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WATER RESOURCES – AN ANALYSIS OF TRENDS, WEAK SIGLANS AND WILD CARDS WITH IMPLICATIONS FOR RUSSIA

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WATER RESOURCES – AN ANALYSIS OF TRENDS, WEAK SIGNALS AND WILD CARDS WITH IMPLICATIONS FOR RUSSIA[4]

Water resources are crucial for the continuity of life. Humans and living species need fresh water for drinking and sanitation, while industries in most sectors of the economy need water for some part of production processes themselves. Access to fresh water is a grand challenge at the global level, mainly due to increasing water consumption, a low rate of replenishment of resources as well as external factors, like climate change, that significantly reduce amount of water available. The solutions to the existing water problems require systemic approaches for the sustainable use of water resources, while advancing water infrastructure and providing circular use of water.

Russia is one of the countries, which is relatively better positioned compared to a number of other countries in the world regarding the availability of water resources. However, there are still considerable issues regarding the protection and use of water resources, purification processes, water networks, consumption patterns, discharge, treatment and re-use.

The present study focuses on the use of water resources in Russia with a long term perspective developed through a Foresight study. The first step involved a scanning exercise, to be followed by future scenarios on the second step, and strategy proposals for action on the third one. The paper presents the results of the scanning phase.

The present paper consists of four parts. The introduction reviews the key issues and challenges concerning water resources. The first part describes the detailed research methodology. Furthermore, trends and uncertainties are identified in the course of the study, and their implications for water resources in Russia are discussed. Particular attention is paid to state-of-the-art situation in three domains identified in the scope of research: sustainability of water systems, water use by households and industry, and new water products and services. Weak signals and wild cards are described in the third part. The paper concludes with a brief description of the next phases of the study and follow-up activities planned in the project.

Keywords: water resources, sustainable water systems, water use, water goods and services, trend scanning, weak signals, wild cards.

JEL codes: H4, H5, H87, I30, M11, R20, R52, Q01, Q02, Q15, Q18, Q22, Q25, Q26, Q27, Q53, Q54, Q55

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About the project

The "Study of Global Challenges and Long-term Trends in Innovation Development" is a joint Foresight project dedicated to water resources, implemented by the National Research University Higher School of Economics and “Renova” Group. It was implemented from May 2014 through June 2015 and included a comprehensive interdisciplinary study of the processes and instruments for water resources regulation, as well as subsequent recommendations for policy-makers.

The project on water resources aims at:

- Analyzing trends, drivers and uncertainties in water supply, demand, use and re-use with a particular focus on:
    - Sustainability of water systems
    - Water use by households and industry
    - New water services and products
- Exploring emerging opportunities and threats for the future and assessing their implications
- Presenting suggestions for strategies and actions based on new technologies, applications, and new business models for water supply, transfer and use.

This paper presents trends and uncertainties in the water sector - weak signals (information about potential changes that may play out in an unknown direction) and wild cards (events, the occurrence of which is extremely small, but the effect can drastically change the external conditions and lead to unexpected trajectories of the future) identified through literature review and expert methods.

Introduction

As water resources are limited, solutions to address the Grand Challenges in this sector should include measures for the efficient water use. The intensity of these challenges varies between countries depending on their geographical location and level of socio-economic development. However, what is common is the search for ways to improve the efficiency of water production and use, as well as to mitigate the impacts of factors affecting water availability, including climatic conditions, natural disasters, demographic changes and urbanization, technological advancements, economic growth and prosperity, and social and cultural values [UNESCO, 2012].

Researchers are attempting to forecast how these drivers will evolve over the next decades and what measures should be taken by consumers and policy makers in order to address the water-related hurdles and develop a vision for a sustainable use of water resources. In such an attempt in 2011, the experts of the International Water and Sanitation Center note that "*water sector operates in a dynamic environment of rapidly changing levels of economic development, demographic change and governance contexts that have significant impacts*" [IRC International Water and Sanitation Center, 2011: 3] and note that trends in the sector are very uncertain.

Despite its importance as a natural resource, today water is not accessible and readily available, particularly for industries and people living in urban areas. Therefore, people have the right to access and use water "for free". On 28 July 2010, through Resolution 64/292, the United Nations General Assembly recognized the human right to water and sanitation and acknowledged that clean drinking water and sanitation are essential to the realization of all human rights [United Nations, 2010]. On the other hand, the production of goods and provision of services, especially those that require water supply over long distances, is associated with certain costs. This makes water a commodity, while markets of water products and services rapidly develop. This creates a complex situation, and frequently, conflict in the utilization of water resources.

UNESCO [2012] distinguishes the following categories of water consumers:

1. ecosystems (whose water demands are determined by the water requirements to sustain their condition and to restore the benefits for people);
2. energy (volumes of used water are rarely reported and thus are poorly known);
3. food and agriculture (the largest water consumer);
4. human settlements (water for drinking and household use); and
5. industry (consumption of water resources and the degree of environmental impact vary substantially across sectors [UNESCO, 2012]).

It is important to set the scene in each category in order to understand the current context and what is likely to emerge in the future within that context.

The amount of water use has been growing at an alarmingly high speed over the course of the last century. It is projected that **global water demand will increase by 55% in 2050** in comparison with the level in year 2000. Specialists forecast that by the year 2050, 3,9 billion people (or approximately 40% of world's population) will face in serious limitations to their water consumption. About 240 million people will not have sufficient access to drinking water, and 124 billion people will not have appropriate facilities for water disposal (i.e. will have inadequate sanitary conditions) [OECD, 2012a].

The Water and Energy domains are inextricably interlinked. Whilst water is crucial for the production, distribution and use of energy, energy is crucial for the extraction and delivery of water. As the drivers of human health, economic growth and environmental sustainability, the development of long term water and energy strategies are crucial. At present, increased global **water consumption is also linked to the increased global energy consumption trend**. According to the International Energy Agency (IEA), in 2010, 15% of total water consumption was spent on electricity production, which makes up 75% of water resources consumption in the industrial sector. Every year energy production requires 580 billion cubic meters of freshwater. [OECD, 2012b]. As global industrial production is expected further grow, it will continuously require more electric power, and, thus, more water. Therefore programs aimed at the reduction of water resources consumption (deficit) should also include energy efficiency measures.

