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S&T PRIORITY SETTING. INTERNATIONAL PRACTICES AND THE CASE OF RUSSIA

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The paper discusses practices of science and technology priority setting with respect to national and global challenges.
General approaches to priority setting with particular focus on types of priorities, selection criteria, methodologies and formal procedures are illustrated on international experience (for Germany and the UK).
Recent developments and problems to be resolved in S&T priority setting are analysed in detail for the case of Russia. The solutions suggested target ensuring practical applicability, objectivity, and transparency of priority setting procedures and results.

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1. Introduction

Present-day research activities are growing in scale, have inter-disciplinary nature and global coverage; their impact on global innovation-based development is also increasing. Despite significant growth of R&D expenditures in developed countries, no single one of them is capable of conducting fully-fledged research covering the whole range of subject areas. Therefore setting sound priorities for science, technology, and innovation (STI) activities becomes particularly important, since they determine the prospects not only for scientific, but also socio-economic development. Most developed countries have been working on setting STI priorities for quite some time, the latter providing the basis of their STI policies.

In recent years, science and technology (S&T) policy shaping in the majority of developed countries was becoming an increasingly integrated process, with various priority types and relevant implementation tools applied at different management levels and by different stakeholders.

STI policy largely continues to address the objective of increasing productivity of the national innovation system, reducing barriers between its various actors, and promoting their successful cooperation – thus trying to identify "functional" or "structural" priorities.

Many countries are also traditionally working on setting and regularly updating thematic priorities, which include specific S&T fields investing in which could potentially bring the biggest social and/or economic effects in the medium to long term. A sufficiently widely articulated range of social and/or economic objectives, to be accomplished by orienting science and technology development accordingly, is obvious in such priority-setting exercises.

Furthermore, elements of a newly emerging "societal challenges" model are becoming increasingly prominent in current S&T policies, based on taking into account global and national challenges and trying to find adequate answers to them. Such answers require significant social and technological changes – which, in turn, would only be possible if R&D organisations join forces with companies [see, e.g., OECD Reviews of Innovation Policy: Sweden 2016, 2016]. A feature of this model is an increased accent on applied and targeted basic research. A complex problem arises in the scope of this model – designing and implementing strategies of interdisciplinary and inter-industry nature, which significantly increases the importance of strategic planning, management, coordination, and mission-oriented priority setting, to help accomplish major socio-economic objectives.

Under these circumstances it becomes important not only to efficiently apply various types of S&T priorities but also design new approaches (models) to develop integrated priority systems (comprising functional, thematic, and targeted priorities), oriented towards new emerging policy tools (including in the scope of the "whole-of-government policy" concept), such as Foresight, horizon scanning, monitoring, etc.

A historical view of priority setting approaches reveals their close connections with S&T policy shaping models prevailing at the time. Gassler et al [6, 2004], describe the following successive approaches:

1) traditional, based on industrial policy priorities (originally with the accent on military technologies, which subsequently has shifted towards civilian ones);
2) system-oriented (focused on functional aspects such as cooperation, networks, etc.); and finally
3) target-oriented one (trying to meet social and economic challenges, including global ones).

If the first three approaches correspond to the linear and network innovation development models, the last one belongs to the so-called societal challenges model.

The paper analyses practical experience of setting national S&T priorities in the scope of present-day STI policy objectives, which are increasingly oriented towards meeting global and national-level challenges. The focus is on accomplishing strategic socio-economic development objectives, making efficient use of national competitive advantages, and concentrating on application of more productive innovative technologies.

2. The process and results of R&D and innovation priority setting

Generally, "priority setting can be defined as a negotiation process in which diverse actors and stakeholders seek to agree on common goals, objectives and actions" [OECD, 2012]. Keenan and Cervantes (2010) define this process as "choosing some activities which involve allocation of public resources over others" [M.Keenan, M. Cervantes, 2010]. There are also more specific definitions in literature, concerning priority setting in particular fields or for particular activities (see e.g. "Priority setting is processes by which decision about the allocation of scarce health care resources are taken, [Robinson S., Dickinson H. et al, 2010]).

The following key elements of STI priority setting clearly stand out in these definitions: the process and participants of priority setting, and the actual priorities as results of this process. Taken together, all major priority setting elements can be graphically represented as the following scheme (figure 1).

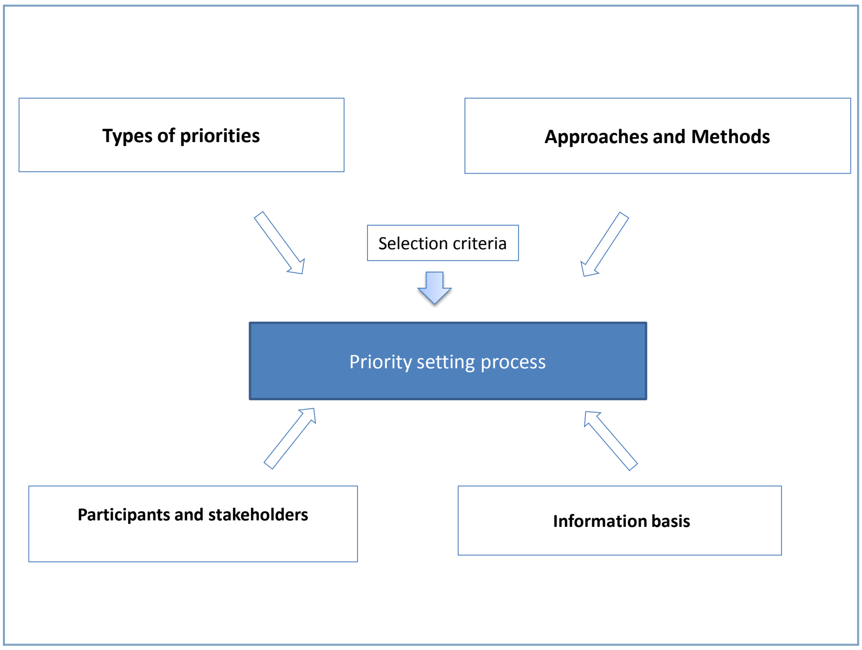

Figure 1. STI priority setting model

2.1 Types of priorities

Presumable the most solid foundation for classifying priorities seems to be the purpose of priority setting, the interested parties, and the level of priorities but still approaches, criteria, techniques, and information basis for priority setting largely depend on the type of priorities to be set. Literature frequently describes three priority setting objectives [Gassler et al., 2004; Georghiou, Harper, 2011; Keenan, Cervantes, 2010; OECD, 1991 etc]:

- thematic priorities;
- functional, structural, or generic priorities;
- targeted (mission-oriented) priorities.

Thematic priorities are S&T fields investing in which could make a biggest contribution to solving major social and economic problems in the medium to long term. The Russian Federation “Science and Innovation Development Strategy Until 2015” defines priority S&T development areas in the Russian Federation as “thematic science and technology development areas of inter-industry (interdisciplinary) significance, capable of making the biggest contribution to ensuring national security, accelerating economic growth, increasing the country's competitiveness by developing technological basis of the economy and research-intensive industries" [Interministerial Commission for Science and Innovation Policy, 2006]. Simachev defines S&T priorities as "a certain small number of research areas on which the state's, businesses', and the society's attention and efforts should be concentrated… in the interests of ensuring stability and sustainable development, competitiveness of the economy, and high quality of life" [Russian Science Foundation, 2015]. In this respect thematic priorities are frequently set in the form of national-level critical technologies lists, but such lists may also be prepared for specific industries, subject areas, and regions while functional priorities are activities (policy areas) whose objectives include further development and improvement of the R&D sphere and the innovation system aiming at identifying the national innovation system's "problem areas" and relevant policy tools, e.g. accelerated development of universities' R&D potential; upgrading research personnel, etc. These priorities are usually believed to have the highest importance in terms of allocating required financial resources.

Some studies propose to use the terms "horizontal" or "generic" priorities essentially as synonyms of "functional priorities". E.g. in Bilat-USA these are seen as "policy priorities, span from measures to support human resources in research, public-private cooperation, research infrastructures, and international cooperation. Their primary objective is to create a favourable environment for conducting research, to address certain structural weaknesses, and to ensure, in the same manner as thematic areas, the socio-economic development of society, its competitiveness and knowledge base" [BILAT-USA, 2010]. Here thematic and functional priorities serve as a basis for national or industry-level R&D programmes, strategic plans, or other working documents of development institutes, foundations, R&D centres, or other participants of the national innovation system. Thus these priorities are usually set for the medium-to-long term, but policy decisions are made in the scope of the established government agencies' and institutions' structure – the ones which are actually expected to take specific steps to implement the selected priorities. Under such circumstances a conflict of interest may arise between traditional structures and new activity areas. Therefore there is a need to explore "structural priorities" aimed at creating new institutions and organisational structures, capable of implementing thematic and functional priorities as efficiently as possible. In this case structural priorities can be seen as a special kind of functional priorities.

