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Energy technology Foresight 2030 in Russia: an outlook for safer and more efficient energy future

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Abstract

Russia is one of the key players at the world's energy markets. The country's plans to further research and innovation in the sector impact the world energy outlook.

The paper examines the energy block of the Russian S&T Foresight 2030, developed by experts in 2011-2013 and approved by the Prime minister in January 2014. The official document, which covers six areas, including 'Energy efficiency and energy saving', defines the key science and technology (S&T) areas Russia has to embark upon in order to boost its competitiveness. The energy part of the study covers global challenges, threats, and opportunities for Russia, prospective innovative markets for its products and services. Moreover, Russia's innovative technologies and products are assessed, including the potential demand and competition aspects and benchmarking against global leaders.

The paper features major outcomes of the energy block and puts the exercise in a comparative perspective with similar international studies of Kazakhstan, Germany, Canada, the UK, USA and international organizations.

The author concludes that in Russia energy efficiency and energy saving priorities dominate the policy agenda, with relatively little attention to advancing renewable energy technologies. The Foresight horizon is also markedly shorter than that of similar studies in the OECD countries. Following international practice, in 2015 Russia plans to perform a new government-led S&T Foresight for the energy sector alone.

Energy technology Foresight; energy efficinecy, Russia

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1. Introduction

In Russia the plans for long-term sustainable and efficient development of the energy industry are grounded in the country's leading export positions, and the industry's role in generating government budget revenues. However, the industry itself is very energy consuming and for a long time innovative ways of energy production were low on the priority list [1-320]. Moreover, the industry is highly inertial, has a long investment cycle, the development of new technologies requires substantial time and investments, as well as interdisciplinary research. Therefore, in practically every sub-sector there are several possible scientific and technological development paths to pursue, and a wrong or non-optimal choice may result in major losses and increased lag behind the leaders.

For this reason, Russia is regularly performing national S&T Foresights that cover energy as one of the areas. These are approved at high level (President or Prime minister), and further detailed in the 'Lists of priority areas and critical technologies'. The Russian key objective of Foresight 2030 is rather broad – to identify prospective science and technology areas that address major social and economic issues and boost country's competitiveness. The data sources for the study are more than 2,000 experts in 15 countries, over 200 international and national Foresight studies, as well as statistical, bibliometric and patent data. High-level expert panels were held to discuss the key milestones. Certain 'Energy efficiency and energy saving' study outcomes were specified by Grebenuyk et al. [2].

Energy Foresight is a tool employed by developed and developing economies (China, France, Greece, Kazakhstan, the UK, USA, Japan, South Korea, Thailand and others), well described in the literature [3; 4; 5; 6: 7; 8; 9; 10]. Not surprisingly many authors focus on the methodological details of Delphi Survey as the cornerstone of the study [for ex. 11, 12].

The paper starts with a review of global trends and the ones that are most relevant for Russia identified in national, sectoral and corporate energy technology Foresights. Further, the main outcomes of the Russian energy Foresight are outlined, including priorities and the future energy vision, the ways Russia will influence and be influenced by the global trends, future markets, products and services, as well as country's promising science and technology areas. After that the Russian study is compared with similar ones performed in other countries, including objectives, thematic priorities and time horizon. Finally, the paper offers conclusions and future implications of the study.

2. Russian S&T Foresight 2030: outcomes for energy

2.1 Global challenges affecting Russian energy sector

Among the most important factors in the post-industrial energy paradigm are advancing growth in sectors and high-tech industries with low energy consumption, the use of a wider range of energy sources, localized production and bringing production nearer to consumers, and the introduction of energy efficiency programs, expand smart energy grids and energy information systems. By 2035 a modest increase in energy demand is forecasted in OECD countries. At the same time it is expected that the share of oil and coal (and, in some countries, nuclear fuel) in the total energy consumption will decrease, while the share of natural gas and renewables will grow [13].

Russia faces the exhaustion of traditional hydrocarbons and prospects to explore them in complex locations. Similarly a significant proportion of global oil supplies prospected over the last 20 years are in hard-to-reach locations, which means that development of the sites and setting up the corresponding infrastructure is resource and energy intensive [see, for example, 14; 15]. All forecasts assign USA the leading role in the production of tight oil [18; 19]. According to some estimations over 70% of the liquid hydrocarbon growth in 2010-2025 will happen in the segments of high-technology exploration and alternative fuels, such as liquefied gases, GTL/CTL and biofuel [17]. Nuclear energy also requires new technologies: in 40-50 years or earlier the world will face the exhaustion of the world's supplies of Uranium-235 [16].