The water – food – agriculture nexus is also crucial as water is one of the key inputs in the entire agrifood supply chain. Agriculture is currently the largest user of water at the global level, accounting for 70% of total withdrawal [FAO, 2011]. Water scarcity and decreasing availability of water for agriculture constrain irrigated production overall, and particularly in the most hydrologically stressed areas and countries [UN, 2014]. Excessive use of water for irrigation leads to degradation of farmlands; causes the rise of groundwater level and secondary soil salinization. As a result, salted soil is inappropriate for agricultural use. On the other hand, by 2050 there will be much less water left for irrigation, as it will compete with other human needs.

Demand for water resources in both urban and rural settlements has been increasing dramatically. A substantial part of the world population does not have access to clean water and/or water disposal systems. The UN estimates that 11% of humanity (0.8 billion) cannot access safe water, 17% of humanity (1.2 billion) live where water is physically scarce, 22% of humanity (1.6 billion) face economic water shortage (inadequate infrastructure/cost) and 36% of humanity (2.5 billion) still lack basic sanitation [United Nations, 2013]. UN experts estimate that the Millennium Development Goal (MDG[5]) for sanitation will not be attained by 2015. Considering the rapid urbanization process, particularly in Africa, South Asia and China, it may be expected that cities will be the main sources of crises in water as well as food and energy.

Industry is one of the main users of water, which is used in production processes, e.g. for heating, cooling, cleaning/washing, manufacturing, extracting etc. Industrial water is either provided by a public/private supplier or self-supplied through making use of available ground- and/or surface water resources. Moreover, industry is one of the major water polluters.

[5] The 7th Millennium Development Goal "Ensure environmental sustainability" includes a number of objectives and specific performance indicators. Task 7.C is one amongst them: to halve by 2015 the proportion of the population without sustainable access to safe drinking water and basic sanitation. The following indicators are used to monitor achievement of this task: 7.8 Proportion of population using an improved drinking water source and 7.9 Proportion of population using an improved sanitation facility.

Unfortunately, not all industrial water is treated before its disposal. Water withdrawals for industry currently represent 22% of total water use with 59% in high-income countries and only 8% in low-income countries. In 2025, the industrial withdrawal is expected to represent about 24% of total water consumption [UNESCO, 2014]. 70% of industrial waste is dumped into untreated water in developing countries.

Russia is one of the countries with affluent water resources. More specifically, groundwater resource potential on its territory is about 400 km^3 per year. However, these resources are distributed unevenly: not more than 10% of their volume is located in the European part of the country, which accounts for more than 70% of the population and productive capacity [Water Strategy of the Russian Federation, 2009].

The present research recognizes that strategies for water resources should be covering the entire life-cycle approach, covering water use, recycle / reuse and discharge, as well as the sustainability and environmental impact on water basins, in a comprehensive manner. Therefore, three inter-related domains have been identified to address different aspects of exploiting water resources: sustainability of water supply systems; water use by households and industry; and new water services and products. These three domains cover the five categories identified by UNESCO.

The *"sustainability of water systems"* domain in this study encompasses climate and water resources, surface and ground water sources and their condition, management of water resources in hydraulic engineering systems, transboundary water governance issues, economy of water resources, recycling and reuse of water and its "micro" and "macro" purification, and cross-sectoral water issues.

The domain *"water use by households and industry"* covers issues linked with changing society and lifestyles and the economic development. The term "water use" refers to the amount of water used by an individual, community or a nation for a certain task or need.

Finally, *"new water products and services"* considers water industry challenges that create demand for new products and services, which are universal. The following topics are considered in this sub-category: institutional (public and private ownership of water and water systems; international financial institutes and water reforms and water tariffs), regional and national water use (groundwater use; water storage; water-energy-food nexus; and culture of water use) and client-oriented products and services (water and wastewater treatment).

Methodology

The aim of this paper is the identification of the key trends, drivers and uncertainties along with the identification of Weak Signals of future emerging trends, and Wild Cards in the forms of future surprises, shocks and other unexpected events, which may disrupt the future of the Water Resources sector. By identifying key developments and uncertainties the scanning phase of the study provides a background for the development of future scenarios, which is the key activity of the second phase.

As the first product of the project, this paper develops and presents a set of "Global Trends in the Water Sector". Scanning is defined as by the UK's Chief Scientists Advisers' Committee (2004) as:

> "*... the systematic examination of potential threats, opportunities and likely future developments including but not restricted to those at the margins of current thinking and planning. Horizon scanning may explore novel and unexpected ideas as well as persistent trends and issues*" [DEFRA, 2002].

Trends typically involve those change factors that arise from broadly generalizable change and innovation. These are usually experienced by everyone and often in similar contexts. Trends characterize broad parameters for shifts in attitudes, policies and business focus over periods of several years that usually have global reach. They may be larger than the power of individual organizations and sometimes nations [*Saritas, Smith*, 2011]. Issues may be the threats, opportunities or a mixture of them related to trends, underlying processes, possible events, and other future developments. In most cases Horizon Scanning goes beyond the identification of trends and issues to cover drivers of change as enablers of trends, weak signals of emerging future change, wild cards of potential high impact but low probability events. Most organizations and even nations need to collaborate in order to change, exploit or mitigate the implications of all these expected or unexpected events and developments.

In the present study, the STEEPV framework [*Loveridge*, 2002] was used to map trends identified to ensure that a broad range of them are covered, which may stem from various factors in the overall Water Resources landscape. The set of categories is intended to be sufficiently wide-ranging and comprehensive to consider a wide variety of inter-related and inter-dependent issues (Table 1). It is not a rigorous conceptual framework, but rather a set of categories that have proven to be useful for stimulating broad thinking or convenient for classifying topics, trends or drivers.