"Mission-oriented" priorities are set, taking into account global and national-level challenges, to accomplish major national socio-economic objectives, implement large-scale national programmes or projects (which may comprise various S&T subject areas) such as improving economic growth quality, technological modernisation of the real sector of the economy, promoting development of knowledge-based economy or information society. Examples include priorities included in the Societal Challenges block of the Horizon 2020 programme being implemented by the EU since 2014 [Horizon 2020, 2016].The Societal Challenges section addresses such issues as increasing efficiency of research and innovation activities in the following areas:

- Health, Demographic Change and Wellbeing;
- Food Security, Sustainable Agriculture and Forestry, Marine and Maritime and Inland Water Research, and Bioeconomy;
- Secure, Clean and Efficient Energy;
- Smart, Green and Integrated Transport Systems;
- Climate Action, Environment, Resource-Efficient and Raw Materials;
- Europe in a Changing World – Inclusive, Innovative and Reflective Societies;
- Secure societies - protecting freedom and security of Europe and its citizens;
- Science for and with Society.

Societal challenges responds directly to the policy priorities and societal challenges identified in the Europe 2020 strategy and aim to stimulate the critical mass of research and innovation efforts needed to achieve Union's policy goals. This approach covers not just technological but also social innovations. They can influence thematic research priorities at the operational level.[OECD, 2010].

Depending on the administrative level where the priorities are expected to be applied, national, industry, or corporate priorities can be distinguished. In terms of users one can distinguish between priorities set for the government, individual ministries, various science, technology, and innovation promotion foundations, and other participants of the national innovation system.

2.2 Selection criteria

Priority selection criteria depend on the actual type and level, i.e. national priority selection criteria are usually formulated quite broadly. According to Bilat-USA [2010] « the most relevant criteria for priority setting are:

- strength in particular research fields: existing research capacities, quality of research in a given field, future promising research fields;
- relevance: contribution to socio-economic development of a region/country/system/».

In the US national priority setting (critical technologies) projects “critical level” of specific technologies was linked to their several characteristics including importance to a wide range of industries, scope for application in integrated systems, and potential contribution to solving national-level social problems [Popper S., Wagner C., Larson E., 1998]. The French “100 Key Technologies” are supposed to “give France a competitive edge and increase the country’s appeal in the next 5-10 years” [Technologies clés 2010, 2006]. In the Czech Republic an objective was set to “identify more important technologies (research priorities) highly likely to be demanded by the Czech industry and the service sector, which would help to accomplish strategic objectives in key sectors important for improving national wellbeing and increasing quality of life” [Klusacek, 2004]. The Scandinavian Research Programme priority setting [Salo, Lieslio, 2006] appeal criteria were used including novelty and potential contribution to increasing industry’s competitiveness, producing desirable social and environmental effects and practicability including researchers’ competitiveness, and potential for application of created R&D results. Denmark’ S&T priorities are expected to contribute to dealing with major social problems, and at the same time (through R&D investments) serve as a driver of economic growth, employment, and wellbeing [Danish Ministry of Higher Education , 2015].

Apokin et al [2015] believe that a good understanding of long-term challenges to Russia’s socio-economic development, and of factors affecting demand for technological innovations these challenges create, is essential – since they make up a major component of some of medium- and long-term national socio-economic development. Promoting new technological competencies is vital for maintaining national competitiveness and security, which requires setting relevant priorities – due to lack of sufficient financial and labour resources for simultaneous “frontal” modernisation.

These trends were reflected in adjustments made to the lists of Russian national-level priorities and critical technologies in 2009-2010 [Poznyak A., Shashnov S., 2011]. The adjustment process was primarily focused on R&D areas with a potential for a sufficiently speedy commercialisation, and capable of producing significant socio-economic effects. For doing so the following criteria were applied during the adjustment process:

- Contribution to increasing GDP growth rate, improving its structure, and increasing competitiveness of the Russian economy;
- Contribution to Russia’s national security, including its technological, environmental, energy-, food-, and information-related aspects.

These trends, and related requirements to take into account global and national-level challenges to and targets for the country's socio-economic and technological development, were also considered in the approach adopted in the priority setting and critical technologies identification exercise conducted in Russia in 2014-2015 (see section "Russia: new approach to select S&T priorities in the 2014-2015" of this paper).

Criteria for setting national-level priorities are frequently described using rather general wording, though in some cases they're more detailed. The Czech Republic approach used two criteria to select critical technologies: importance and practical applicability. The first was composed of 23 indicators divided into four groups: economic importance, social importance, environmental impact, and feasibility of R&D results and the latter used 12 indicators grouped into two blocks: market potential and S&T potential.

On the institutional level related criteria are usually formulated more precisely than on the national one; frequently they are presented as a two- or three-level hierarchy of indicators. An example is the five criteria applied by the National Institutes of Health [1997] to make decisions on funding biomedical research:

- public health needs;
- scientific merit of specific study proposals;
- potential for advances in a particular area;
- distribution across diverse research areas (since it is impossible to predict exactly where advances will occur); and national training and infrastructure needs.

2.3 Approaches and methods

Approaches to priority setting can be classified on the basis of how formalised they are, and what role government agencies play in the process. The first characteristic allows identifying two broad approaches to priority setting: application of quantitative analytical techniques, and expert evaluation by relevant (informed) stakeholders [BILAT-USA, 2010; WHO, 2013].

The first approach is based on techniques such as bibliometric analysis of citation databases, patent analysis, benchmarking, etc.; its application requires adequate access to relevant data. In case of, e.g., benchmarking, the overall development level of an area or a technology is compared with the level achieved by reference country, industry, or region.

The second approach implies holding series of consultations and expert events involving all interest stakeholders, to ultimately achieve a consensus regarding the priorities to be set.

If during this process the main decisions are made through consultations with stakeholders in the research and innovation system, or even with public involvement, we have a “participatory approach”. When Research Councils and other consultative bodies play a major role, by making recommendations on directions and priorities of research policy, this is called an “advisory approach” [BILAT-USA, 2010].

Depending on the main vector of discussions and consultations, the approaches may be divided into top-down and bottom-up types. “The former include governmental priorities expressed by government ministries that reflect strategic priorities (e.g. economic development) or public missions (e.g. health). The latter essentially reflect the priorities of research producers: researchers themselves, research institutions and funding agents” [OECD, 2010].Though different approaches may prevail in particular countries’ priority setting practices in most cases elements of all of the above approaches are applied in combinations.

This is achieved most systematically and consistently when Foresight methodology is applied for priority-setting purposes. In many developed and emerging countries (Japan, UK, Germany, China, the Republic of Korea, etc.) S&T priority setting systems are based on results of large-scale Foresight projects covering all major S&T development areas.

Since the late 1960s, the Japanese Foresight results provide a basis for identifying priority R&D areas and forming critical (key) technology lists. The US have accumulated significant experience of developing critical technologies. The first “National Critical Technology Reports” were published in the USA as early as in the 1990s. Four projects on identifying critical technologies were implemented in France (“100 Key Technologies” projects). In China and the Republic of Korea critical technologies are selected in the course of Delphi-based Foresight studies, and a series of subsequent expert discussions. The British innovation development priorities are set in the scope of integrated projects implemented in the framework of the National Foresight Programme. The German Ministry of Education and Research conducts an ongoing Technology Foresight study to determine potential demand for research and development from economy and society (a more detailed analysis of national priority setting practices is provided below).

In recent years, Foresight methodology was systematically applied to set and implement priorities on the European Commission level. The new European Horizon 2020 Research and Innovation Framework Programme [European Commission, 2011] launched in 2014 is the financial instrument implementing the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe’s global competitiveness. It has integrated the EU framework programmes on promoting R&D, competitiveness and innovation. Results of various foresight studies of STI development prospects were actively applied to develop the previous and the current framework programmes. Horizon 2020 also provides for a strategic foresight study to specify the programme's strategic priorities and plan their implementation [European Forum on Forward Looking Activities, 2015, a,b].

Under the auspices of the European Commission operates the EFFLA, which proposed a priority-setting approach comprising four interconnected stages and involving various stakeholders [European Forum on Forward Looking Activities, 2015, a]:

- strategic Intelligence, which mainly involve "knowledge" stakeholders such as academics, thought leaders and independent researchers (This step is mainly bottom-up);
- sense-making, which will also engage the former stakeholders but the process is led by the Commission;
- selecting priorities (the step engages a wide spectrum of more formal stakeholders in open consultations (including the public, NGOs and other lobby groups. The most important part of this step is the decision part, which is in the hands of the Council, European Parliament and the Commission).
- implementation is entrusted to the Commission which normally is assisted by Programme Committees with representatives from Member States.

A system based on various quantitative and qualitative Foresight techniques is applied to set priorities, such as critical technologies, bibliometric and patent analysis, SWOT analysis, statistical analysis, and a wide range of various expert-based methods including expert panels, interviews, expert polling, and moderated discussions.

Combining various approaches and involving various stakeholders allows to reduce the risk of getting undesirable priority-setting results. The choice of approaches and techniques directly depends on the availability of information for priority setting.

2.4 Information basis

In the scope of the present-day S&T policy-shaping model, S&T priority setting is seen in the context of designing a long-term sustainable socio-economic development strategy, and is oriented towards major national-level socio-economic objectives. This approach was very common in recent years in the majority of developed countries

Information basis for priority setting usually comprises the following sources:

- strategic documents for the socio-economic sphere, science, technology, and innovation;
- medium- to long-term S&T development forecasts;
- statistics on S&T development and the country's S&T potential;
- analytical materials, etc.

