics of CTM these services achieve surprisingly high ranks which can be interpreted as an indication of the importance of STI related service businesses. However since the service classes are still rather broadly defined it remains an indicator of indicative nature only lacking solid and profound calculation basis. As for comparative analysis of countries such analysis needs to be expanded by country specific analysis.

Mendonça et al. (2004) conclude that trademarks are a suitable indicator for measuring product innovation and sectoral change given the basic nature of trademarks as one instrument to differentiate products in the market. In addition trademarks reflect cultural and societal changes in a sense that trademarks as ‘word marks’ but also as ‘picture marks’ mirror at least to some extend the changing preferences and attitudes of society. Hence trademarks combine quantitative and qualitative information in one indicator. Eventually indicators based on trademarks give indications of the rates and directions of product innovations in different

**Table 15.3** STI related service trademarks (Community trademarks)

| 1996–2011 | | | | | 2012 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| rank | class | number | % of total trademarks | | rank | class | number | % of total trademarks | |
| 8 | 38 | 69,046 | 3.22 | 16,48 | 8 | 38 | 5,537 | 3.01 | |
| 17 | 39 | 48,743 | 2.28 | | 18 | 39 | 3,790 | 2.06 | |
| 34 | 40 | 23,073 | 1.08 | | 32 | 40 | 2,302 | 1.25 | |
| 5 | 41 | 113,438 | 5.3 | | 4 | 41 | 10,977 | 5.96 | |
| 3 | 42 | 147,216 | 6.88 | | 3 | 42 | 11,486 | 6.24 | 16.46 |

Source: OHIM 2012
Note: Data for 2012 are preliminary

industrial sectors, international patterns of specialisation, links between technological and marketing activities and the evolution of economic organizations and structures (Mendonça et al. 2004).

However trademark based indicators can be used complementary to other STI indicators, especially patent based indicators for testing the evidence found.

The index of trademark revealed comparative advantage (TRCA) provides an indication of the country's capacity introducing and marketing innovative goods and services which are protected by trademark hence statistics analysis. It is a ratio of goods and service class $i$'s share in country $j$'s total trademarks to goods and service class $i$'s share in the world: $TRCA$. $TRCA = \frac{trademarksij / \sum_i trademarksij}{\sum_j trademarksij / \sum \sum_j trademarksij}$ where $i$ denotes the sector, $j$ is the country, $i = 1, 2, \ldots, I$, and $j = 1, 2, \ldots, J$. Alternatively, it can also be expressed as a ratio of country $j$'s share of trademarks in goods and service class $i$, to country $j$'s share of total trademarks (across $I$ sectors) in the world (across $I$ sectors and $J$ countries):

For a given class $i$, a value of this index greater than one indicates that the country $j$ has a comparative advantage in that class (Yusuf and Nabeshima 2009). The analysis shows that countries show clearly different specialization profiles with the exemption of scientific, nautical, surveying, electric, photographic, cinematographic, optical weighing etc. which is a strength of Korea, Japan and the US while vehicles; apparatus for locomotion by land air or water are specialization features of China, Korea and Japan. The trademark statistics analysis nit surprisingly mirrors the underlying industrial structure of these countries (Table 15.4).

#### 15.3.1.2 Patents

Patent statistics together with innovation surveys are considered reasonable information sources to measure innovative activities of commercial entities, namely companies (Archibugi and Pianta 1996). However more recently research entities, namely Higher Education Institutes and Public Research Institutes, are becoming more active in patenting inventions for the purpose of commercialization of such.

**Table 15.4** Top five sectors of trademark specialization, OHIM filings 2000–2007

| | China | India | Korea | Japan | US | Euro6 |
|---|---|---|---|---|---|---|
| Agricultural, horticultural and forestry products | | | | | | 1.2 |
| Apparatus for lighting, heating, etc. | | | 3.3 | | | |
| Beers; mineral and aerated waters | 2.5 | | | | | |
| Building materials(non-metallic) | | | | | | 1.2 |
| Chemicals used in industry, science and photography | | | | | 1.4 | |
| Firearms; ammunition and projectiles; explosives; fireworks | | | | | 1.3 | |
| Furniture, mirrors picture frames goods(not included in other classes) of wood | 2.3 | | | | | |
| Lace and embroidery, ribbons and braid | 2.3 | | | 3.0 | | |
| Leather and imitations of leather | 2.4 | 2.5 | | | | |
| Machines and machine tools; motors and engines (except for land vehicles) | | | 2.8 | | | |
| Musical instruments | 3.1 | | | 4.9 | | |
| Pharmaceutical, veterinary and sanitary preparations | | | | | 1.4 | |
| Precious metals and their alloys and goods in precious metals or coated therewith | 3.0 | | | | | |
| Preserved, dried cooked and fruits and vegetables; | | | | | | 1.2 |
| Scientific, nautical, surveying, electric, photographic, cinematographic, optical weighing etc. | | | 3.4 | 2.4 | 1.5 | |
| Surgical, medical, dental and veterinary apparatus and instruments | | | | | 2.1 | |
| Textiles and textile goods | 3.2 | | | | | |
| Tobacco; smokers' articles matches | | 5.2 | | | | |
| Transport; packaging and storage of goods | | | 2.2 | | | 1.2 |
| Vehicles; apparatus for locomotion by land air or water | 3.2 | | 3.6 | 3.6 | | |
| Yarns and threads, for textile use | | | | 2.2 | | 1.2 |

Source: data taken from Godinho and Ferreira (2012), p. 508; values in table indicate TRCA

Hence patent statistics provide additional information with regard to the inventiveness and application orientation of these institutions.

One frequently used indicator to measure knowledge and technology specialization of countries is the Revealed Technological Advantage' index (RTA). RTA expresses the technological advantages of countries and firms in technology fields expressed and captured by patent classes (IPC). The RTA allows for the measurement of the level of country (or firm) patenting activity in particular technology fields and especially for international comparison. However the analysis is only possible for countries with a large number of patents (primarily developed countries) since analyzing a small number of patents in a country leads to a distorted picture of country's advantages. Especially taking into account the time dimension such analysis gives valuable insights in the changing importance of technology fields.

Godinho and Ferreira show remarkable results in their analysis of PCT applications, applications to EPO, JPO and USPTO the dynamics of Chinese and Indian patenting activities (Godinho and Ferreira 2012). In their analysis it becomes evident that China and India can be expected to catch up with leading patenting nations, namely the US as the recognized most patent active economy. China is likely to catch up in terms of PCT patents as early as in 6 years time, India in 13 years time. For achieving similar patent numbers at EPO it will take China another 20 years (India 30), USPTO 30 years for China (26 India) and JPO 27 (China) and 33 (India). Such analysis however rests on the assumption that patent applications and grants develop along the trend identified over the last 15–20 years. Moreover it presumes that there are no major changes and adaptions in national and international patent rules and laws.