Table 1. STEEPV framework with examples of what is covered under each category

Category	Examples
Social	Ways of life (e.g. use of leisure time, family living patterns), demographic structures, social inclusion and cohesion issues (fragmentation of lifestyles, levels of (in)equality, educational trends)
Technological	Rates of technological progress, pace of diffusion of innovations, problems and risks associated with technology (including security and health problems)
Economic	Levels and distribution of economic growth, industrial structures, competition and competitiveness, markets and financial issues
Environmental	Pressures connected with sustainability and climate change, more localised environmental issues (including pollution, resource depletion, and associated biodiversity, and welfare concerns)
Political	Dominant political viewpoints or parties, political (in)stability, regulatory roles and actions of governments, political action and lobbying by non-state actors (e.g. pressure groups, paramilitaries)
Values	Attitudes to working life (e.g. entrepreneurialism, career aspirations, deference to authority, demands for mobility (across jobs or places, etc.), preferences for leisure, culture, social relations, etc.

The Scanning work within this project involved a mixture of methods involving scoping, desk research, expert meetings, STEEPV analysis and brainstorming activities. First, a scoping exercise was undertaken in August 2014 to clarify the focus of the activity and areas of study. One leading expert was selected for each of the three sub-topics of the study, based on his/her professional and research record. These experts, together with the project team and in consultation with business, produced a scoping document describing each thematic area in detail. Second, a review activity was undertaken to identify trends in global, international and national references and strategy documents. These included reports and strategy documents produced by the international organizations such as the United Nations agencies (Food and Agriculture Organization and other), Organization for Economic Cooperation and Development (OECD); national strategies and official statistical data for the Russian Federation; and research publications by international and national scholars (see references at the end of the text for the full list). The identified trends were detailed by experts from the perspective of three areas of the project to be presented at the international expert seminar. The preliminary results were presented at the workshop “Global Trends in the Water Sector” which was held on November 7, 2014. The national and international experts from the US, Brazil, Japan, India, Republic of Moldova, Belarus, and other countries gave presentations on the international perspectives on the three thematic areas, a brainstorming session was undertaken to discuss the trends under each of domain. The international and national experts had an opportunity to review the lists of trends and to complement them with their knowledge and experience. Two key questions were asked to the experts for consideration:

1. What are the trends, issues and uncertainties in the water sector in each theme?
2. What would the implications be for Russia?

Based on these steps, the final list of trend was produced.

A STEEPV framework was generated to map the trends under relevant categories and to indicate the systemic relationships between them. The expert meeting was concluded with a discussion on possible implications of the trends for Russia.

The current report presents the selection of key trends identified by the project team, which were complemented and validated by the expert panel. In the following sections of the paper, first, trends will be presented followed by the discussion of them in the context of Russia. The paper will be concluded with a discussion and future work to follow up on the research presented here.

Trends for Water Resources

Identified trends in the sphere of water resources can be divided into two groups: trends which are relevant for many countries and those, which are mainly typical for Russia. The complete list of trends based on the scoping activities and expert reviews is presented in the Table 2 below.

Table 2. List of water resources trends produced through STEEPV analysis

Trends category	In the world	In Russia
Social	• Water challenges for the poorest people are persisting. Problems with sanitation and waterborne diseases • Health impacts of water treatment technologies (e.g. use of chlorine and chlorine compounds during the drinking water treatment) • Increasing risk of water-related conflicts between countries • Increasing demand for freshwater due to global population growth • Public and private ownership of water and water systems may conflict with human right to water • Motivation for more rational use of water (not to be considered as somebody's own or free good) • A significant part of the world population does not have an access to a stable water supply, which creates environmental refugees (i.e., North Africa) and water terrorism	• The quality of drinking water in water supply systems in Russia and post-Soviet countries often do not meet sanitary standards and raises consumer concern. A significant part of the population use household filters or buys bottled water • Absence of water-supply and organized water disposal in significant number of the Russian settlements. In some cities water supply is available only several hours per day • Increasing demand for water in Russia. It has already decreased almost two times over the last 10 years (~from 300-380 to 180-200 liters per person per day) while it is constantly increasing around the world (European level is 120-150 liters). This is largely a result of introducing metering systems and widespread installation of modern plumbing

Technological	• Increasing efficiency of water use through technologies for water saving. Technologies for treatment and recycling of water and promotion of zero-discharge • Increasing availability of water cleaning and filtering technologies • The implementation of centralized information systems for measuring resource use (beyond meters) • The widespread use of smart metering and payment technologies to enable variable tariffs for different users • Differentiation of water supply technologies for small settlements and big cities. The challenge of water supply in rural areas and poor cities' suburbs still exists: a connection to major water pipes and water treatment systems becomes very expensive, small-scale systems usually cannot provide a similar level of water quality • Increasing efficiency of irrigation technologies • Technologies enabling 100% water desalination for drinking purposes. Quick cost-cutting of desalination technologies and processes enhances rising demand for desalinated water • Solar desalination has already allowed for reducing the costs of desalinated water twofold and there are strong estimates that there are additional possibilities to cut the price further down as many as 3-4 times • Membranes continuously replace chemicals. Particularly forward osmosis technology is a new promising form of water desalination and treatment • In regular water purification, chlorine will be gradually replaced by Ultra Violet (UV) disinfection • The volume of water that evaporates from reservoirs exceeds world domestic and industrial water withdrawal. The challenge of evaporation makes countries build mid-scale reservoirs and develop chemical covers and leak proof puddles • Water resources consumption is increasing due to increased energy consumption. Thus the most promising and cost-efficient technologies are combo water-energy solutions based on water re-use in the energy sector • Nuclear desalination for small and mid-sized reactors becomes one of the most attractive tandems in water-energy nexus	• Insufficient wastewater treatment in the majority of Russia's industrial enterprises and utilities leads to the deterioration of water facilities. The deterioration of the Russian water supply-disposal infrastructure exceeds 60%, which causes relatively low technological efficiency and higher number of accidents. It is necessary to replace about 5% of pipeline routes per year, while in Russia a little more than one percent is being replaced