Global challenges and trends, important socio-economic challenges and problems are also among major elements of information basis for priority setting. Priority setting also involves taking into account global and national S&T and innovation development trends and availability of resources (funding, personnel, materials and equipment, R&D groundwork, etc.).

Analysis of best international STI priority setting practices reveals that methodologies and mechanisms for selecting and implementing high-priority fields, major areas and critical technologies are constantly being improved to match new global and national-level challenges. In recent years a clear trend has emerged towards systemic objective setting and extending the range of information sources, including long-term S&T foresight studies and various combinations of quantitative and qualitative techniques [Meissner, Gokhberg, Sokolov, 2013].

2.5 Selection procedure

In a generalised way, the priority setting process can be presented as a three-stage procedure:

- drafting a basic priority list;
- in-depth discussions of the draft list at expert events;
- finalising the list following political consultations.

When planning and organising the priority setting process, care should be taken to ensure that the following requirements are met [Glod et al, 2009; Georghiou, Harper, 2011]:

- it is discriminant in nature, i.e. priority and non-priority S&T areas can be distinguished;
- it adheres to a certain aggregation level (neither too broad (all-encompassing), nor too narrow S&T areas are included in the list of critically important ones);
- it should be "integrated" into the national S&T policy-shaping process;
- it should be objective, generate sufficiently reproducible results if the procedure is repeated (i.e. invariance in a situation of experts' potentially lobbying particular areas).

At the first stage, a preliminary list of priorities is drafted based on the selected information sources, and materials necessary for its subsequent discussion. Depending on the nature of issues, these could include lists of major socio-economic objectives, and innovative products required for accomplishing them; more important research fields and areas; candidate critical technologies, etc.

During the next stage, in line with the selected approaches and techniques (e.g. expert panels and discussions, critical technology method, Delphi surveys, etc.) the actual initial priority setting takes place, with participation of relevant stakeholders.

The following conflicts potentially arising in the course of priority setting should be noted [OECD, 2010a; Dalrymple, 2006; Georghiou, Harper 2011]:

- specialisation (selecting a small number of areas), or diversification;
- balance between a broad "democratic" process, and a managed one;
- choice of the targeted stage of the STI process;
- supply- vs demand-led orientation;
- varying time horizons;
- uncertainty about resources.

Meeting these conditions is one of the more important issues associated with priority setting process. A key problem of national S&T priority setting (and their practical implementation) is associated with the exceptional difficulty (sometimes even impossibility) of comparative assessment of the amount of resources (financial, labour, etc.) invested in relevant research areas, and expected effects.

According to P. Cunnigham [2013], measuring R&D effects is a major challenge because they may emerge years after the R&D results were published. Relevant time horizons must also be defined, and the balance between investments and results measured, together with the effects created by interaction with other research areas, results generated in the business sector, etc. The OECD follows a similar argumentation "Despite the emergence of new quantitative tools for evaluation, the conceptual underpinnings of priority setting remain quite weak and expert opinion continues to predominate in the evaluations used by policy makers to make policy decisions" [OECD, 2010].

At the last stage the selected priorities are finally approved on the political level, taking into account previously made assessments and outcomes of debates. Usually descriptions of agreed priorities are also prepared (e.g. critical technologies), outlining their major characteristics, application spheres, possible support measures, and potential social, economic, technological, and other effects from implementing these priorities.

Specific forms this process takes depend on the existing organisational structure of R&D and innovation management, and on the relevant legislation. Various specific procedures and techniques applied in the course of priority setting are described below, using Russia as an example.

According to the OECD, efficient priority setting implies the following (OECD, 2012):

- Include broad and active participation of relevant stakeholders and support informationflows to achieve common understanding and consensus;
- Mix different approaches, such as bottom-up and top-down, supply-led and demand-informed, to avoid possible bias in the selection process;
- Be linked from the outset to budgetary and implementation issues.

As a rule, in the process of setting priorities possible tools are discussed for their implementation. OECD notes that ”Although the priority-setting phase is distinct from the implementation phase, it is important to consider the resources and capacities (knowledge, networks andmoney) that are available or have to be made available to implement the chosen priorities. These estimations should be a key part of the related strategic plans” (OECD, 2012).

Finally major results of this process are lists of priority STI development areas and critical technologies, which require top-priority support. These may comprise targeted, thematic, or functional priorities reflected in various strategic documents (e.g. strategies, white papers, policy papers, memorandums, etc.). National-level priorities usually attract the most attention and are implemented using various STI policy tools.

3. National priority setting experience

As noted in many European countries (Germany, UK, etc.) decisions to support specific STI areas are based on results of foresight studies conducted by public organisations, research centres, universities, and consulting firms. Such studies identify global STI development prospects, assess the country’s competitive advantages and impacts of previously implemented R&D and innovation support programmes. Along with governments, results of such studies are actively applied in making management decisions by other stakeholder groups, such as the real sector companies and R&D organisations.

3.1 Germany

Context and participants of the priority setting process

Germany has a decentralised research system with autonomous public research institutions and universities. Priorities are set at the national level and level of individual institutions following discussions between the government and the scientific community. So top-down and bottom-up approaches are integrated. On the federal level, the Ministry of Education and Research [Federal Ministry of Education and Research, 2015a] is responsible for shaping research policy while the Federal Ministry for Economic Affairs and Energy [Federal Ministry Economic Affairs and Energy, 2015] supervises development of innovation and technology policy and supports the development of the Eastern German States with special programmes. Other ministries also provide support to R&D in areas of their responsibility.

Setting priorities for its science, technology and innovation (STI) policy, the German Federal Ministry of Education and Research actively applies participative approach which allows for the collection and conside-ration proposals by various participants of the national innovation system. The Ministry of Education and Research has an Advisory Board comprised of more than 20 experts – members of academia and the business community. The board participates in development and implementation of national high-technology development strategy, and prepares recommendations on strengthening Germany’s competitiveness in high-technology markets. Various support measures are also provided to R&D activities on the federal lands’ level. The German parliament has the Commission of Experts on Research and Innovation (members are appointed by the Chancellor of Germany). The commission provides advisory support on research policy issues and regularly conducts expert evaluation of advanced research and innovation projects, and of Germany’s overall S&T development level.

The German Council of Science and Humanities also plays an important role in priority setting, which comprises representatives of public authorities, companies, R&D organisations, and civil society [The German Council of Science and Humanities, 2016].

Priorities and documents (strategies, white papers, critical technologies, priority areas, etc.)

The main directions of the S&T and innovation policy are set in the German High-Tech Strategy [Federal Ministry of Education and Research, 2014]. They are aimed at creating new markets, stepping up cooperation between science and industry, and providing a wide range of support to innovation activities using various new tools. The strategy identifies the following areas which pose the biggest challenges for the economy and society:

- climate, energy;
- health care, food;
- mobility;
- security;
- communications.

To meet these challenges, the following research fields are suggested for priority development:

- Digital economy and society
- Sustainable economy and energy
- Innovative world of work
- Civil security
- Healthy living
- Intelligent mobility

This strategy is coordinated with the Europe 2020 strategy regarding implementation of national and European R&D programmes and it aims to provide matching funds to European programmes. At the beginning of 2012, the federal government published the High-Tech Strategy 2020 Action Plan, which identified ten "Future Projects" of particular social importance [European Commission, 2015]. The priority areas for implementing these projects include the following:

- CO2-neutral, energy-efficient and climate-adapted cities
- Intelligent energy generation systems
- Renewable energy resources as an alternative to oil
- Combating illness with personalised medicine
- Improving health through targeted preventive measures and nutrition
- Independent living for senior citizens
- Sustainable mobility
- Secure identities
- Internet-based services for the economy
- Industrie 4.0 (4th-generation industry)

The plan was adopted by the federal government to coordinate the various ministries' policies and initiatives and to combine the efforts of academia and the business sector, specifically in the following areas: environment protection, energy, health care and healthy nutrition, mobility, communications, and security.

Germany also implements programmes and initiatives to support specific S&T development areas and industries: ICT 2020 [Bundesministerium für Bildung und Forschung, 2015]; Framework biotechnology development programme [Federal Ministry of Education and Research, 2015b]; 6th Energy Research Programme of the Federal Government [Federal Ministry of Economics and Technology, 2011], etc.

Strategies and initiatives to support S&T development are also implemented on the Landers' (State) level, to reflect their region-specific features – e.g. Bavarian Research and Innovation Strategy, Hessen's LOEWE initiative to foster development of scientific and economic excellence, etc.. Furthermore, priorities are set by the German Science and Research Organisations, Max-Planck Society, Fraunhofer Society, Helmholtz Society, Leibnitz-Society which involve more than 100 research institutions in Germany. All associations formulate research strategies and coordinate STI priorities regularly with federal and regional ministries.