It can be concluded that China and India do not exclusively follow national patenting strategies but are increasingly engaged in international patent operations. The first indicator for this finding is the rather short period for these countries to catch up with PCT applications, which in themselves are no patents but the entry gate to international patent applications and filings.

#### 15.3.1.3 Scientific Publications

Wagner and Leydesdorff find that research funds, namely public research funds, are increasingly allocated using publication indicators of institutions as one (although not the only one but still an important one). Moreover at the individual level researchers and scientist employed in public institutions are promoted and tenure decisions made using indicators and impact factors based on citations to published work. These indicators are often object of controversial discussions between scientists and institutes but also at the funding allocation level. The Integrated Impact Indicator (*I3*) is an indicator recently developed weighting highly cited papers more than less-cited ones, allowing the unbundling of venues (i.e. journals or databases) at the article level and the re-aggregation in terms of units of evaluation Wagner and Leydesdorff (2012). The I3 indicator shows that the importance of journals might vary. It can be demonstrated that for example the Proceedings of the National Academy of Science, USA rank top according to I3 whereas they rank 3 according to the 2009 impact factor. Hence the ranks of Nature and Science are changing too against the Proceedings of the National Academy of Science (Table 15.5). The practical implications of such changes in rankings are obvious. Institutions and individuals will be tempted to publish their work in the highest ranking journals to benefit from budget allocations which in turn are decided upon depending on the publications journals' rankings.

Regardless the journal publication statistics allow an aggregate view on the specialization of countries. However such statistics might provide an initial view and understanding of the potential specialization of countries measured by comparison of the countries' major areas of activity and the world total publications in all fields and in individual science fields. However although this analysis might give an indication it's noteworthy to bear in mind that the publication behavior varies between the science fields and regions. The comparison of the world publications published by ISI Thomson Reuters shows the overall dominance of the natural

**Table 15.5** Differences in the ranking of science fields in world publications and Russian publications

| | Difference in ranks between world publications and Russian publications | | |
|---|---|---|---|
| Field (ESI) | Rank papers total | Rank papers share of total publications | Rank citations |
| Agricultural sciences | 1 | 17 | 1 |
| Biology & biochemistry | 2 | 4 | −1 |
| Chemistry | 0 | 2 | 13 |
| Clinical medicine | 6 | 5 | 9 |
| Computer science | 0 | 18 | 1 |
| Economics & business | 3 | 21 | −5 |
| Engineering | −1 | 7 | 9 |
| Environment/ecology | 2 | 13 | 1 |
| Geosciences | −6 | 3 | 1 |
| Immunology | −1 | 15 | −13 |
| Materials science | −3 | 8 | 8 |
| Mathematics | −7 | 12 | −1 |
| Microbiology | −7 | 11 | −6 |
| Molecular biology & genetics | −1 | 9 | −1 |
| Multidisciplinary | 0 | 22 | −19 |
| Neuroscience & behavior | 7 | 14 | 0 |
| Pharmacology & toxicology | 2 | 16 | −6 |
| Physics | −2 | 1 | 4 |
| Plant & animal science | 5 | 10 | 5 |
| Psychiatry/psychology | 3 | 20 | 6 |
| Social sciences, general | 8 | 19 | 6 |
| Space science | −11 | 6 | −12 |

Source: own calculations based on Source: ESI Thomson Reuters, http://esi.webofknowledge.com/fieldrankingspage.cgi; http://esi.webofknowledge.com/allmenus.cgi?option=C, Data January 1, 2002-June 30, 2012 (accessed 12.09.2012)

Note: Differences read as rank of science field in the Russian production of publications minus rank of science field in the total world production of publications by the respective science field. Positive values indicate that in the world comparison the science field is more important in Russia than in global terms, negative values indicate that the science fields is more important in the world than in Russia.

('hard') sciences, physics, chemistry and biology . The comparison of the meaning of the science fields in the global context as measured by the number and share of publications globally and in Russia especially reveals that selected science fields are in comparison significantly less important in Russia in terms of output than in the world but more important in terms of the citations of these papers (Table 15.5).

This observation can be made for chemistry, engineering, geosciences, material sciences and physics. It leads to the conclusion that although there are not as many publications in the science field in Russia (measured by the share of total publications) the number of citations of these paper is relatively higher in Russia than in the world average. This gives a first indication towards formulating hypothesis's regarding activities and composition of respective scientific communities and networks globally and in the countries, here Russia, especially. Hence one could conclude that there is either a relatively small or a relatively weak scientific community in the country which in turn is closely connected and uses citations more frequently than other national communities in the world. Simultaneously one could argue that the quality of the fewer publications of this national scientific community is higher than elsewhere thus members of this scientific community cite publications more frequently. A similar analysis can be done the other way around, e.g. in pharmacology and toxicology and economics and business Russia has slightly more publications in relative terms than the global community but citations are clearly less frequent. Immunology and multidisciplinary are two science fields which are almost similar in ranking of global and Russian total number of publications but which are characterized by a significantly lower number of citations of Russia publications than on the global level.

Braun and Dióspatonyi (2005) find evidence that the number of publications of a country or region is influenced by the membership of regional scientist in scientific journals editorial boards (Braun and Dióspatonyi 2005). Given that the sole number of publications might give an indication of scientists activities especially when analyzing time series of publications of 10 or more years. However comparison between countries is likely to be biased when comparisons' of countries' scientific performance is based on publications statistics.

(c) Network analysis

*Networks* appear in many different forms in the NIS. With the explosion of knowledge and especially growing number of highly specialized analysis science and technology fields in line with the increasing importance of platform technologies and presumably platform science fields in the future networks become evidently more important for the exchange of (mainly tacit) knowledge but also for leveraging the inherent knowledge potentials. Networks clearly are at the crossroad of Foresight and STI policy providing especially competences and capacities for information collection and processing which is essential for Foresight studies. Moreover networks, namely in the shape of technology platforms, have the potential to function as a hub for STI information and data collection but also for implementation of STI measures based on these information given their outreach and the assumed commitment of participants towards joint visions and goals in selected fields which in turn indicates the willingness to accept forward looking change.

Networks come in many different shapes. In some cases networks are informal loose connections of different actors with in some cases diverging agendas used and more occasional joint activities. The other extreme are networks initiated by third parties equipped with professional organization, joint visions and missions and professional management which supports in many different ways. Networks, especially technology platforms as one type of networks can be characterized as shown in Table 15.6.