Economic	• Greater competition in goods and services in the water market • Design of new, more customized business models in water management. For example: due to limited water availability in San Paolo 60% of companies in textile moved to other regions • Wider application of future-oriented risk analysis of water-dependent sectors • Priority development of water-intensive sectors • Wider application of techniques for mapping and measuring the level of government investment • Increasing availability of financing for industrial and urban water cleaning • Increasing water export and trade of “virtual water” between water-supply and water-deficit countries • Water-consuming shale gas extraction and hydraulic fracturing turn into a broadly discussed issue as water stressed countries search for alternatives • As far as world business leaders pay more attention to water management and use it as a PR tool, eco-friendly water treatment and use will soon provide extra market value for firms • In developing countries the water sector ranks third in investment attractiveness in infrastructure after transport and energy	• Long-term tariffs for water supply-disposal services will be adopted in 2016 in Russia. Although this is a positive development, it is not enough to make the water sector attractive for investors The Russian water sector has some positive improvements in the performance of measures with a short pay-off period, e.g., energy service contracts related to the installation of private meters and optimization of the hydrodynamic modes of payment in order to save money on electricity bills • In Russia there are institutional problems in the water supply to apartment buildings after the switch to metering systems. After the apartment owners purchase the meter for the entire apartment building, water supply companies loose access to it • Russia’s water utility enterprises’ debts are steadily growing due to decreasing tariff revenues and inadequate presentation of technological losses

Environmental	• Increasing pollution of water basins – rivers, ground water, etc., especially in the developing and under-developed countries • Climate change, desertification, and ice caps melting. Higher frequency of extreme weather phenomena, floods, droughts • Widespread adoption of the "zero-discharge" concept, i.e. no water is discharged to rivers, but repeatedly treated and re-used • Critical levels of groundwater around industrial areas • The number of people who are at risk of flooding is gradually increasing • In Asia 90% of disasters are related to water • Increasing concerns are related to transboundary water pollution • The deterioration of hydraulic structures and reservoirs increase the risk of disasters especially in flooding periods • Environment unfriendly virtual water flows (national, international and global trade transfers water from [often dry] rural areas to higher population urban centers) • New canals, dams and reservoirs provide water for economic use but at the same time, a displacement of huge amounts of water can destroy local fisheries, farming, and traditional recreation zones	• In Russia and post-Soviet countries insufficient water treatment leads to serious environmental consequences • Chinese market opens up for Russian water products • Increasing threat of water deficit for Russia's Eastern water basins due to large consumption by the neighboring China's industries • Seasonal changes in water supply (e.g. water accidents in Central Russia) • The excess rate of groundwater use compared with the rate of replenishment. The exhaustion of groundwater gradually becomes a threat to sustainable water supply in some regions • The increasing volume of open waste water in cities with "micro-pollutants" (i.e. rain water from cities containing chemicals including medical waste, used cosmetics, dyes) pollute water sources
Political	• Although governments are often involved in water regulation (in particular, through strategy-making and promoting innovations), the public sector is usually slow in catching up on trends (for example, Brazil missed such an opportunity and now imports all the equipment for water treatment from China, Finland) • Increased competition for water in transboundary river basins are characterized by the escalation of tensions in political relations and even water-related conflicts • Privatization of water supply companies • Multiple water stakeholder collaboration • Service policies for big/small towns • Introduction of new normative and tariff policies with diversified regulation • Changes in the legal basis for water management	• Critically low cost of water supply and disposal services in Russia and post-Soviet countries • Water supply-disposal companies' tariff regulation in Russia and other post-Soviet countries is often normative (heavily influenced by the government) • Development potential of public-private partnership (PPP) as competition for the monopoly market. Currently, the market share of private water supply operators exceeds 20%. However, it has not led to significant changes

Value / Cultural	• Changing lifestyles and water consumption patterns. Increasing quality of life is usually considered to be associated with higher water consumption • Changing attitudes towards state policy and complying with it • Water is considered to be a free good, a gift of nature, especially in rural communities that do not have water meters. It leads to a permanent wasteful water use and will eventually lead to local crisis situations	• Irrational water resources use for industry and agriculture in Russia in comparison with the European Union and the USA gradually creates water resources deficit, which has escalated in several regions of the country

Following the discussion on the trends in each category, the participants of the workshop were invited to prioritize the topics for further elaboration. During the first round of discussion and prioritization a total of 25 trends were prioritized out of 60 presented above. The shortened list included 9 trends related to the sustainability of water supply systems; 7 trends for water use by households and industry; and 9 trends for new water services and products. These are elaborated further in the next sections of the paper. Following the descriptions through a second round of prioritization, three trends were selected under each domain, which will be presented in a table at the end of each section below.

Sustainability of water systems

It is projected that **global water demand will increase dramatically in the future** (by 55% in 2050 in comparison with the level in year 2000). This will require making water sector rank third by the volume of attracted infrastructure investment after transport and energy. World Health Organization's (WHO) study for quantifying the impact of projects aimed at advancing water quality, identified the main **economic benefits of investments in drinking water purification**. The overall gain projected by the WHO equals to USD 84 billion per annum. The breakdown of the key impacts from achieving the MDGs for water and sanitation are presented below in Table 3 [*Hutton, Haller*, 2004].

Table 3. Overall benefits of achieving the MDGs for water and sanitation

Types of benefits (selected)	Breakdown (annually)	Monetized benefits (in USD bln a year)
Time saved by improving water and sanitation services	20 billion working days	63
Productivity savings	320 million productive days gained in the 15-59 age group 272 million school attendance days 1.5 billion healthy days for children under five	9.9
Health-care savings		7 (for health agencies) 0.34 (for individuals)
Value of deaths averted, based on discounted future earnings		0.0036
Total benefits		**84**

Sources: [OECD, 2010; *Prüss-Üstün et al*., 2008; *Hutton, Haller*, 2004].

