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E. Kyzyngasheva, L. Proskuryakova

GLOBAL ENERGY TRENDS AND THEIR IMPLICATIONS FOR RUSSIA: A PATHWAY TO THE NEW ENERGY WAVE

BASIC RESEARCH PROGRAM
WORKING PAPERS

SERIES: SCIENCE, TECHNOLOGY AND INNOVATION

WP BRP 64/STI/2016

This Working Paper is an output of a research project implemented within NRU HSE's Annual Thematic Plan for Basic and Applied Research. Any opinions or claims contained in this Working Paper do not necessarily reflect the views of HSE.

E. Kyzyngasheva[1]*, L. Proskuryakova*[2]

GLOBAL ENERGY TRENDS AND THEIR IMPLICATIONS FOR RUSSIA: A PATHWAY TO THE NEW ENERGY WAVE[3]

Despite the success of many countries in increasing energy saving and energy efficiency, the global energy consumption is expected to continue its growth. The main reasons are economic development and population growth happening primarily in developing and emerging economies, especially in India and China. In such circumstances fossil fuels will remain the dominant energy source in the medium and even long run. The present research paper aims at analyzing the current global trends in the energy sector identified through literature review and expert tools, and their influence on Russia. Considering a broad range of factors, the paper determined the following main challenges for the Russian energy sector: tightening competition at international energy markets, the need for comprehensive modernization and stronger energy efficiency measures, the need for technological catch-up in a number of energy sector segments, the need to increase recovery factor at traditional oilfields, and the need to diversify energy mix by increasing the share of renewables. The paper also considers the main rationale for the last challenge that include strengthened security, reliability and sustainability of the Russian energy sector. Among the key preconditions for advancements in renewable energy are improvements in investment climate, modernisation of the central grid and changes in energy policy. The paper is based on the outcomes of the first stage of the Foresight project devoted to renewable energy technologies.

JEL Classification: O13, P47, Q42, Q43, Q47.

Keywords: energy trends, renewable energy, global energy sector, Russian energy sector.

[1] Research Assistant, Research Laboratory for Science and Technology Studies, National Research University “Higher School of Economics”. Email: kyzyngasheva@gmail.com.
[2] Leading Research Fellow, Research Laboratory for Science and Technology Studies, National Research University “Higher School of Economics”. Email: lporoskuryakova@hse.ru.
[3] The “Study of Global Challenges and Long-term Trends in Innovation Development” is a Foresight project implemented by the National Research University Higher School of Economics. The authors would like to show sincere appreciation to the Renova Group for the support of the study. We would like to extend a personal note of thanks to Mr. Viktor Vekselberg, President of “Skolkovo” Foundation, Chairman of the Board of Directors of Renova Group.

Introduction

The majority of international companies and organizations underline the trend of growing global energy consumption (e.g., IEA [2014a]; BP [2015], Statoil [2014]. For example, IRENA [2016] forecasts global energy demand to grow by 30% in 2030, IEA [2014a] - by 37% in 2040 compared to 2014, despite the decreasing energy intensity of developed countries. Energy consumption has changed over the last 40 years: OECD countries considerably reduced their energy demand growth rate due energy efficiency and energy saving measures, implemented primarily by households and industries, as well as the development of natural resources use culture (Figure 1). These countries also substituted a substantial share of coal with natural gas and renewables [IEA, 2015a]. Asia and Latin America, in turn, have built up energy demand mostly due to rapid economic development, and increased the share of coal in the final energy consumption.

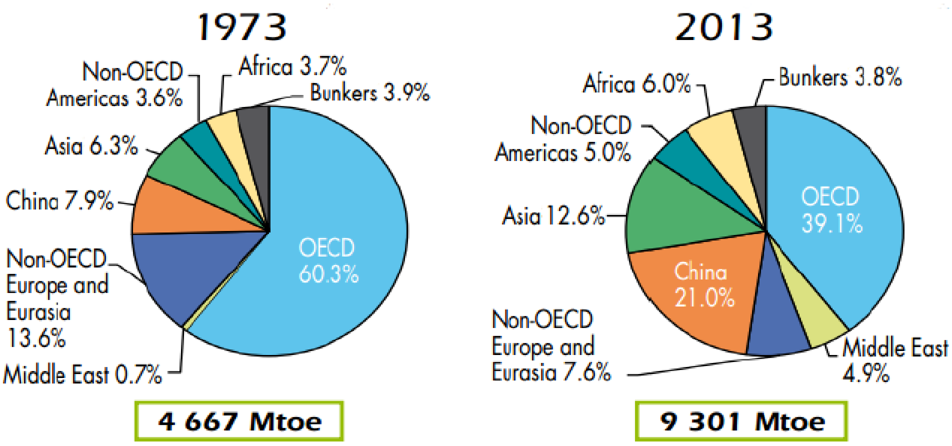

Figure 1. Total final energy consumption in 1973 and 2013 by the world regions.