Priority setting methodologies and procedures

The most important strategic tool for identifying the economy's and society's future R&D needs is the BMBF Foresight Programme [Federal Ministry of Education and Research, 2015e]. In the framework of these studies future development prospects are analysed, using a 15-year horizon. The results help to set the agenda and priorities for the national research and innovation policy. These studies are commissioned by the Federal Ministry of Education and Research, and are typically conducted by a consortium comprised of several research organisations. In the course of the foresight study the consortium's leader involves experts from the Federal Ministry of Education and Research, other relevant government agencies and other stakeholders, including representatives of universities, R&D centres, and companies. Technology assessment is carried out with the parliamentary office "Technology Assessment Bureau", affiliated with the Karlsruhe Institute of Technology (KIT).

Since 2010, Germany has been implementing an ongoing structured foresight study (with a four-year cycle) which includes two interconnected stages, during which S&T development prospects are analysed through integrated research of global trends, high-technology-related risks, prospective products, etc., to identify and assess the S&T sector's potential to meet emerging economic and social needs. This approach implies the active application of various expert-based procedures involving local and international experts.

The foresight study identifies major "prospective trends", assesses their consequences and prepares recommendations to help make relevant decisions. Information about anticipated trends and challenges is widely disseminated among all relevant stakeholders including politicians, members of executive agencies, industry, academia, and general public, to inform them about prospective needs and more important technologies.

The results are applied to prepare various strategic documents and initiatives which are developed by the Ministry of Education and Research, Ministry for Economic Affairs and Energy, and other relevant government agencies. Results of the foresight projects may also be applied by regional (federal lands') ministries, private sector companies, and other stakeholders providing support to the R&D sector. Currently foresight studies' results are primarily oriented towards the further development of the foresight process, and supporting its newest format – the High-Tech Strategy 2020.

Implementation of priorities (basic research programmes, thematic and industry-specific programmes, etc.)

National strategies and priorities are implemented mostly through the programmes managed by the federal ministries. In Germany, thematic R&D programmes serve as the main STI policy implementation tool. A significant effort is made to co-ordinate ministries and instruments. The Federal Ministry of Education and Research supervises most of these programmes, while the Ministry for Economic Affairs and Energy is responsible for R&D programmes on energy, transport, and space. Ecology, environmental protection, and nuclear safety research are the domain of the federal ministry, which bears the same name. Similarly, issues related to R&D on food quality, agriculture, and consumer protection are supervised by the Federal Ministry of Food, Agriculture and Consumer Protection.

Thematic programmes are designed in line with priorities set in the High-Tech Strategy 2020 for relevant technology areas. E.g. the BioEconomy 2030 programme is aimed at strengthening the competitiveness of German biotech industry, and concentrates on balanced nutrition and climate change. The integrated programme ICT 2020 specifies the following priority areas for strategic research and development: ICT in Complex Systems; New Business Processes and Production Technologies; Internet of Things and Services.

These programmes determine the German economy's future technological potential and competitiveness, so they are supported by the government and the private sector at all levels – including financial support for the development of major technologies, the establishment of innovation alliances and strategic partnerships. Specific programmes to support R&D in relevant priority areas are funded through a system of tenders. All programmes and tools are regularly adjusted, and if necessary updated.

Länder programmes are aimed at creating research and innovation clusters to support high-tech development on the regional level.

3.2 UK

Context and participants of the priority setting process

The Department for Business, Innovation and Skills (BIS) is primarily responsible for shaping science, technology and innovation (STI) policy in the UK. In setting and implementing its strategic priorities the department is assisted by a wide network of committees, councils, and advisory groups, on the government, departmental, and parliamentary levels. These include Technology Strategy Board (since August, 2014 – Innovate UK), Higher Education Funding Council for England (HEFCE), Council for Science and Technology, Research Councils, etc. The Council for Science and Technology consults the prime minister and government ministers on strategic aspects of STI policy, and provides information and analysis support for making decisions aimed at maintaining a high level of British research and development activities.

The Parliamentary Office of Science and Technology (POST) and the Parliamentary and Scientific Committee (PSC) also contribute to shaping STI policies.

Priorities and documents (strategies, white papers, critical technologies, priority areas, etc.)

Medium- and long-term national S&T development priorities are set in the UK Innovation and Research Strategy for Growth 2011[Department for Business, Innovation and Skills, 2011a]. Its objective is to increase the UK's potential to accelerate commercialisation of emerging technologies, and to facilitate creation of relevant value chains.

The strategy determines subject areas and sectors for priority S&T development:

- life sciences;
- high added value production;
- nanotechnology;
- computer technologies.

Key innovative technologies identified as priority investment areas include the following:

- synthetic biology;
- energy-efficient computing;
- energy storage;
- graphene-based materials.

In 2012, the UK started implementing the new Industrial Strategy aimed primarily at developing technologies, skills, funding mechanisms, and partnership between academia and business [Department for Business, Innovation and Skills, 2012]. The strategy identifies eleven high-priority sectors and industries (which either have already reached top international level or are likely to do so), for which the government jointly with relevant industries have designed specific strategies to support their further efficient development through long-term investments. The Strategy for the UK Life Sciences (2011) [Department for Business, Innovation and Skills, 2011b], the Nuclear Industrial Strategy: the UK's Nuclear Future [Department for Business, Innovation and Skills, 2013a], the Agricultural Technologies Strategy (2013) [Department for Business, Innovation and Skills, 2013b], etc. These strategies set development objectives for relevant sectors (areas), identify the most promising technologies and steps to be taken to accomplish appropriate objectives.

The aforementioned Industrial Strategy and its Implementation Plan also identifies eight "great technologies" where the UK has potential to become a world leader [Department for Business, Innovation and Skills, 2014]:

- Big data and energy-efficient computing;
- Satellites and commercial applications of space;
- Robotics and autonomous systems;
- Synthetic biology;
- Regenerative medicine;
- Agriscience;
- Advanced materials and nanotechnology;
- Energy and its storage.

The following S&T areas were selected for priority support in the medium term [Innovate UK, 2014]:

- graphene;
- energy-efficient computing;
- new visualisation technologies;
- quantum technologies;
- synthetic biology;
- technologies which do not require animal testing;
- energy storage.

A full list of foresight and horizon scanning projects, documents and reports is available at the website of the Government Office for Science [Government Office for Science, 2015].

Priority setting methodologies and procedures

STI development priorities are set by the government through a process of broad public debates and consensus building, involving all relevant participants of the national science and innovation system. In priority setting, the government relies on the results of various foresight studies, the results obtained by the Horizon Scanning Centre, and on consultations conducted in the course of strategy development. A key trend is the emphasis on contributions from interested parties and expert advice. Formal tools are also used to evaluate outcomes and socioeconomic effects before the research is carried out.

Currently the UK Foresight Programme – a major data source for setting STI priorities – promotes projects either on key research issues (such as flood risk management), or S&T areas with a potential to have major practical impact (e.g. spectral characteristic of electromagnetic radiation).

The starting point of a project may be either a key subject area where impressive results and potential solutions have already been obtained, or a prospective field for which potential practical applications and technologies need to be identified and/or elucidated. There are two criteria for the selection of topics: “Problem-oriented” topics requested by different departments (ministries) – such as Obesity, Infectious Diseases, Flood and Coastal Defense and promising areas with potentials for exploitation – such as Cognitive systems, Exploiting Electromagnetic Spectrum etc.

Programme participants analyse the potential of specific technologies in the scope of various independent projects4 (e.g. Cyber Security and Crime Prevention, Cognitive Systems, etc.). The projects are put together through a consultative process with participation of members of the R&D community, government agencies, research councils and other stakeholders. Recently completed projects include Future Flooding (2004), which served as the basis for national Making Space for Water (2006) and Tackling Obesity (2007) strategies. The latter was subsequently developed into a new inter-departmental national strategy Healthy Weight, Healthy Lives (2008). There were other projects, which have significantly affected the government policy-shaping process5. Each such project is independent, but the British government takes steps to bring them together again under the auspices of the Horizon Scanning Centre’s S&T

[4] See http://www.bis.gov.uk for more.
[5] See www.foresight.gov.uk for more.

Secretariat. The Horizon Scanning Centre implements short-term projects on specific issues with 10-15 year horizons. The obtained results are applied by various government ministries and other agencies in policy shaping.

All in all, the UK foresight projects generate detailed information that is sufficient for proposing alternative approaches and steps for further discussion and development of strategies to meet key challenges, and make political decisions to produce relevant strategic documents.

Implementation of thematic priorities (basic research programmes, thematic and industry-specific programmes, etc.)

The implementation of established priorities is supported by research councils, the provision of joint public-private funding to institutes (centres) operating in industries and sectors identified as high-priority ones in the Industrial Strategy, and through other mechanisms.

Research councils develop R&D programmes in line with higher-level strategic documents. Relevant programmes set more detailed priorities, which are implemented via R&D projects and other support tools. Every year research councils invest about 3 billion pounds in research in medical and biological sciences, astronomy, physics, chemistry, mechanical engineering, ecology, economics, social science, and humanities.