Consequently networks play several roles in STI. Among the most prominent and important roles of networks is their significant potential to serve as a reliable information base for the development of targeted next generation of STI policy

**Table 15.6** Characteristics of technology platforms as one type of networks

| | Feature | Characteristic | | |
|---|---|---|---|---|
| Policy priority characteristics | Meet the national (supranational) STI priorities | Short term | Mid term | Long term |
| | Meet national (supranational) industrial competitiveness goals | | | |
| Knowledge related characteristics | Complexity of the network | Low | Medium | High |
| | Ratio of existing knowledge versus the need of new knowledge generation | Knowledge combination dominant | Balanced | Knowledge generation dominant |
| | Competitive situation of national STI and application landscapes | Outstandingly strong internationally | Competitive | Weak |
| Application characteristics | Degree to which application fields can be defined and described in a clear and appropriate way | Precise | Illustrative | Vague |
| | Closeness of the network to application | Short term | Mid term | Long term |
| | Underlying degree of technical feasibility and uncertainty of reaching the intended goals | Predictable | Risky | Highly uncertain |

measures and for Foresight studies. Thus its reasonable to analyze networks in the light of STI and of Foresight simultaneously.

One measure for network analysis is the “distance among pairs of inventors” measure which displays linkages in the network through calculating geodesic distance which is defined as the minimum number of steps that separate two distinct inventors in a network (Balconi et al. 2004). Such measure can give a proxy for the degree of directness of relationships between the actors but does not describe the intensity and the formality of the relationship. In addition some actors might show a large number of links in the network which is a pure indicative proxy for their activities in a STI network, e.g. the given the nature of STI the power of networks is largely determined by the intensity and frequency of interactions between the network members rather than the pure number of formal linkages between the actors.

Insights into the quality of relationships can be drawn from the number of patents which are either joint patents or have at least inventors from different institutions which belong to a network named, joint publications of scientific or academic papers between different actors but also to some extend by citation analysis of patents citing scientific publications of network members and vice versa.

Patent statistics and related indicators are means to measure the impact of university patents and scientific publications for innovations in industry. In addition to quantitative patent data innovation surveys deliver useful additional evidence on the impact of research activities either internal in companies or external to companies and other research related academic activities, such as meetings and informal contacts with university researchers (Balconi et al. 2004).

(d) Sustainability assessment

Sustainability is often understood as policies and related measures aiming and targeting at ecological aspects and demographic developments an related artefacts. However in the context of STI policy and Foresight which by definition have long term horizon sustainability is understood in the context of reliability of framework conditions which due to the nature of the underlying science especially do not call for continuous radical changes rather for modest adjustments. Still the environmental aspects need to be integrated in STI in a seamless manner which reflects both the science, technology and innovation dimensions as well as the explicit focus on environmental aspects (Rennkamp and Stamm 2009; Wieczorek et al. 2010). The challenge here is to integrate the global challenges inherent in environmental issues into current STI levels at different levels. Thus far environmental aspects are essential components of most Foresight studies either with an explicit focus on future environmental solutions, long term environmental impacts on STI or the impact of STI results on the environment. In that sense the environmental dimension is included in Foresight studies consequently in STI policies. However this dimension is not explicitly considered and covered by respective indicators yet.

In this light sustainability and STI policy inherit an explicit conflict of aims and goals since STI policy increasingly becomes a policy field which is subject of renewal and continuous adjustment by policy with numerous experiments to increase performance and value from this policy field. However the policy side regularly neglects the time horizon which is the major driver for value from science but also from sustainability and environmental conflict. In this sense sustainability oriented NIS, respectively STI, can be defined as driven by networks of private and public actors who generate STI outputs which are applicable and conducive environment. While Foresight studies deliver indications for potential STI policy measures such measures consequently can be targeted at the demand side, e.g. the application side of STI results mainly by enhancing markets providing absorptive capacities through regulations which make the application of technologies obligatory in certain fields but also at the supply side, namely by measures either creating or smoothly adjusting the infrastructures for public science, research and development and human resources (Rennkamp and Stamm 2009).

In a broader sense the interaction of STI with society increasingly requires enhanced knowledge acquisition and processing by society. Such also requires the alignment of research agendas and infrastructures with knowledge needs and action plans within and among societal spheres, i.e. science, politics, business, law, mass media, and education (Jappe 2006). These requirements are commonly known to stakeholders, especially to decision makers in the STI systems. However there are other gatekeepers in these systems whose intention does not necessarily follow the decision makers original ambitions (Lyall 2005).

(e) Globalization of NIS

Innovation and technology diffusion are a major driver of economic performance of countries especially in the age of globalization where national innovation systems are developing towards more integration crossing national, regional and cultural boundaries (Chan and Daim 2012). For the individual country the challenge arises to develop sharp profiles in the global STI competition and to set priorities in the allocation of especially public funds for STI in order to succeed in the medium to long term.

The integration of STI related policy measures is recognized to require integration in the governance scheme and especially in the adjustment of governance to new challenges such as globalization of the STI land sphere (Lyall and Tait 2005). Here globalization is putting additional pressure on national STI Foresight studies to determine STI fields which offer short time but at the same time sustainable competitive STI induced advantage over other countries which are expected to result in societal and economic benefit.

Thus far international cooperation in STI is not developed to the fullest extent. This holds especially true for the role and potential of national STI in the race with global challenges for which the global potential is not fully leveraged so far neither in respective globally oriented Foresight nor in respective STI measures. Global STI cooperation in most cases focuses on the knowledge generation as this is the usual and commonly accepted shape of cooperative STI while the absorption of generated knowledge is not considered and exploitation streams especially in case of public funded STI are commonly at national, regional or local level. Hence STI policy needs to pay increased attention to the demand side of STI and respective measures by education and (absorptive) capacity building.

Such measures at the crossroads of STI policy and Foresight include feasibility and Foresight studies, regulatory mechanisms, initial funding for the introduction of resulting solutions at global scale with respective coordinated approaches between countries. Most often Foresight studies take into account indicators which mirror the global networking of national STI systems. Among these indicators are the technology balance of payments, PCT patent applications, joint international co-authored publications, royalty payment flows between countries, STI induced FDI, complementarities of technological specialization profiles.

### 15.3.2 Analysis Based on STI Indicators

Foresight studies presume that STI policy needs to be either readjusted or continued in the current shape. Hence the issue arises if and how STI indicators can reflect the sustainability of policy measures which are in most cases a precondition of Foresight studies. Here measurement of the sustainability of Foresight studies as well as of STI measures is essential.

For long time STI indicators are measuring and reflecting the strength and power of NIS. Meanwhile it has become common wisdom that science, technology and innovation are no longer a phenomenon occurring in national boundaries but are in many shapes determined and influenced, if not generated, by global communities, e.g. by globalization of STI (Cantwell and Janne 1999). This holds especially true for global markets determining the respective application potentials. Consequently it follows that NIS are more globalized which is expressed in cross border technology flows, international co-authored publications, PCT applications for patents, community trademarks among others. Similarly Foresight exercises though with national focus always need to take into account global scenarios and developments instead of pure national developments. Done strategically Foresight inspires the organization to learn about possible future scenarios and enables them to prepare accordingly to meet the resulting challenges for their institutions / organizations by integrating Foresight into their strategic planning (Bezold 2010). Strategic planning at the same time is a central matter of STI policy which in turn is based in evidence thus indicators. It follows that the success of Foresight as a strategic planning tool is determined by the underlying STI related indicators among other determinants.