The main difficulty on the way to more efficient water use is the insufficient volume of investments in the water sector. The main difficulty in attracting investments is that despite the expected high returns, the investor and beneficiary are usually different persons. As one may conclude from the Table 3, the added value of the water investments is gained not only by end users, but the society as a whole; the government saves money on emergency costs, tourism is advancing, healthcare system becomes more efficient. It is nearly impossible to channel these benefits in the form of dividends to a particular investor.

There is a growing need for investment in **global water infrastructure** that surpasses similar cumulative investments in traditional physical infrastructure (roads, railways, telecommunication and energy distribution). This is due to the prolonged exploitation and the lack of ongoing recovery of water basins (especially in cases of ponds and agricultural sector reservoirs), the deterioration of hydraulic engineering units, and siltation of water reservoirs.

Data for several world regions indicate that in the course of the last 40 years the rate of **groundwater consumption** has **surpassed the rate of** its **replenishment**. The groundwater depletion is gradually becoming a threat to the sustainability of the water supply in some regions: it has doubled and reached approximately 280 cubic kilometers in 2000 (for comparison: in 1960 that figure was about 130 cubic kilometers). For instance, greater ground water use in coastal areas leads to groundwater salinization, which complicates their use for the supply of drinking water [*Wada et al,* 2012].

Natural disasters pose a substantial threat to many countries. It is expected the number of people who are at risk of floods will increase from 1.2 billion in 2010 to 1.6 billion in 2050, and the economic value of assets at risk of floods will rise by 340% (up to 45 trillion USD) during the same period. Moreover, the frequency of extreme weather phenomena, floods, droughts are expected to be higher due to climate change [OECD, 2012a] and this requires the creation of a system of a sustainable water supply in the regions most affected by fluctuations, i.e. water storage facilities as well as water pipelines should secure water needs in at risk regions.

Accidental water pollutions, such as unauthorized discharge, pipeline breakouts, and accidents at oil wells are often complemented by the so-called “micro-pollutants” (i.e., medical waste, used cosmetics, dyes) that accumulate at water sources gradually. **Insufficient wastewater treatment** in the majority of industrial enterprises and utilities is yet another reason for the deterioration of water facilities and eventual pollution.

The sustainability of water systems is an important factor for preserving **water ecosystems and fishery stock**: among the negative impacts are nitrogen and phosphate fertilizers from crop fields, eutrophication processes. OECD notes that badly designed agricultural and fisheries subsidies, targeting increased volumes of crops and overfishing, could further stress land, water and ecosystems.

Water is scarce and water basins and systems are not always within the boundaries of one country. The **transboundary** nature of **water basins** have important consequences for their **governance** and may lead to political tensions and inefficient distribution of water resources [United Nations, 2013a]. The Mesopotamia, Nile, and Amu Derya basins can be considered among the most vulnerable areas for conflict [*Peek*, 2014]. Imbalance, and eventual problems, in the distribution of water resources are observed within the boundaries of individual countries too, such is in the Amazon basin. The substantial differentiation between groups of countries occurs in the rational water use (quantitative attributes) and the condition of water resources (qualitative attributes) [*Soncini-Sessa*, 2007]. OECD member-countries show positive dynamics in indicators reflecting both rational water use and condition of water resources, unlike other groups of countries, including the BRICS countries [OECD, 2012a].

Furthermore, we note the **absence of regulations and mechanisms for the functioning of the water market** in the international distribution of water-intensive products manufacturing, and diversion of runoff.

Improved water management is essential to regulate competition for water needs among urban and rural regions, industries, energy producers, and ecosystems. In the absence of proper water management, water availability may become a major problem already in 20 to 30 years from now leading to lost opportunities, health and environmental damage [OECD, 2012a]. Among the persistent problems of water resources management is the weak management of water basins, including an incomplete set of criteria used for making decisions on the distribution of water resources among users.

The key trends in sustainable water systems are related to climate change, inefficient water resources distribution and water management (Table 4).

Table 4. Trends in sustainability of water systems

Contribution	Trends
Climate change	• Higher frequency of extreme weather phenomena (floods, droughts, tsunami) deterioration of hydraulic structures, siltation of reservoir, for ex. increased number of people and volumes of property at risk of flooding • Negative impacts on water ecosystems, fisheries, agriculture, water transport sector, etc. • Problems with natural groundwater replenishment
Inefficient distribution of water resources	• Increased demand for water around the world due to growing population and economic growth, leads to increasing competition for limited water resources. Lack of effective market institutions lead to inefficient allocation of water resources among different industries and sectors of economy, between countries for trans-boundary water basins and between (groups of) people • Growing share of world population with lack of access to drinking water and appropriate water disposal • Lack of international regulation and mechanisms for "virtual water" trade
Water management	• The rate of groundwater use does not match the rate of its replenishment • Ineffective control over water pollution leads to water contamination, including "micro-pollutants" (i.e., medical waste, used cosmetics, dyes) • Lack of investment in water infrastructure • Deterioration of hydraulic structures and siltation of reservoirs

Water use by households and industry

A substantial part of the world population does not have access to clean water and/or water disposal systems (a pre-requisite for proper sanitation). In the course of the past 10 years, we have seen an **increase in global water demand and consumption**. During this period an opposite trend was observed in Russia. The sales volume of water-sewage utilities has nearly halved. This is partly a consequence of the introduction of individual water use systems by large industrial consumers, and a result of the widespread installation of meters and modern plumbing equipment in the housing sector. Thus, average water consumption by households in Russia has gone down from over 300 liters per person per day (in Moscow from 380 liters) to 180-200 liters. However, there is still some way to go in order to reach the European average - 120-150 liters per person per day [Russian Federal State Statistics Service, 2013].

While in developed countries there are growing concerns over the **renewal of main water supply and disposal infrastructure**, in the New Independent States (NIS) of Eastern and Central Europe and Central Asia (EECA) (including some parts of Russia), the quality of drinking water in water supply systems often does not meet sanitary standards and raises consumer concerns (a significant part of the population use household filters or buy bottled water). Consequently, in the NIS EECA countries there is a growing number of cities where waste waters undergo at best only mechanical purification, and in many cities clean water is supplied only during certain hours.