In the scope of the Industrial Strategy, the most significant have been the joint public-private investments into the Aerospace Technology Institute, the Advanced Propulsion Centre, and centres for agricultural innovation and support of agritech companies. The Industrial Strategy also provides for public investments into the eight key interdisciplinary technologies mentioned above, for which the country has advanced R&D results, technological and industrial facilities. Also, in the scope of each priority area the so-called Catapult Centres have been established, to provide access to necessary equipment and technologies for joint use with staff of other participating companies and laboratories. Eight such centres are currently operating: Cell Therapy, Digital, Energy Systems, Future Cities, High Value Manufacturing, Offshore Renewable Energy, Satellite Applications, Transport Systems.

Many policy documents recommend broad STI policy, decentralised governance structures, policy planning, experimentation and agility.

3.3 Russia

Context and participants of the priority setting process

During the last decade, Russia has accumulated significant experience in priority setting and identifying critical technologies. Over the last two decades, Russia has amassed considerable experience in projects establishing developmental guidelines for Russia's S&T complex and taking into account national interests and global trends in science, technology and innovation development. The lists of priority areas (PA) and critical technologies (CT) and detailed descriptions of CTs, are the main outcome of these projects. The first lists of PAs and CTs were drawn up in Russia back in 1996 and were subsequently revised on several occasions.

Priority areas in the development of science, technology and innovation are inter-industry (interdisciplinary) thematic areas of S&T development which are capable of making the greatest contribution to national security, accelerating economic growth, and increasing Russia's competitiveness by developing the technological foundations of the economy and science-intensive industries.

Critical technologies are a group of inter-industry (interdisciplinary) technological solutions which establish the prerequisites for further development of different thematic areas in technology, have broad potential for competitive and innovative applications in different economic industries, and collectively make the greatest contribution to developing priority S&T areas.

This work has been considerably stepped up after 2003, when the RF Ministry of Education and Science started to regularly commission studies to design lists of priority S&T development areas and critical technologies. Based on results of the studies conducted in 2004-2005, following discussions and endorsement by relevant ministries, new lists of priority S&T development areas and critical technologies were approved by Russian presidential decree (№ Pr-843 of 21 April 2006).

The most recent list was approved by the President of the Russian Federation in 2011 and included eight priority areas and 27 critical technologies [Order of the President of the Russian Federation No. 899, dated 7 July 2011]. Until 2011, PAs and CTs were compiled predominantly as thematic priorities and were geared towards prospective product (services) markets [Sokolov 2007; Poznyak, Shashnov 2011].

At the federal level, the Russian Ministry of Education and Science is responsible for S&T priority setting. The Russian Ministry of Education and Science regularly monitors the results of PA development projects through government programmes and special federal programmes, innovative development programmes by publicly owned companies, the development of technology platforms and other state policy instruments. Provisions are in place to collect statistical information on domestic spending on research and development in PAs (through federal statistical observation via the form ‘N2-Science’). This information allows us to judge the effectiveness with which these PAs and CTs are developed.

In 2013, the National S&T Foresight System was established in Russia, to support the prospective needs of the economy including the manufacturing sector, taking into account the development of key production technologies. Studies to identify socio-economic and S&T development areas particularly important to Russia in the medium to long term are conducted in the framework of this system. Strategic planning is supervised by the Inter-Departmental Commission on Technology Foresight of the Presidential Council for Economic Modernisation and Innovative Development’s Presidium.

For specific industries, this is performed by relevant federal executive authorities. Additionally, regional executive agencies design development strategies for Russian regions, which may indicate key R&D areas where the region’s leading production and research facilities should concentrate their efforts.

Priorities and documents (strategies, white papers, critical technologies, priority areas, etc.)

Key documents of the recently established National S&T Foresight System comprise the Russian Long-Term S&T Foresight; and Lists of priority S&T development areas and critical technologies for the Russian Federation. Whereas the first document sets the general framework for S&T development, the second identifies the most important inter-industry (inter-disciplinary) subject areas with potential for making the biggest contribution to accelerating economic growth, ensuring national security and increasing the country’s competitiveness. These lists were first adopted in 1996 (comprising 7 priority S&T development areas and 70 critical technologies); since 2002 they are approved by the Russian president. The lists were updated in 2002 and 2006. The current version was approved in 2011 and comprises 6 civil priority development areas and 26 critical technologies:

Energy efficiency, energy saving, nuclear energy

- Basic power electrical engineering technologies;
- Nuclear power engineering, nuclear fuel cycle, safe nuclear waste and depleted nuclear fuel disposal;
- Efficient organic fuel-based energy production and conversion technologies,
- New renewable energy sources, including hydrogen energy;
- Efficient energy transmission, distribution, and usage systems.

Life sciences

- Biocatalytic, biosynthetic and biosensor technologies;
- Genome, proteome, and postgenome technologies;
- Cellular technologies;
- Bioengineering technologies;
- Reducing negative impact of socially significant diseases;
- Biomedical and veterinary technologies;

Information and telecommunication systems

- Access to broadband multimedia services;
- Technologies and software for the distribution of high-performance computational systems;
- Electronic components bases and energy-efficient lighting devices;
- Information, management, navigation systems;

Nanosystems

- Computer modelling of nanomaterials, nanodevices, and nanotechnologies;
- Production and processing of construction nanomaterials;
- Production and processing of functional nanomaterials;
- Diagnostics of nanomaterials and nanodevices;
- Nanodevices and microsystem devices;
- Nano-, bio-, information and cognitive technologies.

Transport and space systems

- High-speed transport systems and smart control systems for new transport types
- Next-generation space-rocket and transport vehicles;

Efficient environmental management

- Monitoring and forecasting environmental trends; preventing and managing environmental pollution;
- Preventing and managing natural and anthropogenic emergencies;

- Searching, prospecting, developing natural resource deposits, and mining technologies.

In addition to the federal-level critical technologies, several ministries have developed industry-specific lists of critical technologies – e.g. for the energy and health sectors.

Certain priority development thematic areas and industries are specified in Russian federal government programmes – the key tool for allocating government budget funds. R&D is mainly funded through the following programmes:

- Russian Federal Space Programme for 2006-2015
- “Research and Development in Priority Areas of the Russian S&T Complex for 2014-2020”, which includes the Federal Targeted Programme “Research and Development in Priority Areas of the Russian S&T Complex for 2014-2020”
- Development of Civil Aviation Technologies in Russia in 2002-2010 and until 2015
- Development of Russian Spaceports in 2006-2015
- Development of Civilian Maritime Vessels and Equipment in 2009-2016
- Development of Electronic Components Base and Radioelectronics in 2008-2015
- Thematic area “Production of Next-Generation Diesel Engines and Components in the Russian Federation in 2011-2015”
- Next-Generation Nuclear Energy Technologies in 2010-2015 and Until 2020
- Development of Pharmaceutical and Medical Industries in the Russian Federation Until 2020 and in the Subsequent Period
- Support, Development and Application of the GLONASS System in 2010-2020
- Development of Russian Transport System in 2010-2020
- Federal Targeted Programme “Development of Education in 2011-2015”
- Development of the Russian Water Sector in 2012-2020”
- Nuclear and Radiation Security in 2008 and Until 2015
- National Chemical and Biological Security System of the Russian Federation (2015-2020)
- Increasing Road Safety in 2013-2020

National-level S&T priorities were also set in the scope of the National Technology Initiative (NTI), a programme of measures to create radically new markets, restructure existing industries, radically upgrade them on a totally different technological basis, and create conditions for Russia to achieve global technology leadership by 2035[National Technology Initiative, 2016].

NTI priorities comprise S&T areas were major breakthroughs can be expected, and markets which would provide quick solutions for specific important and relevant problems with economic and social development. Thus an integrated approach is assured, combining prospective demand- and supply-side aspects. At the same time markets to be included in the NTI must meet several criteria: be sufficiently large or have an adequate growth potential; contribute to national security; Russia should have a potential to secure a sizeable market niche.

Thus this tool should be primarily used to support the fastest-growing areas with relatively low level of technological readiness (e.g. photonics, neural technologies, advanced production technologies, etc.), and industries where major breakthroughs can be expected and where Russia has chances to become a leader. NTI would allow to lay down R&D groundwork and prepare the environment for accelerated development of critical technologies.

S&T priorities are not set exclusively on the national level. Numerous federal executive agencies put together industry-level priority systems, in the form of strategies, critical technologies, or roadmaps. This was done by the RF Ministry of Health, Ministry of Energy, Ministry of Communications, Ministry of Industry and Trade, Ministry of Transport, and some other departments. Additionally, regional authorities design development strategies for their regions. These may include R&D areas the leading regional production and research centres should concentrate on.

Another tool for supporting research in Russia is research foundations. For example, the Russian Science Foundation provides grants to finance basic and exploratory research in the following priority subject areas [Russian Science Foundation, 2015]:

- New technologies for the production and processing of heavy oils;
- New approaches to combating infectious diseases;
- Prospective manufacturing technologies;
- Inter-ethnic relations and ethno-social processes. Analysis of international and Russian experience. Reasons for conflicts and mechanisms for anticipating, preventing and managing them;
- Prospective industrial biotechnologies;
- Electrochemical and thermoelectrical technologies for power engineering;
- Smart technologies for robotics and mechatronic systems;

- Reducing risks and managing consequences of natural and anthropogenic disasters;
- Restorative, regenerative, and adaptive medicine;
- Prospective quantum communications and computing;
- New agritechnologies for managing the main sections of trophic chain to optimise the Russian population's diet;
- Neural technologies and cognitive research.