Notes: Asia excludes China. The charts include international aviation and international marine bunkers.

Source: IEA, 2015a.

Amongst the main instruments to restrain energy (especially fossil fuels) consumption growth are the measures ensuring energy saving, energy efficiency and application of renewable technologies (RES). RES are also instrumental in addressing climate change and environmental degradation and could substitute for fossil fuels – the main energy source today.

However, given today's level of extraction global fossil fuel reserves are expected to be exhausted within decades: coal in 109 years, natural gas – in 54 years, and crude oil reserves in 53 years (compared to 2014) [BP, 2015]. British Petroleum (BP) acknowledges the projections may be influenced by external factors, and, should circumstances change, could possibly be extended. Should these estimations be true[4], there are not more than 50 years to develop new energy sources and deploy related technologies (Figure 2). Figure 2 shows the estimation of different types of fossil fuels exhaustion for crude oil, natural gas, and coal.

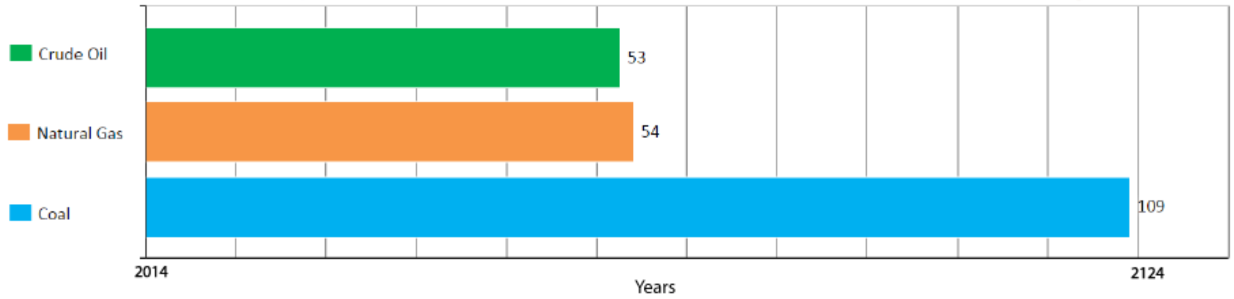

Figure 2. Fossil Fuels: estimated years of extraction remaining.
Source: BP, 2015.

The share of renewable energy sources in the energy balance of developed and many developing countries is growing slowly but continuously. The share of RES in the global energy mix, earlier predicted by the World Bank for 2020, had already been achieved in 2010. Currently all RES continue to show high growth rates and renewable energy solutions are becoming more competitive in the market. In 2014 the share of renewables accounted for 18.4%, and average annual growth was expected to amount 0.17% with currently adopted policies around the world [IRENA, 2016]. In global electricity generation renewables (including large hydro) accounted for almost 22% in 2013 and this value is projected to reach 26% by 2020 by IEA [2015b]. Global investment in renewable energy in 2014 constituted 270.2 bln USD, largely due to the increase of investment in solar and offshore wind energy [*von Zitzewitz*, 2015]. IEA [2014a] projects that the RES mix on 2050 will be mostly formed by wind (34%), hydropower (30%) and solar technologies (18%).

A research group from University of Technology in Lappeenranta (Finland) modelled the development of selected technologies across European regions with a view to identify technical and financial opportunities for the transition to 100% RES in Europe [Bogdanov, 2016]. The research group took into account entire RES potential in Europe, a number of advanced power storage and transmission technologies, as well as changes in energy demand in several sectors. The calculations showed that achieving the goal is possible based on wind (45%) and solar (27%) energy due to their higher potential compared with hydropower. One of the main conclusions of this study is that 100% RES-based energy sector will be more competitive than the one based on fossil fuels and nuclear energy.

[4] The Club of Rome predicted in the 1970ies that fossil fuels would have been exhausted in 2000. This forecast did not come true as new technologies have been deployed by extractive industries and new reserves have been discovered.

Russia accounts for only 1.5% of renewables in centralized power production and is somewhat outside the global trend despite high renewable energy potential [RusHydro, 2015]. This is mainly explained by the abundance of Russian fossil fuel resources that are among the largest in the world (2nd place in total proved reserves for coal and natural gas, the 6th in crude oil). This fact ensures the country's short-term economic and energy security, meets current and near future needs of the Russian economy in raw hydrocarbons, coal and uranium [Ministry of Energy of the Russian Federation, 2009]. However, in considering major energy sources, policy-makers and consumers should take into consideration not only economic advancements, but also impacts for long-term energy security, consumer satisfaction, guaranteed access to safe energy sources for entire population, environmental sustainability, climate change and public health, all of which contribute to the quality of life and are in line with the new energy paradigm that settles around the globe. Today the share of oil, gas and coal constitute 90.6% in the total primary energy supply (TPES), amounting to 731 Mtoe (Million Tonnes of Oil Equivalent) in 2013 (figure 3).