Unlike energy, manufacturing, and housing, which will be successful in sectoral competition for water resources, **irrigation is expected to suffer dramatically** from structural changes in water consumption.

Today we see wide industrial application of new water treatment technologies with use of **low pressure membrane technologies** (i.e. in secondary use in Singapore, desalination in Israel, etc.). Compared to other technologies with the same effect (i.e. biomimetic nanosystems), these technologies have the biggest scale of use. The greatest installed volume as of 2008 has occurred in the Americas (44% in the US), 19% in Europe (including Eastern Europe and a few in neighboring states), and 23% in the Pacific Rim [*Furukawa*, 2008]. In 2012, the US Department of the Interior published experimental results of a data-driven analysis to evaluate the technical and economic factors that impact lifecycle costs for low-pressure (microfiltration and ultrafiltration) membranes. The researchers quantified differences in the fouling propensity for an alumina ceramic and a polyethersulfone (PES) polymeric ultrafiltration membrane [*Guerra*, *Pellegrino*, 2012]. Generally these technologies are expensive and only cost-effective if payments for water use are sufficient to cover the costs.

Of importance to mention, that the cost of water supply and disposal services in Russia and NIS EECA countries is critically low, which often leads to bankruptcy of the water supply enterprises, especially in towns / small settlements. This situation generates high risks for the stability and quality of public water supply. A cubic meter of water in the Russian water supply system costs less than RUB 30 (in 2013), which is cheaper than a half liter bottled water Furthermore, water **tariff regulation** methods applied to water supply and wastewater disposal companies in NIS EECA countries is often done based on political (social) rather than economic considerations. For example, in calculating expenditures the companies take into consideration normative losses (instead of actual losses). This distorts the real picture: if losses are insignificant, why upgrade the networks?

Trends in individual and industrial water use could be grouped into those, related to water infrastructure and tariff policy and, those related to investment policy and institutional ones (Table 5).

Table 5. Trends in household and industrial water use

Contribution	Trends
Water infrastructure and tariff policy	• Ineffective policy instruments or implementation oversight lead to industrial enterprises discharging wastewater outside proper disposal systems. Lack of funds for renewal of main water supply and disposal infrastructure • Scale optimization of water supply enterprises and their activities (to overcome the inefficiency of water services in small towns and settlements) • Most countries face the need to renovate (replace) capital equipment, both for production and infrastructural • The price of water supply and wastewater disposal in Russia and the former Soviet countries is extremely low • Tariff regulation of water supply and wastewater treatment in Russia and the former Soviet countries has political (rather than economic) reasoning and generates high risks for stability and quality of the public water supply • Wasteful water consumption patterns among population and households
Investment policy	• Advancement of public-private partnerships (developing countries) and public sector borrowing (developed countries) • In Russia during the 10 years of PPP experience there is no statistically significant difference in enterprises' performance as compared to other institutional alternatives • Remunicipalization of water supply and disposal enterprises in Europe
Institutions	• Horizontal «regionalization» of water business (economy of scale) • Institutional problems in the water supply to multi-apartment buildings, including metering and connection to water supply systems by developers

New water products and services

Researchers note slow evolution of **water use culture**, which implicitly defines a wide range of aspects within water use among households. Even the developed countries apply a combination of measures, including tariff regulation and intense PR and awareness raising campaigns promoting water-friendly equipment to change water-use practices. Given the global urbanization trend this cultural aspect plays a continuously growing role, as it determines the range of issues connected to the water use by households.

The use of chlorine and chlorine compounds during drinking water treatment in some countries (including many Russian cities) increase the risk of morbidity. However for **least-developed economies** the implementation of basic treatment (even individual chlorine purification) and the development of simplest irrigation systems could have a profound effect on economic growth and contribute to better healthcare.

There is a direct relation between financial support (mainly credits, but also grants) provided by international financial institutions and the requirement for privatization of water services. It may create substantial social risks (which have to be carefully evaluated) in **developing countries** with a large share of the poor population. The most famous example is a so called Water war in Cochabmba, Bolivia [*Olivera, Lewis*, 2003; *Nickson, Vargas*, 2002; *Spronk*, 2007].

Developing countries face the operating costs vs. capital expenditures dilemma: in the past years many of them have gradually raised water tariffs. However, this additional money is spent on covering growing operating costs. Thus it creates an endless circle: obsolete water capacities require higher operating expenses and money gained from tariff` increase is not used to make capital investments to modernize the water supply systems. Additionally freezing of tariffs makes water sector unattractive for investors. International practice, in contrast, shows a gradual increase in water tariffs that allows covering current operating costs. Optimization of inefficient operating costs is seen as an investment resource. In concession agreements such a policy could be called “tariff increase resulting from better service quality”.

The trade of real water between water–rich and water-poor countries is usually impossible due to long distances and associated high costs, while the **trade of “virtual water”** happens often. The “Virtual water” contained in the product, first introduced by Tony Allan in 1993 [*Allan*, 1993; 1994], is the water used for the production of an agricultural or industrial product. Thus, if a country exports a water-intensive product, one may say that it exports virtual water. In this way some countries satisfy the water needs of other countries [*Hoekstra*, 2002]. Most importantly, virtual water may become an alternative source of water, but it needs to be wisely used. The current trend is international trade of “virtual water” (in the form of water intensive products) between water-scarce and water-rich countries. However, it is often the case that national, international and global trade transfers water from (often dry) rural areas to higher population urban centers. The existing studies estimate global “virtual water” trade between nations to be from 1340×109 m^3 (in 2000) to 683×109 m^3 per year [*Hoekstra, Hung*, 2002, 2003; *Chapagain, Hoekstra*, 2003; Oki et al., 2003]. These important developments make researchers talk about the water footprint [see for ex., *Ercin, Hoekstra*, 2014; *Mekonnen, Hoekstra*, 2011]. The virtual water consumption by industry and agriculture is presented in Table 6.