Priority setting methodologies and procedures

In 2014-2015, the Russian Ministry of Education and Science organised work on updating the current lists of priority S&T development areas and critical technologies. In the course of the new cycle of research, the focus was put on both increasing science's contributions to economic and social development by dealing with the most relevant objectives, and the practical application of results that were obtained in the identified priority areas. Priorities were updated taking into account the goals set by the national authorities, and the opinions of the expert community. This work resulted in a set of S&T development priority areas (PA) and critical technologies (CT) for the Russian Federation, constituting one of the most important instruments in the government's science, technology and innovation policy.

Principles, criteria and methods to select S&T priorities in the 2014-2015

The analysis of global experience in identifying S&T priorities shows that the methodical support and mechanisms used to select and implement priority areas and critical technologies are forever being improved in line with new global and national development challenges. However, a clear trend of systematic problem-setting and problem-solving, use of a wide range of varied information sources, including long-term S&T development forecast materials, and combinations of different qualitative and quantitative methods can be discerned [Meissner et al 2013].

These trends fully emerged when S&T priorities were being updated in Russia and were characterized by a pronounced practical focus on increasing the contribution of science to the development of the economy and society.

Basic principles of modifications to priority areas and critical technologies:

- a focus on solutions to key socio-economic problems;
- a temporal implementation horizon of 10 years;
- concentrating on three fundamental criteria during their selection: contribution to economic growth, solving social problems and ensuring technological security;
- opportunities to harness competitive advantages (the country's territory, existing stocks of resources, etc.);

- evaluating the accessibility of any resources required (finances, human resources, material and technical resources, scientific and technological advances, etc.);
- taking into account global science, technology and innovation development trends;
- selecting a limited number of the most important S&T priorities with a view to concentrating existing resources on them.

Calls to develop Russia's S&T potential and the need to concentrate this potential on the most important areas of economic and social development in view of anticipated technological breakthroughs lie at the foundation of the updates to the national S&T priorities system.

Special attention was paid to opportunities to harness the country's competitive advantages, so a restricted number of the most important S&T priorities were chosen which are capable of being fully implemented in Russia.

A system of criteria was used to select the critical technologies which takes into account their contribution to economic and social development and to guaranteeing the technological security of the country.

CT selection criteria:

- the economic effects of implementation, including:
  - opportunities for domestic producers to occupy niches in new markets or new segments of existing markets;
  - increasing the competitiveness and quality of products;
  - increasing production volumes and workforce productivity;
  - reducing the extent of annual losses;
  - reducing energy- and material-intensive production.
- the social effects of implementation, including:
  - increasing the population's quality of life;
  - increasing life expectancy;
  - solving demographic problems;
  - reducing the level of social tension.
- the contribution to ensuring technological security, including:
  - import substitution of mass-market products in the domestic market;
  - overcoming the dependence on imports of critical technologies, equipment and products;
  - reproduction of strategically important resource types;
  - guaranteeing the security of complex technical facilities.

S&T priorities modification procedure

Current priority areas and critical technologies were modified in the round now ending according to the system shown in Figure 2.

In the context of the procedure to adapt the priority areas and critical technologies, special attention was paid to establishing a system of targeted S&T priorities geared towards solving some of the most important socio-economic problems. However, analysing the challenges and treats caused by instability in global and regional processes, and a wide range of factors holding back growth in the Russian economy, played an important role. Calls to develop Russia's S&T potential and the need to concentrate this potential on the most important areas of economic and social development in view of anticipated technological breakthroughs lie at the foundation of the approaches used to establish the national S&T priorities system. Nevertheless, a comprehensive approach was used, ensuring that the clear goals set out in official documents and proposals by federal executive bodies were taken into account alongside recommendations from the expert community.

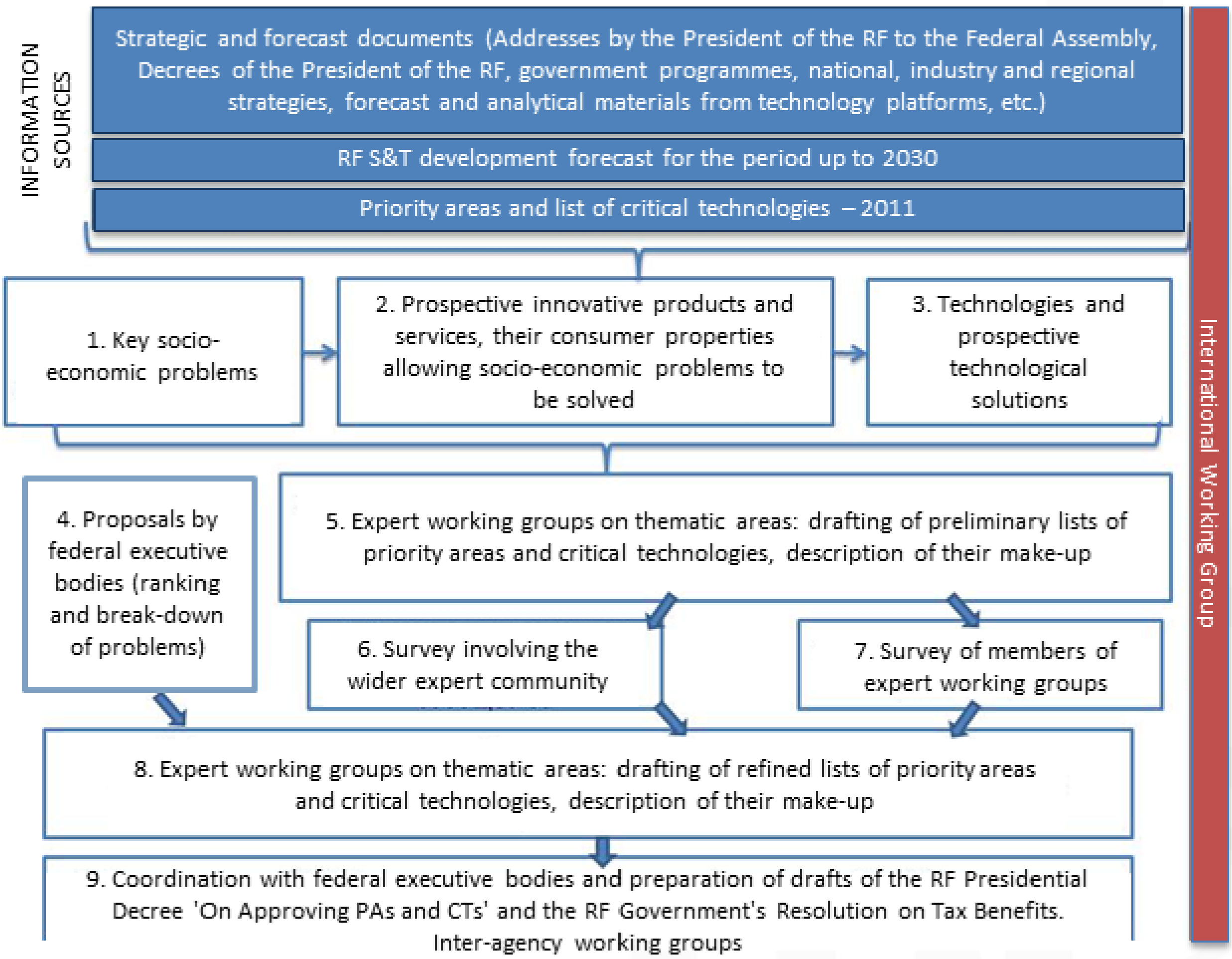

Figure 2. Priority areas and critical technologies modification system

This work required the use of a complex approach making it possible to take stock of the clear-cut goals expressed in official documents and the proposals of executive bodies alongside recommendations from the expert community.

A special Interdepartmental Working Group (IWG) was established to coordinate the work, which included representatives of federal executive authorities, the Presidential Administration, the Russian Academy of Sciences, development institutes, leading national R&D and production centres and universities. The IWG developed a methodology for updating the lists, and priority selection criteria. Nine expert groups were formed for thematic areas, comprising leading professionals in relevant fields representing the government, scientific and business communities. Members of the IWG and thematic working groups took part in a series of expert discussions, surveys, and in-depth interviews.

An important feature of this round of modifications was the use of results from the S&T Development Forecast for the Russian Federation for the period up to 2030 [Sokolov A., Chulok A., 2011] as the information base. First, using these materials, global and national socio-economic development challenges were evaluated and a list of prospective markets for innovative products (services) and technologies allowing Russia to commit to the current trajectory of stable innovative development was drawn up. In addition, data sheets on current critical technologies, results from critical technology implementation monitoring and materials from foreign analysts and foresight studies were used as the information and analytical base.