Analyzing STI policy based on indicators causes a number of reasonable methodological problems. Reasonable shares of indicators are non-quantifiable since they contain strong social-political dimensions. This implies that using traditional quantitative methods causal modeling, although possible in principle, shows limited analysis potential due to the unknown and hidden relationship between actors providing data and the multiple interrelations between different policy fields. Also the indicators are carrying a certain degree of uncertainty which due to the overarching complexity of the policy fields described is almost non-reducible neither can this uncertainty be fully described or even delineated. Moreover there is limited possibility to prove causality between the different indicators, e.g. the impact and influence of each policy measure which has an impact on the validity and reliability of the respective analysis. Thus conclusions drawn from such analysis need to involve not only quantitative indicators but be complemented with qualitative indicators which are considered to provide explanations or at least indications of the causality of indicators. This is to assure the traceability of causal relations indicated by quantitative indicators. Eventually the analysis of STI indicators describes complex social-political and socio-economic problem fields.

A possible solution to overcome these challenges lies in the morphological analysis which can assumed a useful, non-quantified method for investigating problem complexes, which cannot be captured by formal statistical and mathematical methods hence causal modeling and simulation. The morphological box developed eventually is complemented by a cross-consistency matrix. Although both methods are slightly subjective in development and calculation represent they allow a fairly traceable and plausible causality analysis. Prove for this has been delivered already by Ritchey who run compared identical morphological fields running consistency checks and finally by discussing the different assessments included in the morphological box gaining a deeper understanding of the nature and interrelationship of the policy fields involved and their respective impacts (Ritchey 1998).

### *15.3.3 Foresight Based on STI Indicator Analysis*

In many cases Foresight studies follow STI indicator analysis. This does not imply that such analysis is done with the intention to launch Foresight are commonly initiated with the aim of launching Foresight. This is especially reasoned in the available information base which still consists of a mixture of (partial) knowledge, assumptions, and ignorance. The decision to launch Foresight on this basis can be assumed a policy related decision since especially in the initial phase of Foresight the expectations of stakeholders and potential participants are high with regard to their own personal and institutional interest. Such policy decisions need to be made before conclusive scientific evidence on these problems illustrated by the indicator analysis is available, while at the same time the potential error costs of wrong decisions can be huge. Hence the uncertainty inherent to a Foresight of complex problems needs to be taken into account. At this stage quite often controversies arise which aim at three interrelated factors: uncertainty in the knowledge and information base, differences in framing of the problem, and the inadequacy of the institutional arrangement at the science-policy interface (Van der Sluijs et al. 2005). However the underlying STI indicator analysis provides reasonable solid arguments for Foresight with the explicit target and aim of developing potential scenarios and future developments which are eventually being used to derive respective measures and responses to meet the upcoming challenges and prepare the NIS to compete globally, regionally and locally. Moreover the societal context needs to careful consideration given the fact that in a broader sense, e.g. in terms of technology and innovation since finally society is accepting or rejecting responses derived from Foresight and thus from STI indicators analysis. The inclusion of this societal context beyond the often quoted and used technology and application dimensions of Foresight requires a more sophisticated, e.g. deliberative, reflexive, and multidimensional approach to uncertainty assessment. Here uncertainty should be a central element in the development of scenarios and equally important in the initial design of Foresight. Uncertainty in this context refers to technical, methodological and societal uncertainty (Van der Sluijs et al. 2005). Hence Foresight methodologies need to been chosen and bundled to reduce the overall uncertainty to a reasonable level especially by combining quantitative and qualitative approaches. Thomson and Holland (2003) find that complementary cross-section and temporal analytic approaches, e.g. the combination of quantitative and qualitative methods meets this requirement.

### *15.3.4 Strategy Studies and Policy Analysis Based on Foresight*

In result of Foresight studies roadmaps and strategy studies are employed to leverage the value of the findings from Foresight. Such studies and analysis are based on scenario-based investigations of possible futures which result from Foresight. Scenarios in turn are a tool to support decision making under uncertainty. Still scenarios are commonly build on assumptions which are subject of continuous change (Shearer 2005). These assumptions express the beliefs and perceptions but also the expectations of stakeholders, e.g. individuals and institutions involved in developing and building such scenarios. To assure the scenario building is reasonably objective and not determined by individual's perceptions and expectations.

Through the development of different kinds of scenarios for different applications and purposes it becomes evident that either other or more sophisticated STI indicators are needed. Wenstøp and Seip (2001) argue that multi-criteria decision analysis (MCDA) is a suitable tool for policy analysis including a variety of indicators, here STI indicators. Policy maker always need to make multi-criteria backed decision taking into account their legitimacy and quality of the respective decisions in terms of consequences (Wenstøp and Seip 2001).

## 15.4 Measuring the Impact of STI Policy: Implications for Foresight Studies

STI policy is measured by numerous indicators which have been described in the chapter. However the majority of these indicators are ex post indicators mirroring the recent status of the STI ecosystem, e.g. a national innovation system. Foresight studies on the other hand too are built on indicators which are used for the development of scenarios describing potential future developments. In course of that STI policy is in most cases developing policy responses to the potential developments which are evidently identified by Foresight studies. Hence it's reasonable to look at indicators which are used already or which have the potential to be used in both application, STI policy assessment and in Foresight. Although especially the Community Innovation Survey and the European Innovation Scoreboard intend to deliver indicators suitable to measure the economic impact of STI (Bloch 2007) there is still a gap in indicators mirroring the social and environmental impact of research activities (Luukkonen 1998; Lepori and Reale 2012). Lepori and

Reale use descriptors to capture more qualitiative data and information integrated in indicators, markers to capture assumed measureable outcomes and indicators which create the link between qualitative and quantitative dimensions. Ex-ante impact assessment of STI policy measures is commonly based on the analysis of participants of a respective STI policy measures, namely of funding support programs (Lepori and Reale 2012). In such cases applicants to funding from STI policy are usually required to describe the intended goal and output of the funded project work. From the large stock of funding applications trend analysis is in pricnciple feasible. However it needs to be kept in mind that such information is in many cases characterized by a bias of the funded party towards the funding party. The funding applicant will with some reasonable likelihood formulate promising potential outcomes and applications of the funded work which turns out to be unrealistic after a certain time of project work. The reason for this is the evaluation procedure and criteria applied by funders which commonly include assessment of the outcomes expected. Still such databases of funding project proposals also contain information though in verbal form which are useful information for the creation of indicators which stress a shift from input and output indicators spillovers, flows and process indicators by means of collaboration patterns, co-publications, co-patenting, etc. Another dimension of increasing importance is 'learning from experiences', e.g. past measures. Such learning is often achieved by the exchange of experiences with STI policy measures between the different NIS actors involved with the clear aim to refine and improve future initiatives (Kuhlmann 2003). Here ex post evaluation and impact measurement of STI policy measures is enriched by a future thinking dimension.