Table 6: Actual and virtual water consumption in selected countries, 2006-2014

Nation	Per Capita Withdrawal (Liters/p/y)	% Domestic	% Industrial ("virtual water")	% Agriculture ("virtual water")	Year
Brazil	297,000	28	17	55	2006
Russian Federation	546,000	19	63	18	2000
India	627,000	7	2	90	2010
China	425,000	12	23	63	2007
USA	1,518,000	13	46	41	2005
Japan	696,000	20	18	62	2000
Germany	463,000	12	68	20	2001
Worldwide	681,358+	10	20	70	2014*

* Worldometers, 2014, annualized from. Jan 1-Nov 6, 2014, UN statistics.
Sources: [*Gleick et al*., 2011]

What is important indeed is the dawn of the actual (not virtual) water trade. Pure water seems to be becoming a tradable good in this century. Experts expect that in the middle of 21st century fresh water from Lake Baikal may replace petroleum in the structure of Russian exports. However, in case of excessive water sales this approach may become a threat for sustainability of water sector.

Climate change makes dry areas become dryer and warmer, and other regions, especially tropical ones, face more frequent and large-scale floods. Another consequence of climate change is the higher probability of natural disasters: since the 1950s, the number of natural disasters has risen exponentially and water-related disasters (either droughts or floods) represent more than one third of the total. This challenge **requires** the **considerable adaptation of existing water systems** – building new reservoirs, improving flood management and developing anti-evaporation and leak-proof technologies.

The abovementioned UN resolution on human right to water and sanitation is a great human rights achievement, and, at the same time, a limitation for **market mechanisms of water-pricing and intensive privatization** as advised by the World Bank. For many developing countries, the World Bank funds represent a unique opportunity to renovate their obsolete water systems. For instance, in Bolivia, Philippines and Tanzania the rapid liberalization of water industry led to serious conflicts between the poor population and local authorities. Thus, a human right to water may represent a constraint for investors.

Developing countries face the biggest challenges in water use and management – almost all of them experience water shortages, a deteriorating environment and fast urbanization. They have to solve several problems simultaneously: develop large-scale infrastructure projects, establish or modernize municipal water systems and increase water sector productivity. At the same time those countries ought to rebalance their water use structure and upgrade respective institutional regulations for national and transboundary basins.

Developed countries are the major producers of water-related technological innovations and have the most advanced water-use policies. This is true for Europe (European Water initiative), Asia (with Singapore best-practices) and North America (International Joint commission that manages US-Canadian Great Lakes). Groundbreaking water treatment and recycling technologies and eco-neutral infrastructure projects represent the main focus of innovative water technologies in those countries.

The main principle of the water sector organization is conservatism, given its social implications. Internationally there are various **legal forms that water supply and wastewater disposal enterprises** assume. In developed countries public enterprises dominate the picture:

- “German model” with joint-stock companies, usually owned by local authorities;
- “French model” with high share of public-private partnerships;
- “England model” with water supply infrastructure privatized on the basin principle (not by the settlement principle).

Furthermore, in continental Europe investments in the sector are usually attracted through public borrowings (i.e. municipal bonds), even in the case of public-private partnerships. The reason for this is rather pragmatic: public borrowing is cheaper than private. Of fundamental importance is that investments are rarely made from the current budget and loans are paid back due to economic activity of the water supply enterprises [*Mandri-Perrott, Striggers*, 2013].

In developing countries the main burden usually lies on PPP contracts and private investment (due to high risk of budgetary borrowings) [World Economic Forum, 2005].

The overview of the state-of-the–art practices allowed us to narrow the research focus of the three topics on the following issues.

Policy makers should be aware of the way we have dealt with water use both historically and in the present. These insights are a good basis for assessments of water use by industry and households and water restrictions that feed into the new water management programs. By **mapping water use** and comparing it to economic value we can see where this limited resource is of most benefit to us. Moreover, it is necessary to monitor the flow of water from the environment to the economy and back [Australian Bureau for Statistics, 2012].

The costs of access to clean water increases in many countries around the world following the escalation of water stress. For individual water use it means lower quality of life and there is a high degree of uncertainty associated with the establishment of property rights on water. For municipal water use it means that rural areas and slums are weak competitors for scarce water resources, and it poses a huge social problem. Among industrial and agricultural water users enhanced cross-industrial competition for water creates a need for higher productivity. Technology solutions aimed at the resolution of this challenge are directed towards design of new less water-intensive production processes and equipment.

The problem of scale optimization of water supply enterprises activities is common for many countries. In small settlements (towns) the limited scale of activities leads to a lack of managerial and technical competence and to high unit costs (coupled with lower consumer's purchasing power). In the European Union scale optimization is solved through establishing horizontal links, either by creating one inter-municipal company in several settlements through the merger of assets (e.g. Poland, the Czech Republic), or by conducting inter-municipal competition for selection of a private operator for several municipal institutions (e.g. Romania). Some recent developments point to a "remunicipalization" of the public services sector, including water, which we may soon see in the European Union.

Emerging trends related to water products and services were classified by their main contribution. These trends are linked to either solutions increasing the productivity or the volume of water resources, or with an aim to physically reallocate existing volumes of water. Trends in water products and services could be grouped into those that are aimed at attaining higher productivity as compared with existing solutions, provide users with additional resources and offer infrastructure solutions (Table 7).

Table 7. Trends in new water products and services

Contribution	Trends
Higher productivity	• Combo hydro-energy technologies • Water-saving technologies (bio-gas recovery systems, water meters, ultrasonic sludge pre-treatment, pipe rehabilitation and relining systems, and water derivative products like water-free toilets) • Increased competition from Asia (especially China) in higher-end of water products and services
Extra-resources	• Desalination (new methods, solar and nuclear options) • Treatment (UV and membranes versus Chlorine and other chemicals)
Infrastructure solutions	• Multifunctional dams • Small and mid-sized water reservoirs, chemical covers and leak proof puddles • Country–wide channels

Weak Signals and Wild Cards

The main trends that were identified above are the likely developments of global water resources. However, they could be diverted or completely reversed by certain factors, which seem unlikely or are little known at present – weak signals and wild cards [*Saritas, Smith*, 2011]. The weak signals and wild cards, which are identified in the project, range from big ocean current shifts to pandemics that radically change water demand practices (Table 8).