1. Key socio-economic problems

In this work, particular attention was paid to establishing a system of key socio-economic problems which will shape the science and technology agenda for the next 10 years. To this end, a wide range of information and analytical sources was analysed, including strategic and foresight documents on national, industry and regional levels (messages and decrees by the President oft the Russian Federation, government programmes, industry and regional programmes and development concepts). Following this work, a summary list of goals and problems, comprising more than 30 items, was drafted. These problems were then analysed in terms of their importance for Russia as a whole and for individual industries and regions and the potential contribution that science and technology could make to solve these problems and their feasibility. This resulted in the creation of a list of the 85 most important socio-economic objectives, grouped into several main blocks:

- ensuring sustainable and balanced economic growth;
- creating the necessary conditions for sustainable development and combating the causes and consequences of climate change;
- sustainable energy and water supply;
- balanced development of the regions and a balance in the development of cities and towns;
- maintaining and supporting the health of the population and guaranteeing active longevity;
- ensuring the population's security.

2. Prospective innovative products (services)

For the problems making the final list, preliminary lists of prospective innovative products and services which will help to solve these problems were drawn up. Special attention was paid to those which were deemed to be critically important (without which the problem cannot be solved). The properties (parameters) of the chosen products and services which allow the problem to be solved were indicated.

3. Technologies and prospective technological solutions

This list comprised specific technologies which are critical to the creation of the identified products and services (they enhance 'weak' points and allow the required consumer properties to be achieved in the products and services). The potential for development and practical implementation of the technology in Russia, together with possible risks and limitations, were also evaluated. Alongside this, any technologies which need to be developed in order to produce certain innovative products immediately were identified. From this list of specific technologies, blocks were created ('technological solutions') bringing together technologies which are similar (uniform) in terms of their development methods and principles. Based on this analysis, whole chains of 'problems – products – technological solutions' were formed which were subsequently refined through expert review procedures (an example of this breakdown in the 'Environmental management' area is given in Fig. 3).

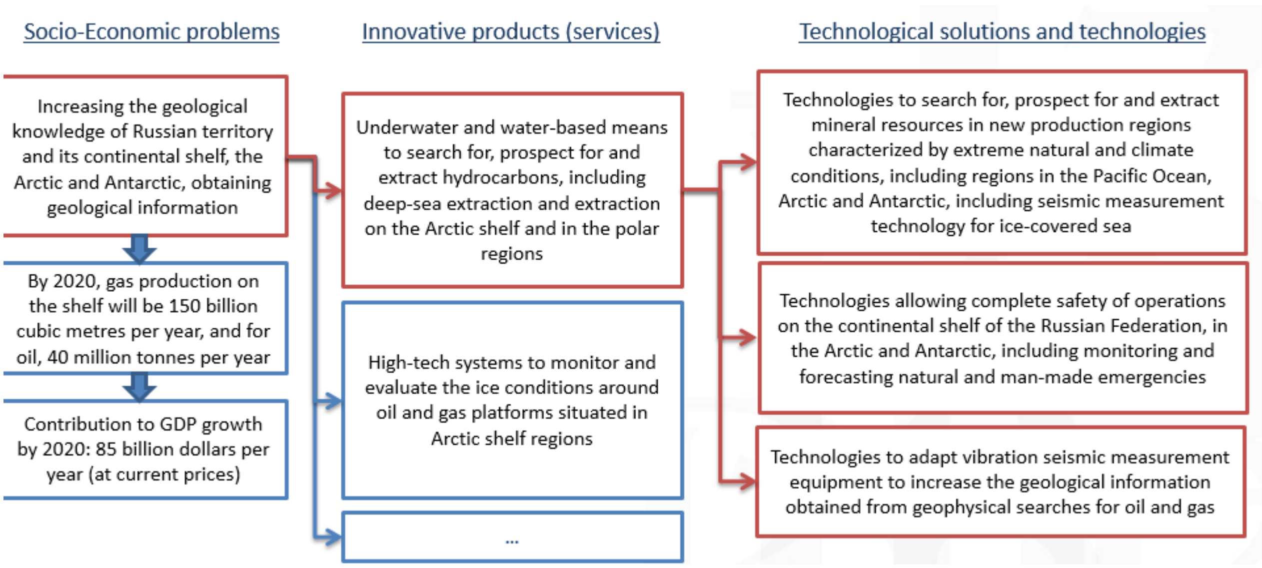

Figure 3. Breakdown of socio-economic problems: identifying some of the most important products and technologies (using environmental management as an example).

Having analysed these chains, new proposals on the formulation of priority areas and critical technologies were prepared. These took into account the resources required for their implementation (financial, human, material, etc.) and the possibility of using alternative technological solutions and importing individual technological solutions in the corresponding area.

Expert procedures

In order to establish the final lists of critical technologies, a series of expert studies were carried out: surveys and interviews of representatives of the expert community and federal executive bodies and moderated discussions involving members of specially created thematic expert groups (in total more than 20 discussions). In total, more than 400 experts took part in the expert procedures - representatives of leading research institutions, higher education institutions, the business community, federal executive bodies, development institutes, science and research support foundations and other organizations (Fig. 4). Experts took part in various surveys and interviews and in two rounds of expert discussions.

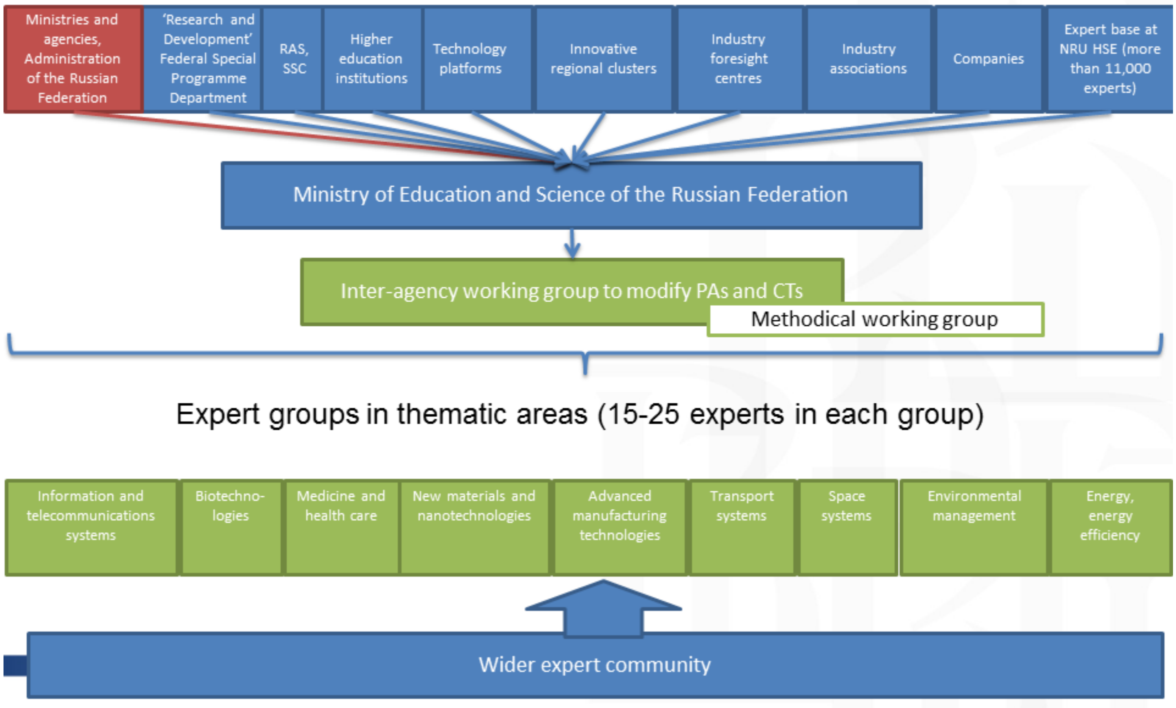

Figure 4. Formation of the expert community

Thematic groups were formed in the following areas which guaranteed continuity with the current priority areas:

- biotechnology;
- medicine and health care;
- information and telecommunications technologies;
- space systems;
- transport systems;
- new materials and nanotechnology;
- advanced production technologies;
- environmental management;
- energy efficiency and energy saving.

Expert working groups in the thematic areas comprised 15-25 individuals. The make-up of each group was balanced in order to represent the different types of organizations. They included representatives from federal executive bodies and development institutes (2-3 individuals), representatives from the business community (4-8 individuals), and representatives from research centres and higher education institutions (12-15 individuals). The representatives in the working groups from the scientific community were selected based on the results of a bibliometric analysis, while the representatives from the business community were chosen based on proposals by large companies, companies implementing innovative development programmes, technology platforms and innovative regional clusters. To ensure that the experts' work was as productive and amenable as possible and to avoid pressure from some experts on others, the decision was made that there would be no 'heads' of the working groups; all experts would work on a par with one another. Where necessary, expert working groups could exchange information with one another to reflect any critical technologies which were interdisciplinary in nature in their final lists.

New lists of priority areas and critical technologies

After modifying the existing PAs and CTs having involved representatives from federal executive bodies and the wider expert community, eight priority areas for development in science and technology and 25 critical civilian technologies were selected for their role in helping to solve socio-economic problems and for their potential for practical use in the medium-term and for significant socio-economic effects.