It's common practice for assessing the STI policy measures ex post. Quantitative indicators such as patent numbers, publications number, citation counts are publicly available from specialized databases. Other indicators are the number product and process innovation and the cooperation frequency and type of NIS actors are mainly collected by surveys and aimed at being converted into indicators. Patent indicators are frequently used in Foresight studies. The value of patent indicators lies in the availability of long time data series which analyzed over the years show tendencies of technology field development if differentiated following the international patent classification or industrial developments if industrial classifications are used (Blind 2008). Lagging, e.g. ex post type indicators used in the evaluation and impact assessment of STI policy measures are the R&D dynamics, e.g. the development of the absolute R&D related investments but also the relative investments, e.g. R&D as share of GDP. These indicators are then broken down at the performing level and the financing level, e.g. governments, industry, foreign funding for financing sources and government, HEI, industry for performance of R&D to name the major actors. A more precise indicator is the investive expenditure within the R&D budgets of companies. This is complemented by the inventory, e.g. the number of new companies which is considered an indicator for the volatility and the rate of change of industries. In case of technology based companies this indicator can also be considered an indicator of the either ongoing or expected technological change. Still although these indicators are typically used for STI policy measures these indicators need to be complemented by more in depth analysis of the underlying technology fields which then gives valuable input for future STI policy design. Such is often done in Foresight with the aim of scenario development. The education and qualification of human resources in an NIS is often measured and assessed in innovation studies or innovation reports which aim at SWO analysis of single NIS'. Standards, e.g. technical standards are issued by certified bodies/ agencies with different outreach and legal implications. Surveys in different shapes among researchers and innovators and reviews of national STI policies by expert panels are the most commonly used evaluation and impact assessment approaches (Georghiou and Larédo 2006). The composition and application of transparent indicators are a meaningful way to enable expterts often asked for doing such impact assessments to explore the overall meaning and position of the STI policy measures in question hence providing an even more objective and solid assessment of such measures (Trochim et al. 2008).

Very recently a classification approach for technologies was developed considering three basic criteria for differentiating technologies. Firstly the underlying field (s) of science, e.g. the science base or origin is considered, secondly the actual application field measured as the industrial class (goods and services) and thirdly the socio-economic dimensions is taken into consideration which expresses the expected diffusion and adoption of the technology hence its (impact) (Gokhberg et al. 2013). The discussed STI indicators are per se reasonable and useful for use in Foresight studies but they need to be classified, structured and complemented by in depth additional analysis (Blind 2008).

The structuring and classification of indicators is essential to ensure a comprehensive understanding of the indicators and the spillovers between indicators. The pure extrapolation of STI indicators into the future will very likely lead to misleading results because most if not all indicators are not only determined by the STI policy measures and the surrounding framework conditions but also by the human factor, psychological influences and processual determinants. The human factor and psychological influences are important in case of budget allocation related decisions which are eventually expressed in any STI expenditure related indicator. Here issues like political stability and economic stability are important for decision makers to allocate resources or reschedule such decisions. Such effects are mirrored in statistics, e.g. indicators with a reasonable time lag only. Processual determinants are for example the time lag between patent applications and issue of patent rights by issuing agencies and respective measures which are taken or not taken by these agencies to change the current regime. Another example for critical assessment of the suitability of STI indicators for Foresight studies is the number of new (sometimes also called 'young') technology firms. The absolute number of these may give an indication of the attractiveness of a market or a technology but over longer time it's more reasonable to consider the survival rate of these companies and their attachment to the originally focused market or technology. The reason for that concern being that established companies especially are usually using their market power or even dominance to limit new companies expansions hence diffusion of their technologies. Moreover especially in technology driven industries a reasonable mergers and acquisitions tendency has been recognized in the last decade. Here established companies might take over new companies with the aim of incorporating their competences in their own processes and product portfolios. Thus the importance and success of corporate venturing of established market actors reaches a new dimension. Although there are solid indicators available for venture capital as external funding of new companies such are rarely available for established companies which might declare it in their balance sheets in varying form, be it as R&D investive expenditure treated like equipment investment or financial investment with unspecified purpose.

## 15.5 Conclusions

There is a broad range of STI indicators available currently with sufficient time coverage. However as it was shown STI indicators lack a future orientation so far but are more restricted to ex post status quo description and analysis. The internet development has direct implications for the development and use of STI indicators since numerous new data sources are available beyond the established statistics which provide new data for both existing indicators and for the development of new indicators which may supplement traditional STI indicators (Scharnhorst and Wouters 2006).

Traditionally the focus of STI indicators was and still is mainly on R&D related indicators. The reason for this is probably of statistical nature. It took decades to establish the nowadays common R&D statistics in most countries in the world. Although the nature of innovation is changing and so is the nature of science and technology there is so far no STI indicator response on more than regional level which seriously mirrors these changes. Moreover existing indicators do not account for the fact, some might argue for the assumption, that research (science) thus technology and innovation are mainly driven by creativity. Therefore Foresight studies and in line with them future oriented STI indicators should consider the human factor more prominently and pay attention to the science and innovation climate at micro, meso and macro level. The usual headcounts of R&D personnel (alternatively FTEs) are indicators for quantity but not for quality and climate conducive science and innovation.

The process of generating science, technology and innovation results and outcomes itself involves more functions of different actors which are not mirrored in indicators but which are often more implicitly included in Foresight studies. New forms of STI, namely innovation, reflect increasing the complexity of economic system, especially through eco-innovation which internalises negative externalities of resource productivity and open innovation which internalises positive externalities of knowledge productivity. This paradigm shift in growth model implies new innovation ‘ecosystem’, new economic ‘laws’ govern innovation activities (increasing returns) and governance for ‘system innovation’ of innovation system (sustainability). The implications for governance for STI systems are manyfold and need to be matched by respective indicators.

- With the still progressing globalisation of STI a governance of international interdependence, fourth wave of globalization, is needed.
- Countries are already on the path to develop and implement differentiation strategies and complementarities instead of mere catching-up on leaders in the fields.
- The broader innovation concept reflects the increasing complexity of system but is not covered by indicators yet.
- This concept calls for governance of STI for sustainable growth, economic prosperity and societal development. The challenge for STI indicators and Foresight lies in including 'innovation policies' instead of 'innovation policy' which goes beyond the 'horizontal innovation policy'.
- Due to ongoing changes in the growth regime the governance of system change/ transition with policy as co-actor for defining appropriate institutional arrangements to achieve societal challenges needs to be mirrored. This implies monitoring the governance of knowledge dynamics to enhance system innovation for sustainable growth and (international) cooperation. The new features in this paradigm to be included in future indicators and dealt with by Foresight studies are cumulative knowledge where positive feed-back mechanisms are dominant, the public good character of knowledge where spillovers are pervasive and an increasing instability of the system where innovation bubbles are inevitable.