More stringent environmental demands on energy and climate change (the increase in the average annual temperature on the planet; changes in rainfall and glaciers; and the rise in sea level and the risk of extreme weather phenomena) are forcing Russia to introduce national legislation in the energy sector in line with the new realities and international practice. This trend is highlighted, for example, in Foresight and regulatory documents of the Asia-Pacific Economic Cooperation [20], Russian companies (i.e. JSC “Gazprom”), Organization of the Petroleum Exporting Countries [14]; and the European Union (EU).

The development of renewable energy technologies is a challenge for Russia, oriented towards the use of traditional sources. According to forecasts of international organizations and companies (IEA, International Gas Union, Organization of the Petroleum Exporting Countries, ExxonMobil, Shell, etc.), the share of renewables in the world energy consumption in 2030 will reach from 14% to 23% [13; 21], Forecasts of international organizations and companies also point to a more active use of industrial and household wastes as energy resources [22; 20].

New types of fuel cells based on hydrogen could come to compete with other power sources [23- 64]. Their development requires a significant reduction in costs and the creation of infrastructure and a market for corresponding devices. There is potential to develop hybrid energy plants generating power in excess of 20 MW and with an efficiency factor above 70% based on high-temperature fuel cells. Although these technologies are currently in the early stages of development, their high potential is noted by many countries and international organizations [see for ex., 18; 20].

The development of advanced fast neutron reactors and closed nuclear fuel cycle technologies will make it possible to considerably increase the efficiency of nuclear fuels and significantly reduce radioactive waste volumes. These technologies are given attention in Russian and international Foresights [see for ex., 23; 24].

Taking into account the main global challenges in the area of ‘Energy efficiency and energy saving’, the most relevant ones for Russia are insufficient volumes and poor efficiency of geological prospecting work; the location of new deposits in extreme climatic and geological conditions; low level of extraction and deep processing of raw materials; lack of technologies to efficiently transfer electricity over long distances; low energy-saving in final consumption; high level of monopolization in domestic energy markets, lack of competition and prohibitively high entry barriers for any link in the value chain. The mentioned challenges that Russian energy sector and the economy are facing force researchers and policy-makers to seek for responses.

2.2 Prospective energy markets and products for Russia

In the Foresight study the prospective markets, products and services were considered in relation to certain groups of energy resources: natural, recycled, converted and secondary, or by-products. Innovative products and services for the "Energy Efficiency and Energy Saving" priority area are shown in Table 1.

Table 1. Prospective markets and product groups for the "Energy Efficiency and Energy Saving" priority direction

Markets	Groups of innovative products and services	Characteristics
Oil from unconventional deposits and unconventional oil	Heavy (less than 20º API) and super-heavy (less than 10º API) oil Oil sands and bitumen (less than 10º API, high viscosity) Oil extracted from rocks with low permeability (including shale), and liquid hydrocarbons related to the extraction of shale gas Bazhenov formation oil (including kerogen)	Higher production cost value compared with traditional oil cost value More "dirty" extraction technologies compared with those used when extracting traditional oil Expanding extraction volumes and geography Unsuitability of existing pipelines for transportation Processing technologies are in the rudimentary stages
Natural gas from unconventional deposits	Coal methane Shale gas Gas from low permeability rocks Gas from deep bedrock Gas-hydrates Water-dissolved gas	Higher development costs compared with traditional gas deposits Expanding extraction volumes and geography Need to use new methods for transportation, mainly by sea, which makes transportation more expensive and restricts unit volumes
Liquefied natural gas	Floating regasification terminals (floating storage regasification unit, FRSU) Plants to liquefy gas on-shore, dispatcher terminals, including ports, capacity to store liquefied natural gas, installations to load ships (methane tankers) Methane tanker fleet Floating plants to produced liquefied natural gas (floating liquefied natural gas, FLNG)	Need to create an entire transport infrastructure "from nothing" Creation of new sources of man-made risks Mobility of shelf gas extraction Mobility of natural gas delivery and dilution
Alternative motor fuels	Synthetic motor fuel made from natural gas, coal or biomass Hydrogen for power generation in fuel cells used in vehicle engines Electrical energy taken from the grid, in electric cars	Increase in man-made and environmental safety of storage and operation Reduction in production cost value Growth in delivery reliability
Fuel cells	Fuel cells with proton-exchange membranes / with polymer electrolytes Phosphate acid fuel cells Fuel cells with carbon fusion Alkaline fuel cells Solid oxide fuel cells Direct methanol fuel cells *Other types of fuel cells are at various stages of development*	Increased efficiency in converting the chemical energy of a fuel into electricity Small footprint Increased capacity High cost of platinum used as the catalyst
Long-distance transfer systems for electricity and fuel	Technology for applied superconductivity (high-temperature superconductors) Gas-insulated lines to transmit high power electricity	Low transmission loss Increased transport volumes per time unit Broadened consumption geography
Storage of electricity, heat and cold	Pumped-storage hydroelectricity Air-storage installations Superconductive magnetic energy storage Electrochemical batteries	Increased working time and battery power Increased efficiency of energy conversion Increased electricity supply reliability