These priority areas included:

1. Safe and efficient energy
2. Bioindustry, bioresources and food security
3. Biomedicine and quality of life
4. Information and communication technologies and systems
5. Space vehicles and systems
6. Next-generation materials and production technologies
7. Environmental management and environmental security
8. Transport and transport systems

All of the chosen priority areas and, in particular, next-generation materials and production technologies, information and communication technologies and bioindustry, transport and space vehicles and systems, are in line with current global S&T development trends. There is close interaction between each of these areas: achievements in new materials contribute to progress in microsystems and information technologies, and microsystems and information technologies in turn stimulate the emergence of new production and transport technologies. Research and development carried out within these priority areas is geared towards 'sustainable production' and production with high added value, allowing for the output of competitive products with the highest possible level of consumer properties while at the same time ensuring that natural, material, human, financial and other types of resources are used efficiently. Thus, there are significant opportunities opening up to increase the competitiveness of Russian products, improve the socio-economic development of the country and raise the population's quality of life.

A list comprised of 25 critical technologies was composed for the selected priority S&T areas – those with the highest potential contribution to accomplishing major national socio-economic objectives, and to innovation-based technological development of the country. The lists were agreed with all relevant federal executive authorities, and Russian Academy of Science provided the basis for the draft presidential decree.

Implementation of thematic priorities (basic research programmes, thematic and industry-specific programmes, etc.)

- Lists of priority S&T areas and critical technologies are among the key STI policy mechanisms applied by federal authorities, development institutes, R&D and production organisations, and other participants of the national innovation system (among other things) for the following purposes:
- shaping medium- and long-term socio-economic, innovation, and S&T policy;
- developing, implementing, and adjusting industry-level national strategic planning documents and national programmes, including federal targeted S&T development programmes;
- composing lists of industry-specific critical technologies;
- developing and adjusting regional-level strategic planning documents, including regional development programmes;
- operational activities associated with organising calls for proposals (project tenders) by development institutes and support foundations;
- designing and adjusting innovation-based development programmes for companies with public participation, strategic research programmes for technology platforms, and development programmes for innovative territorial clusters.

R&D conducted in the framework of priority S&T development areas and critical technologies are supported through national and federal targeted programmes; the key tool is the federal targeted programme "R&D in Priority Development Areas for the Russian S&T Complex in 2014-2020" (supervisor – the Russian Ministry of Education and Science) (the previous programme covered the period between 2007-2013). The programme's budget is envisaged at almost 240 billion roubles (82% to be allocated out of the federal budget). The programme covers applied research and development in priority S&T areas, the development of R&D infrastructure, facilities and equipment, and supporting international projects, including in the framework of cooperation with the EU member states.

Another mechanism for developing priority S&T areas and critical technologies is providing tax breaks and other benefits for conducting relevant R&D. Detailed description of critical technologies has formed the basis of the list of tax-deductible R&D.

The Russian Ministry of Education and Science annually monitors the development of priority S&T areas and critical technologies; the relevant data are collected through official statistical surveys and from accounting documents. The monitoring covers federal executive authorities, the Russian Academy of Sciences, technology platforms, innovative territorial clusters, foundations supporting science, technology and innovation, various organisations active in science and innovation, and other participants of the national innovation system. The data collected in the course of the monitoring subsequently can be applied to update the lists of priority S&T areas and critical technologies. Analytical reports on R&D results are submitted to the RF government.

Conclusion

Best international practices of priority setting indicate that in recent years, the logic of this process was largely determined by the need to apply the priorities in the context of designing national socio-economic development strategies, oriented towards meeting current global and national-level challenges. Therefore the need arises to upgrade methodological support for priority-setting to meet this requirement, which implies more active involvement of a wide range of relevant stakeholders including representatives of civil society, adequately taking into account their interests, and more closely matching the priorities with existing (and newly developed) policy tools.

S&T priority setting process is increasingly oriented towards meeting global and national-level challenges, it refers to all major elements of setting priorities: approaches and techniques, information background, engagement of stakeholders, formal procedures, etc. Examples of best international practices (UK, Germany, etc.) reveal a number of significant developments in these activities (see table 1). Specific approaches and solutions vary depending on the national priority setting context and relevant legislation, the number of major players in the field and their objectives, and available STI policy tools.

In Germany and the UK, a wide range of stakeholders are involved in priority setting, supported by specialised Foresight organisations actively using various approaches and techniques based on this methodology. When such tools are being selected, significant attention is paid to availability of reliable evidence, and particularly in the case of horizon scanning. Both countries have broad and coordinated various-level priority systems (national, industry-specific, and institutional), supported by a range of implementation tools, and systemic evaluation of achieved results. On the whole, priority setting and implementation play a sound role in increasing performance of their national innovation systems.

At the same time, the abovementioned and other countries alike face numerous unresolved problems and limitations hindering more efficient S&T priority setting and implementation.

Table 1. Priority setting. Recent developments and problems

Components	Recent developments	Problems
Approaches and methods	Application of Foresight methodology which implies combining quantitative and qualitative techniques depending on the objectives, including bibliometric and patent analysis Combining top-down and bottom-up, networking and consultative approaches, which increases and extends their potential	Need to further develop methodology for integrating quantitative and qualitative techniques for priority setting purposes Need to determine optimal priorities' aggregation level to match science, technology and innovation socio-economic policy's objectives
Involvement of stakeholders	Broad involvement of national innovation system's participants (public authorities, development institutes, science, business, etc.), and professional experts Development of methodological tools to take into account and reflect their interests during priority setting Valid experts selection procedures based on objective qualifications criteria	Insufficient involvement of civil society representatives Practically zero involvement of "common citizens" in priority setting
Information background	Creation of a reliable evidence base comprising medium- to long-term forecasts, results of previous priority-setting exercises, and other Foresight projects Consideration of account national and international context, and results of benchmarking	No established procedures for assessing potential effects of priority implementation Insufficient integration with results of priority implementation assessment
Selection procedure	Procedures for applying multiple-stage priority-setting techniques in the course of drafting initial lists subsequently to be approved on the political level Development of detailed recommendations at various priority-setting stages, among other things to ensure reproducibility of results and transparency of procedures Availability of legislation and organisational structures supporting priority setting Priority-setting participants receive support by professional Foresight organisations	Need to find optimal balance between "democratic" and "managed" procedures Insufficient reflection in priority-setting process of requirements arising from the need to subsequently integrate the priorities into national policy shaping Domination of expert opinions in priority setting process Insufficient consideration of "common citizens'" interests in priority setting No established procedures for final selection of priorities (insufficient transparency); danger of individual participants' lobbying specific interests

Both recent developments and problems related to S&T priority setting were analysed for case of Russia. The priority setting and critical technology selection project commissioned by the Russian Ministry of Education and Science and implemented in 2014-2015 was largely devoted to finding adequate solutions for the above-mentioned and other problems.

A number of innovative solutions were proposed for priority setting and critical technology selection methodologies and toolsets, to increase their relevance to the major requirements of the economy and society. The proposed approach is largely based on the results of the Russian S&T Foresight: 2030 (see Gokhberg, 2016) reflecting global and national trends, challenges, and windows of opportunity; prospective markets, major innovative products, services, and technologies; as well as relevant R&D areas. The extended set of tools was complemented with detailed formalised priority setting procedures based on active engagement of the expert community.

New priorities are oriented towards existing or prospective S&T policy tools, including the National Technology Initiative, technological platforms, innovative programmes of large state-owned companies, and innovative clusters. The suggested approach aimed at bringing S&T development priorities closer to the actual needs of the economy and society.

Practical use of the revised approach has shown a number of problems to be resolved. Among the key problems was lack of available information, in particular related to funding priority areas. Therefore it was recommended to launch a system for monitoring S&T priority areas and critical technologies in order to ensure regular assessment of technology trends, allocation of resources, and their contribution to the country's socio-economic and science and technology development. The monitoring system is orientated towards measuring not just overall scientific value of new technologies, but also their contribution to accomplishing important socio-economic objectives.

Concentrating resources on the selected priority areas and critical technologies should allow the government's and business' efforts to be directed at developing existing and creating new technologies which are required to solve strategic social problems, accelerate economic growth, reinforce technological security and increase the competitiveness of the Russian Federation. However, to achieve these effects, the key attention should be paid to the implementation of these priorities, as well as to coordination of efforts of all actors involved: federal executive bodies, SMEs and the scientific community.

One of the instruments for planning the implementation of priority setting and critical technologies is a system of technology roadmaps specifying objectives of particular technology areas as well as possible (e.g. alternative) ways to accomplish them. It could become an efficient strategic planning and priority implementation tool. Such roadmaps should include descriptions of chronologically coordinated "technology routes" and relevant policy instruments, e.g. R&D programmes, strategies for developing technologies and innovative products, and entering new markets.

Roadmaps could also be useful for informing potential users of S&T priority-setting results, since they allow the business community to have a visual presentation of opportunities opened by commercialisation and application of breakthrough solutions offered by critical technologies, and investors – to better understand potential areas for, and conditions of making investments. Roadmaps can also be used by executive agencies, both on the federal and regional levels, to help shape S&T and innovation policies; by R&D organisations and universities to plan and set priorities for their S&T, innovation, and educational activities, find prospective projects and programmes to take part in, and potential partners.

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