A new generation of STI indicators needs to go beyond the common NIS concept which is currently too static and too closed raising the need for a wider systemic framework which includes new patterns of innovation which are emerging from interactions ('coopitition' in open innovation; reorganisation of international value chains; blurring boundaries: multi-'everything'), growth model changes (how positive feed-back loops are managed), sustainability (digitalization & dematerialization which imply more weight of economics of increasing returns), small 'fluctuations' at the start which eventually make big differences (path dependency) and the fact that knowledge dynamics are of different nature (common pool). Moreover the Foresight studies should be expanded by the dimension of changes in STI governance in self-reinforcing systems, the co-creation of supply and demand conditions, the co-evolution of policy, theory and other 'belief systems' and the capacity to make choices under uncertainty. Governance thus is expected to take care of stable frameworks of shared STI objectives with strategic positioning, prioritization and differentiation strategies and eventually increasing share of experimentation with STI policy measures. It seems reasonable to detect such features in course of Foresight studies but nethertheless indicators must provide a reliable solidly founded base for monitoring developments in ever shorter time frames.

Summing up it can be concluded that existing STI indicators are suitable for a broader use of impact assessment activities hence in Foresight studies. This is justifiable by the arguments:

- STI indicators have reached a development stage which allows targeted indicator composition in the recent years. These indicators are increasingly ex ante indicators combining quantitative and qualitative dimensions.
- The interpretation of STI indicators is progressing. There is an increasing in depth understanding for the rational of NIS actors to behave in certain ways und different circumstances which allows to assign more meaning to the indicators.
- STI indicators increasingly take time dimensions into account instead of focusing on static analysis.
- Analysis techniques are progressing, such as semantic analysis which contributes to STI indicators reaching new dimensions. In such more information sources, namely a broad range of by different different information sources can be used for analysis. In doing so these indicators are becoming increasingly relevant for Foresight studies by contributing to build solid base for Foresight studies through more realistic ex ante impact assessments.

Despite the promising potential of STI indicators for Foresight an ex ante impact assessment some major requirements need to be fulfilled:

- STI indicators need to be robust and most current. Extrapolation of STI indicators time series needs complementary qualitative analysis to test the validity of trends which can be detected.
- The quality and comparability of STI indicators needs to be checked using again qualitative analysis. There are different understanding especially in the collection of raw data for STI indicators composition in most countries. Still Foresight will not rest on STI indicators which are purely national indicators.
- STI indicators like patenting and publications can be used for trend and tendency detection but should not necessarily be used for SWOT analysis of countries, regions or industries. Here additional research is required to determine the quality of these indicators.
- In addition to the traditional STI indicators standards and international regulations need to be considered. Standards refer to nationally and to some extend internationally binding technology driven standards which are in place and enforced already but equally important is the analysis of ongoing standardization procedures at national and international levels.
- Despite standards set by indended bodies industrial agreements on standards are important indicators. Such standards are agreements between different industry actors about technologies or interfaces between technologies which are not subject to government regulations. Once set such standards are likely to set the basic framework for a whole industry for a long period.

The IAFS model introduced in this chapter is a systemic model which combines the different aspects of indicators for STI policy and Foresight eventually building the bridge between the existing information and knowledge base and the potentials for extension which are offered by Foresight studies. IAFS is not thought to be a model which can be applied one to one in the overarching STI context netherless it aims at highlighting the major challenges towards STI indicators and Foresight indicators and the potential indicators from both spheres have to generate inspirations for development of the next generation of STI indicators and also Foresight studies and indicators. The major conclusion to be drawn from the IAFS model is that STI in itself is a dynamic phenomena which is creating continuously changing conditions and requirements of the NIS as a whole. Foresight plays an important role here since Foresight mirrors and displays ongoing changes at different levels. Hence the systemic thinking of Foresight and STI, here expressed in terms of STI indicators, is a contribution to a new thinking of NSI with the aim of systems thinking, e.g. systems innovation.

## References


Abramo G, D'Angelo CA, DiCosta F, Solazzi M (2009) University–industry collaboration in Italy: a bibliometric examination. Technovation 29:498–507

Archibugi D, Pianta M (1996) Measuring technological change through patents and innovation surveys. Technovation 16(9):451–468

Balconi M, Breschi S, Lissoni F (2004) Networks of inventors and the role of academia: an exploration of Italian patent data. Res Policy 33(2004):127–145

Bezold C (2010) Lessons from using scenarios for strategic foresight. Technol Forecast Soc Change 77:1513–1518

Blind K (2008) Regulatory foresight: methodologies and selected applications. Technol Forecast Soc Change 75:496–516

Bloch C (2007) Assessing recent developments in innovation measurement: the third edition of the Oslo Manual. Sci Public Pol 34(1):23–34

Braun T, Dióspatonyi I (2005) Counting the gatekeepers of international science journals a worthwhile science indicator. Curr Sci 89(9):1548–1551

Butcher J, Jeffrey P (2005) The use of bibliometric indicators to explore industry–academia collaboration trends over time in the field of membrane use for water treatment. Technovation 25:1273–1280

Cantwell J, Janne O (1999) Technological globalisation and innovative centres: the role of corporate technological leadership and locational hierarchy. Res Policy 28:119–144

Chan L, Daim T (2012) Exploring the impact of technology foresight studies on innovation: case of BRIC countries. Futures 44:618–630

Dlouhá J, Barton A, Janousková S, Dlouhý J (2012) Social learning indicators in sustainability-oriented regional learning networks. J Clean Prod 1–10, http://dx.doi.org/10.1016/j.jclepro.2012.07.023

Donovan C (2007) The qualitative future of research evaluation. Sci Public Policy 34(8):585–597

Donovan C (2011) State of the art in assessing research impact: introduction to a special issue. an integrated impact indicator: a new definition of 'Impact' with policy relevance. Res Eval 21 (3):183–188

Dosi G (1988) Sources, procedures and microeconomic effects of innovation. J Econ Lit XXVI:1120–1171

Freeman C (1982) The economics of industrial innovation. MIT Press, Cambridge

Freeman C, Soete L (2009) Developing science, technology and innovation indicators: what we can learn from the past. Res Policy 38:583–589

Georghiou L, Larédo P (2006) Evaluation of publicly funded research: recent trends and perspectives. In: Futures, Volume 44, Issue 10, December 2012, Pages 905–913 OECD science, technology and industry outlook. OECD, Paris. pp 177–199

Godin B (2004) The who, what, why and how of S&T measurement, project on the history and sociology of S&T statistics, working paper no. 26, http://www.csiic.ca/PDF/Godin_26_a.pdf. Last accessed 30 Oct 2012

Godinho MM, Ferreira V (2012) Analyzing the evidence of an IPR take-off in China and India. Res Policy 41:499–511

Gokhberg L (2000) Intellektual'naya deatel'nost' v structure ekonomiki informacionnogo obschestva (voprosy metodologii). Voprosy statistiki N 6 pp 41–51 (in Russian) [Intellectual activity in the structure of the information society economy (methodological issues)]