Markets	Groups of innovative products and services	Characteristics
Prospective nuclear equipment and nuclear power generation	High-power fourth-generation thermal neutron nuclear power reactors Fast neutron nuclear reactors High-temperature nuclear reactors Low power reactors Innovative pressurised water reactor Optimal NPP generating unit control systems Nuclear district heating	Improvements in technological and environmental safety Increased volumes of non-hydrocarbon energy production
Bioenergy fuel	Bioethanol Biodiesel	Reduction in production cost value Improved operating characteristics Increased energy output
"Smart" grids	Smart networks as part of a Unified Electricity System within the country Smart mini- and micronetworks based on distributed generation	More effective operations, optimization and load distribution across the network Reduced need for large-scale capital expenditure on new substations and power lines

Among the innovative groups of products and services listed above, experts have identified those that will have a radical impact on the global markets in the long term. In ‘Energy efficiency and energy saving’ these primarily relate to fuel with significantly improved characteristics and consumer properties; energy resources produced with the use of innovative technologies or those ones with high consumer qualities and market potential (i.e. electricity from wind turbines, liquefied natural gas, etc.).

For those products, which have a radical impact on the global markets in the long term, key Russian and foreign centers undertaking research and development in these directions have been identified. Among the leaders in this field are organizations from the USA, the EU (primarily, France, Germany, UK and Norway), China and Japan.

2.3 Prospective directions for energy research

Having reviewed the key prospective markets, as well as the most innovative products and services that are likely to appear before 2030, the Foresight study points to existing Russian scientific and technological groundwork in these fields. Here fourteen thematic areas of applied research with the greatest potential were identified.

In fossil fuel production, among the most important research and development areas there are robotic installations for submarine and subterranean hydrocarbon production, remotely controlled and with prolonged automated operation periods; and the development of technologies for efficient hydrocarbon production at unconventional sites (including gas hydrates, oil sands, extra-heavy crude oil, shale gas, coal bed gas) and under anomalous conditions (dense formations, abnormally high pressure, ultra-deep horizons, large depths, low volume density of resources, etc.). Technologies for deep processing of substandard natural gas and low-grade coal resources to produce competitive motor fuels and chemical products are also being actively developed.

Thermal power engineering will develop along the line of materials and technologies used to create highly-mobile high power gas turbine installations with maximum efficiency ratings and minimum harmful substance emissions which in the long term will serve as a key energy base. Intensive research into safe fast neutron and closed cycle nuclear reactors – an important element of centralized energy supplies – is continuing. The development of low power energy is linked to the creation of low-temperature long-life fuel cells with maximum efficiency, with no special requirements to fuel quality and low acquisition and ownership costs.

Regarding renewable energy production, the range of research topics pursued is rather wide: designing inexpensive photoelectric converters with very high efficiency factor and long service life, utilizing the full solar radiation spectrum; development of technologies for high-capacity marine wind-power engineering, to ensure reliable operation of deep-water far-from-shore installations; and development of high-performance hydrogen production technologies based on photochemical and electrolytic water decomposition. As regards distributed energy generation from sustainable sources, high-capacity and high-power low cost energy storage technologies are coming to be of critical importance. Bioenergy plays a special role as it is becoming a new segment of the industry that placed new environment protection and climate change requirements.

The development of energy saving technologies and equipment remains among the major trends of power engineering. A new impetus to advance energy-saving will come from research of smart local power systems with automated real-time management of energy consumption based on integrating electrical and information networks.