Table 8. Weak signals and wild cards in the project's thematic areas

	Weak signals	**Wild cards**
Sustainable water systems	• Water loss/contamination in aging urban pipes • Nuclear accidents contaminated aquatic food webs in Chernobyl and Fukushima • "Freaky weather," like drought in nations' breadbaskets (i.e. California) • "Freakish" aquatic life: intersex fish, mutant frogs and toxic shellfish	• Catastrophic contamination of drinking water (e.g., by fracking or radiation) • Exotic pollutants bypass water treatment (e.g., medicine, nanotech, pathogen) • Big ocean currents shift, changing climate and weather across continents • Hydrosphere geo-engineering (e.g., refilling Lake Chad, Dead Sea, and depleted aquifers)
Individual and industrial water use	• Illegal water taps continue in urban slums • The World misses UN sustainable development goal (SDG) for sanitation • Thousands dying of Ebola in West Africa – how many collected water for their families?	• Society rejects cost to give or sustain clean water for everyone everywhere • "Back to basics:" demand drops for bottled water and virtual water-intensive products • Pandemic changes water demands, limits water operating & maintenance capacity • Hydro-hegemons assert power or hydro-terrorists act (e.g., IS in Iraq now) • Decentralized/on-site water harvesting, treatment & reuse becomes viable • Hydrosphere geo-engineering (e.g., refilling Lake Chad, Dead Sea, depleted aquifers; Lake Balkash, Caspian sea)
Water products and services	• Hegemons have ignored water-sharing treaties and threatened international violence vs. neighbors	• Energy-for-water trading or water cartels become economically and politically viable • "Hot" superpower war disrupts global trade, SDG investment and development aid • Hydrogen fuel cells' proliferate, with pure water as byproduct

Source: [*Sklarew*, 2015].

No matter how improbable weak signals and wild cards seem, all of them are based on uncertain and surprising, but at the same time highly impactful developments, which need to be assessed. In some cases the probability of occurrence may be calculated by using mathematical models. For instance, extreme weather phenomena (e.g. droughts, tsunami) have been already predicted by private and state agencies based on satellite and other data with the use of special software. The less measurable and more uncertain ones such as social, technological and economic disruptions will be captured in scenarios to portray alternative futures and to test the robustness of corporate strategies and government policies.

Conclusions: implications for Russia, discussion and next steps

Based on the above analysis we conclude that the three topics identified for our study are complementary and overlap in a number of issues, including the impact of climate change and its consequences, the limitations for virtual and actual water consumption that require water-saving and water-reuse solutions and the differences in approaches to water management in different country groupings.

Many world countries face “water stress”. Unlike them, it can be said that Russia has a sufficient water supply. The overall intake of water for drinking and economic purposes in Russia amounts to 3% of the total water resources 2/3 of which are discarded back to water bodies as discharge water. The country is among those with sufficient water supply with a little less than 20,000 m^3 of water per person per year[6] [UNESCO, 2012]. At the same time, there are serious problems associated with the extremely uneven distribution of water resources along the country, as well as high “water intensity” of the Russian GDP (about 2.4 m^3 per thousand rubles, which is significantly higher than in economically developed countries [Water Strategy of the Russian Federation, 2009].

The water management measures target difficulties related to housing and sustainable development. The comprehensive policies should cover tariffs, infrastructure, investments and institutions. Every trend listed in this paper is linked to a set of related water management issues.

The specific products and services that may address the main trends and help solve the existing challenges are related to advance of infrastructure, increasing the volume of water resources used (through previously unavailable resources or through re-use of existing stock) and their productivity.

Through our analysis we have identified five major challenges mentioned below for implementation of water-tech innovations in Russia and trends that create new opportunities for Russia.

A key systemic restriction in water use for the next decades relates to competition between agriculture, energy, biofuel production and water use. Given that the amount of renewable water resources is almost fixed and even decreases because of pollution, comprehensive solutions for water development will be required.

Drop irrigation turns into an imperative. This technology may entail a substantial decrease of costs due to high demand in new farmlands in Africa owned by Chinese, Indian and Middle East investors.

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[6] The UN Economic Commission for Europe defines countries with poor water supply as those with less than 17,000 thousand m^3 per person per year.

The challenge of water supply in rural areas and poor city suburbs is especially evident in large countries, like Russia: a connection to major water pipes and water treatment systems becomes very expensive and small-scale systems typically cannot provide a similar level of water quality. A substantial part of Russian settlements do not have a water supply and disposal system.

"Water intensity" of the GDP is an important characteristic of efficient functioning of the economy as a whole. In many developed countries this figure is reduced, while in Russia it remains at a high level. There are several reasons for the high water intensity of production, including unsustainable exploitation of water resources (inter alia, the use of outdated technologies), high level of transmission losses, and absence of efficient economic mechanisms for the introduction of modern water saving technologies.

The Russian water sector is not very attractive for investors. The Russian water sector has significantly less lobbying opportunities than other infrastructure sectors, which complicates its institutional and financial positions. Meanwhile, there have been some positive changes with regard to activities with a short pay-off period. In particular, this concerns the widespread use of energy service contracts related to the installation of private meters and optimization of the hydrodynamic payment modes, the costs of which are covered due to electricity bills savings.

The future studies of water resources may be built on two consistently implemented steps. First, existing scenarios prepared by researchers and international organizations may be analysed, and a set new alternative visions of the future development of water resources in Russia may to be developed. Secondly, for each of the scenarios suitable government policies and corporate strategies may be offered. Finally, action plans and roadmaps may be developed to reach national and corporate goals.

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