Gokhberg L (2003) Statistika nauki. TEIS, Moscow (in Russian) [Statistics of Science]

Gokhberg L (ed) (2012) Ekonomika znaniy v terminakh statistiki: nauka, tekhnologii, innovacii, obrazovanie, informacionnoe obschestvo. Moscow: Ekonomika (in Russian) [Economics of knowledge in terms of statistics: science, technology, innovation, education, information society. Glossary]

Gokhberg L, Boegh-Nielsen P (eds) (2007) Information society statistics in the Russian Federation: harmonization with international standards. Higher School of Economics, Moscow

Gokhberg L, Fursov K, Miles I, Perani G (2013) Developing and using indicators of emerging and enabling technologies. In: Gault F (ed) Handbook of innovation indicators and measurement. Elgar, Cheltenham/Northampton, Ch. 15

Hidalgo A, Gabaly S (2012) Use of prediction methods for patent and trademark applications in Spain. World Patent Inform 34:19–29

Jappe A (2006) Four major task domains of science for sustainability. Fraunhofer ISI discussion papers innovation system and policy analysis, no 10/2006

Kleinknecht A, Montford Kv, Brouwer E (2002) The non-trivial choice between innovation indicators. Econ Innov New Technol 11(2):109–121

Kuhlmann S (2003) Evaluation of research and innovation policies: a discussion of trends with examples from Germany. J Technol Manage 26(2–4):131–149

Lepori B, Reale E (2012) S&T indicators as a tool for formative evaluation of research programs. Evaluation 18:451

Luukkonen T (1998) The difficulties in assessing the impact of EU framework programs. Res Policy 27(6):599–610

Lyall C (2005) Concurrent power. The role of policy networks in the multi-level governance of science and innovation in Scotland. INNOGEN working paper no. 33, May 2005

Lyall C, Tait J (2005) Shifting policy debates and the implications for governance. In: Lyall C, Tait J (eds) New Modes of governance: developing an integrated policy approach to science, technology, risk and environment. Ashgate Publishing, Aldershot/Burlington, pp 1–18

Mendonça S, Pereira TS, Godinho MM (2004) Trademarks as an indicator of innovation and industrial change. Res Policy 33(9):1385–1404

OHIM (2012) Statistics on community trade marks, community designs and appeals. Office for the harmonization in the internal market 2012. http://oami.europa.eu/ows/rw/resource/documents/OHIM/statistics/ssc009-statistics_of_community_trade_marks_2012.pdf. Accessed 30 Sept 2012

Pavitt K (1988) Uses and abuses of patent statistic. In: van Raan AFJ (ed) Handbook of quantitative studies of science and technology. Elsevier, Amsterdam

Pawson R (2002) Evidence-based policy: the promise of 'Realist Synthesis'. Evaluation 8 (3):340–358

Rennkamp B, Stamm A (2009) Towards innovation systems for sustainability – the role of international cooperation. In: Federal Ministry for Education and Research: innovation for sustainability in a changing world. Proceedings of the 2nd South-African-German dialogue on science for sustainability, Bonn, pp 72–77

Ritchey T (1998) General morphological analysis – a general method for non-quantified modeling. In: Presented at the 16th EURO conference on operational analysis, Brussels, 1998, available http://www.swemorph.com/pdf/gma.pdf. Accessed 20 Dec 2012

Scharnhorst A, Wouters P (2006) Webindicators: a new generation of S&T indicators. Cybermetrics 10(1). ISSN 11375019. http://www.cindoc.csic.es/cybermetrics/articles/v10i1p6.html. Accessed 30 July 2012

Shearer AW (2005) Approaching scenario-based studies: three perceptions about the future and considerations for landscape planning. Environ Plann B Plann Des 32(1):67–87

Thomson R, Holland J (2003) Hindsight, foresight and insight: the challenges of longitudinal qualitative research. Int J Soc Res Methodol 6(3):233–244

Trochim WM, Marcus SE, Masse LC, Moser RP, Weld PC (2008) The evaluation of large research initiatives: a participatory integrative mixed methods approach. Am J Eval 29:8–28

Van Der Sluijs JP, Craye M, Funtowicz S, Kloprogge P, Ravetz J, Risbey J (2005) Combining quantitative and qualitative measures of uncertainty in model-based environmental assessment: the NUSAP system. Risk Anal 25:481–492

Wagner CS, Leydesdorff L (2012) An integrated impact indicator: a new definition of 'Impact' with policy relevance. Res Eval 21(3):183–188

Wenstøp F, Seip K (2001) Legitimacy and quality of multi-criteria environmental policy analysis: a meta analysis of five MCE studies in Norway. J Multi-Criteria Decis Anal, Special Issue: Multicriteria Anal Environ Manage 10(2):53–64

Wieczorek AJ, Hekkert M, Smits R (2010) Systemic policy instruments and their role in addressing sustainability challenges. http://umconference.um.edu.my/upload/43-1/papers/014%20AnnaJWieczorek_MarkoHekkert_RuudSmits.pdf. Accessed 30 July 2012

WIPO (2011) International classification of goods and services for the purpose of the registration of marks (nice classification), 10th edn, Part II with list of goods and services in class order. WIPO Publication No. 500.2E/10

Yusuf S, Nabeshima K (2009) Tiger economies under threat – a comparative analysis of Malaysia's industrial prospects and policy options. The World Bank, Washington, DC

# Chapter 16
# Summary – Targeting STI Policy Interventions – Future Challenges for Foresight

**Leonid Gokhberg and Alexander Sokolov**

It has been shown in this book that Foresight and STI policy are closely interlinked. Long term visions for the potential development of STI and the detection of potential challenges towards STI and society resulted from forward looking activities. The issue of implementing respective policy responses naturally arises. This in turn has significant consequences for the governance of innovation systems because challenges and development trends usually affect a variety of policy fields and recommendations for implementation. In this light the interconnection of Foresight and STI policy leads to the discussion of the impact of different modes of governance on the development of national innovation systems as a driver of national values hence economic conditions.

That said leaves the question which role Foresight has in STI policy. Basically one might argue that each actor in any National Innovation System has the right to act on his own behalf and without any obligation to anyone else. However, as society is becoming increasingly aware of upcoming challenges and given the public good nature of science this assumption becomes only semi true. The reason is that future but also already recent challenges, opportunities but also threats are by far too large and complex to be solved by individual actors and are characterized by a significant risk and uncertainty of completion and eventual application. Moreover the current global economic conditions are not favorable to allow public bodies responding to challenges identified by Foresight studies in an appropriate manner. This refers especially to developed countries which are especially affected by an economic but to some extent also political crisis. In such constellation the attitudes of policy makers towards taking risk in form of uncertain STI investments are weaker than usual since more urgent current problems have to be solved. In consequence long term challenges although known are not immediately on the agenda of policy makers and STI implementation bodies.