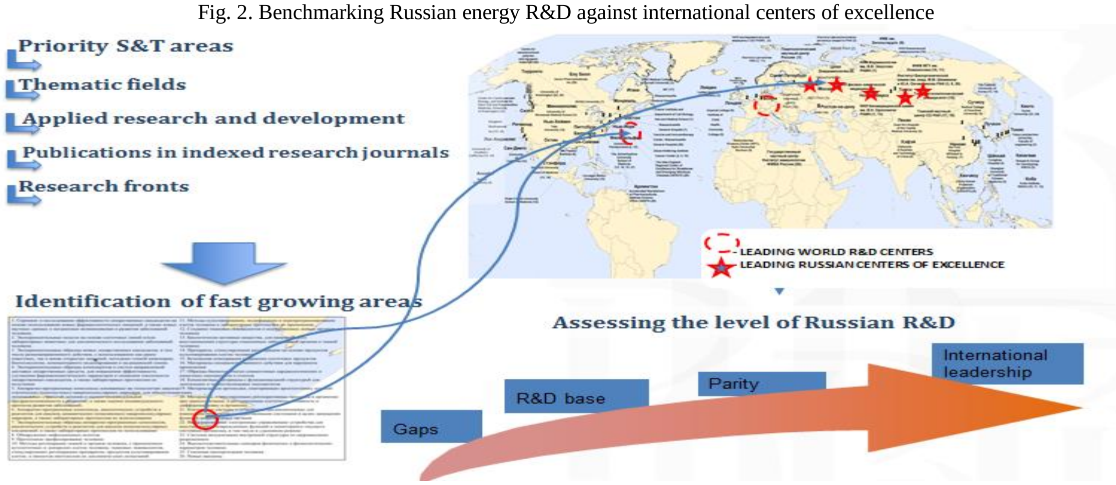
Expert assessments of the level of research in Russia in ‘Energy efficiency and energy saving’ vary considerably: from "blank spots" in fields such as gasification of next-generation solid fuels and technologies and remote control energy equipment to recognition of significant groundwork comparable to global developments (in particular, in safe fast neutron reactors and technologies to extract certain types of untraditional hydrocarbon resources).

3. The study implications and international comparisons

The official document based on the outcomes of Russia’s S&T Foresight 2030 is used in national strategic planning. It will also be the starting point for the upcoming sectoral (energy) Foresight 2035 (due in 2015) and corporate Foresights of the major Russian energy companies [25].

An important element of the study is benchmarking Russian energy R&D against international centres of excellence. This was done through bibliometric (publications, citations, research fronts) and patent analysis, as well as via expert procedures.

Fig. 2. Benchmarking Russian energy R&D against international centers of excellence



The main differences between the Russian and other national and international energy Foresights could be grouped into the following categories: objectives, thematic coverage, time horizon, and level of detail (pertaining to lists of technologies and R&D).

Few international (and only one Russian) future energy studies focus of science and technology. Most of them look into prospective supply and demand [for ex. 16, 20], national and global trends in the industry [for ex.9, 13] and other aspects.

The objectives of the first group of energy foresights are often linked with attaining some key policy goal, i.e. 50% reduction of CO_2 emissions, or ensuring the achievement of a national policy target [for ex., 26, 27, 28, 29]. Compared to these, the objectives of the Russian national S&T Foresight (including the energy area) are rather general (i.e. to identify prospective science and technology areas) and not specifically linked to any policy target. In this way, they are somewhat similar to objectives of the second group of studies, including documents like Canada's Energy Future 2013 and APEC Energy Demand and Supply Outlook [20, 30]. Moreover, the Russian Foresight does not offer a tool for tracking the progress or measuring the input of selected technologies and products in energy efficiency/ energy saving. Like in many countries, official statistical measurement of energy efficiency is done primarily through energy consumption and energy intensity indicators [31].

Most international foresights feature rapid advancement of renewables that will represent a substantial share in final consumption in the next 20-30 years up to 17 percent in the global energy balance [for ex. 32, 33]. Although the focus of the energy part of the Russian S&T Foresight 2030 spreads from fuel cells to bioenergy and smart grid, this has not yet been appropriately reflected in national priorities and strategy documents. The national targets and programs concentrate on advancing technologies for extraction of mineral deposits and nuclear energy technologies. Renewables that occupy prominent positions in many international Foresights [for ex. 34] are forecasted to make up only around 2 percent in total power generation in Russia in 2020 (with the exception of large hydropower stations 25 megawatt and above) [33].

The Foresight horizon of the Russian study is 17 years (2013-2030) and the country's key document in the sphere, Energy Strategy 2035, is due early 2015. Other sectoral documents and studies cover similar time span. The 15-20 years horizon of the Russian documents contrasts with the 20+ and 30+ horizon of many similar documents prepared in OECD, OPEC, APEC and the IEA [13, 14, 20, 30].

4. Conclusions

As the list of prospective markets and products identified through energy Foresight is rather long, the Government will have to make priorities which to support and offer to shift the bulk of investments to business. State-owned energy companies, which dominate the Russian market, may implement some R&D projects through their Innovation Programs, which they were obliged to compose and follow 3 years ago. However, market monopolization works against creativity and innovation.

Given its heavy dependence on extractive industries, Russia is incrementally moving to the 'green economy', and this fact is reflected in the composition of prospective science and technology areas identified in the course of national S&T Foresight 2030. Although the pace of this move is very slow and there is still a long way ahead, some of the Russian R&D centers attained parity or international leadership in certain technologies and products/services.

Harsh external conditions for the Russian energy sector that prevailed in 2014, including sanctions and the fall of hydrocarbon prices, should contribute to the development of advanced and alternative technologies in all energy and other adjoined sub-sectors.

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