L. Gokhberg (✉) • A. Sokolov
Institute for Statistical Studies and Economics of Knowledge, National Research University – Higher School of Economics (HSE), Myasnitskaya st., 20, 101000 Moscow, Russia
e-mail: lgokhberg@hse.ru

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Foresight studies carry the potential to contribute possible answers to the basic question for the role of science in the economy and the overarching societal context. It often appears that science is still considering itself as a self fulfilling prophecy, e.g. justifying its existence and especially public finance with the assumption that scientific work is delivering a given though not predetermined value. This assumption is increasingly challenged by policy and society but to some extent even by industrial opinions holding ever more true in the national S&T policy context. Here the challenge arises if a nation can still afford to maintain a science system framework covering all disciplines to the fullest extent or being forced by financial constraints to focus on selected priority fields. What seems reasonable and plausible at first sight turns out problematic when looking at this challenge from a broader perspective.

Many science fields are already and continue to be more interrelated and interdisciplinary. Consequently to pursue the development of selected, S&T priorities the broad spectrum of S&T fields need careful consideration.

Interdisciplinary science and technology is the result of the underlying basic research. One of course might argue that S&T is global thus a sole country might specialize in a few selected cross-disciplinary fields taking advantage of the development of complementary or underlying fields in other countries. Though such strategy seems reasonable and plausible at first sight, the implementation is likely to fail in the long term. However it needs to be kept in mind that science and technology is mainly tacit knowledge and bound to persons thus cross-disciplinary team work requires different competences and knowledge at one place, which eventually determine a fertilizing research and innovation culture.

Foresight studies run the danger of becoming a tool of professional communities which justify their existence but are barely in a position to influence the implementation and use of Foresight results. However in course of this the confidence and trustworthiness of the Foresight community might suffer to some extent in selected countries. There is obviously a tendency that although emerging and transition countries are willing and keen to learn from other countries in most cases the efforts of countries are limited to 'first phase learning', e.g. getting acquainted with existing approaches of other countries which is step one and desperately needed but not complemented by step two in the learning process which is the further development and adjustment of these approaches to the local, regional and national specific framework conditions.

While Foresight has been applied mainly in developed countries to a large extent for significant time transition countries are discovering the potentials of Foresight for STI policy only for the last decade. However in such course the Foresight and STI communities in these countries often quote the respective international communities for proving their legitimacy without considering their own strengths. However the strength of these international communities' is never asked / questioned at any time in the whole dispute, instead the community is given new drive by new members each of them struggling to survive in the new scheme. Eventually it shows that the established communities and their inherent thinking and attitudes dominate the establishment and the reshape of innovation systems hence Foresight and STI policy at all levels.

The doubtless potential of Foresight studies' contribution to the shaping and future orientation of STI policy is challenged in several ways. Foresight studies are to a large share based on expert knowledge which stems from scientific or engineering background. Scientific results usually do not allow their use and immediate application in given circumstances. The global value chain of scientific production is composed of numerous parallel streams, e.g. in form of research projects which belong to certain science and research fields. Although developments in the scientific value chains might inspire each other to some extent the applicability and usability of the results in fields others than the one of origin are limited at the early stages.

The speed of development of different science fields is not universal, e.g. the likelihood that science fields generate results in time allowing complementary use in other fields is rather low. Having said so it becomes obvious that Foresight might identify promising S&T fields but still can not overcome the uncertainty of achieving success in meeting challenges in a given time. Moreover the general consideration of the time factor is crucial in the public debate. Foresight is of long term nature but there is a strong presence of the immediate proof of return on these financial resources invested into science. Still the awareness of the unpredictability of 'measurable' results from these investments is missing to a large extent. Hence the expectations towards the splitting the work associated with respective science fields between locations, regions or nations are high but the interfaces between these are not considered in course of cooperation models and especially in course of time.

Science fulfills more than the research task and the academic dispute about research findings. Moreover it is common practice that research results are included in ongoing education and training activities. Hence the regional proximity of research and education is weakening for the education and training of the next generation of researchers and engineers. Modern media such as remote learning are becoming more widespread especially in the social sciences but remoteness becomes a challenge for basic sciences when it comes to exercising in labs. That holds still true in the beginning age of virtual labs.

Finally the identification and support of priority fields in most cases do not include the long term impact assessment of these fields. Although direct impacts can hardly be quantified in a long time future horizon, potential effects can be assumed and monitored at early stages.

Eventually it shows Foresight studies have the potential to contribute even stronger to STI policy in many fields.

> Foresight studies show an ever increasing potential to serve as one basis for S&T strategy building at different levels. Foresight based visions which are commonly used for strategy development. However S&T strategy development is different from implementation and varies between the actors developing these. S&T strategy by industry differs from one provided by governments and funding agencies in many ways, e.g. time horizon, S&T development stage, risk and uncertainty acceptance, investments etc.

Given the fact that Foresight studies are in widespread use it is ever more surprising there is little knowledge about the factual implementation of their results. Thus far the assumption prevails that Foresight impacts the national innovation capacities and the quality of national innovation systems. There are reasonable arguments which enforce globally comparative evaluations and impact measurement studies of Foresight over a longer time. Such evaluation should cover the implementation phase and equally important the need to include the learning from previous Foresight studies in the design of new ones.

Most Foresight studies are initiated by national public authorities, e.g. governments or related agencies. However the initiation and the design of these studies are often done by different units. Hence a systemic approach towards the preparation and design of Foresight is ever more needed in order to ease the preceding phase and to limit the repetition of failures and mistakes done at the preparation and design stage.

The design and initiation phases of Foresight studies include the setting of objectives and the identification of themes which need to be aligned to the broader perspective and mission of the initiator but even more important the tendering procedure for launching a study. Typically both public and private studies undergo an initial tendering procedure. The preparation of such tender process and the subsequent assessments and selection of applications are a complex process which is critical already for the quality and validity of the results to be expected. Hence guidelines for the design and preparation of studies, e.g. the tendering procedure, are valuable instruments for Foresight. In line with such guidelines a set of requirements to contractors for undertaking professional Foresight studies should be developed.

At national but also at international level it seems recommendable to establish a network and a central database collecting the experiences of these studies to make them accessible and usable for future Foresight studies. The main focus of such a collection should be on the procedural dimension, e.g. learning from the Foresight processes and the organization of these. Moreover a documentation of such processes will certainly turn out valuable for Foresight practitioners in course of a Foresight study to provide inspiration for solving certain challenges which are likely to occur.

Currently Foresight studies are used for detecting future challenges towards society, the assessment of potential technological developments and the identification of gaps and needs for immediate, mid-term and long-term measures. However Foresight studies also have the potential of being used for the anticipation of potential policy measure impacts and the identification of the next generation of innovation policy related measures. Here a new field for applying Foresight studies is likely to arise in the near future.

Summing up the book chapters provide a comprehensive overview and in-depth discussion of many different facets of Foresight studies and innovation policy. The editors wish to express their gratefulness to all contributors of this book and Basic Research Fund of National Research University, Higher School of Economics who made this book possible.