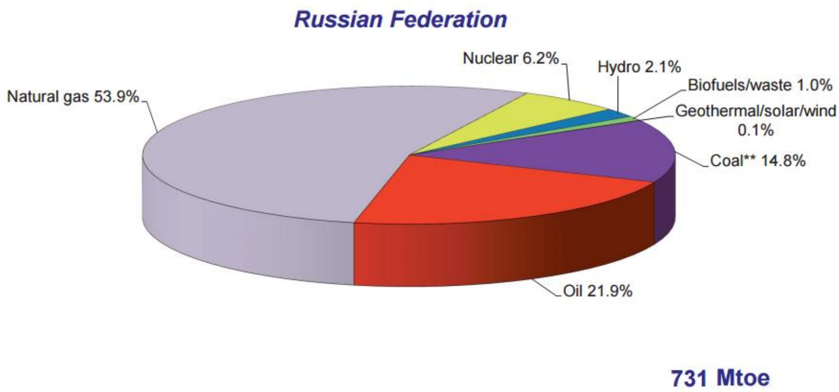

Figure 3. Share of total primary energy supply* in 2013 in the Russian Federation

Notes: Share of TPES excludes electricity trade. Peat and oil shale are aggregated with coal, where relevant. Shares of under 0.1% are not included and thus the total may not add up to 100%

Source: IEA, 2015c.

Russia remains one of the key global energy players. In 2015, after crude oil prices plummeted, Russia reached the record high volume of liquids production from its conventional oil fields (surpassing the 11 million barrels per day in 2014). However, energy sector alone cannot ensure a *"steady and robust economic growth as the economy"* [IEA, 2014b]. The economy and energy sector have to become increasingly innovative and increasingly diversified. This may be a good turning point to advance other energy segments and sectors of economy and the authors support the thesis that RES may be part of this change.

The following features make renewables work as the drivers of change [IRENA, 2015]:

- Diversification of energy sources;

- Technology development;
- Cost-effective energy access in remote areas and for off-grid users; and
- Environment protection and climate change.

Further implications of these drivers for Russia are analyzed.

The paper starts with the description of the methodology and scope of the study followed by trends and uncertainties of the energy sector and their implications for the Russian sector. It proceeds with analysis of renewables as drivers of change in existing world energy mix and their potential. Further, Russia's incentives to shift to the green development path are discussed. The paper concludes with the main research results and provides some plausible development paths.

Methodology and scope

Analysis and conclusions presented in this paper are part of the one-year Foresight study implemented since August 2015. The study also envisages scenario analysis and recommendations for policy-makers and aims at:

- Identification and analysis of the most significant trends, uncertainties and challenges in the energy sector and assessment of their potential impact on Russia;
- Based on the trends analysis and literature review determining the thematic focus of the study - the most significant renewable energy technologies and analyzing their alternative future trajectories;
- Development of recommendations for governmental and corporate strategies and actions in the selected areas.

This paper addresses the first goal and presents trends, uncertainties and challenges in the energy sector.

The aim of this paper is to identify existing global trends and uncertainties in the energy sector and their influence on Russia. This paper outlines the main preconditions for increasing the share of renewable energy sources in the Russian energy mix in order to strengthen security, reliability and sustainability of the Russian energy sector.

The following methods were applied in this study: literature review, desk research, trend analysis, expert survey, and expert seminars.

First of all, a substantial number of publications were analyzed. The literature was selected among the recent publications related to energy and, more specifically, renewables. The selected sources include foresights and future studies of national and international organisations, companies and research institutes operating in the energy sector; foresights, sectoral studies and research papers of consulting companies and investment banks; scientific articles published in energy thematic journals with high impact-factor and papers with a high citation value; research papers published in data bases Scopus and Web of Science; Russian and international energy-related regulatory documents; Russian periodic publications with expert materials; publicly available presentations at national and international conferences on energy. This analysis formed the research framework, scope of the study, identified the role of renewables in the energy sector, preconditions for their deployment, and potential renewable energy sources that may be developed in Russia.

At the second stage of the research global trends and uncertainties in the energy sector were identified and analyzed with implication to Russia. Trends characterize broad parameters for shifts in attitudes, technologies, policies and business focus over some periods of time, and may constitute both threats or opportunities for development [Saritas, Smith, 2011]. Uncertainties, in turn, hamper the sector's development, influence investment decisions and, thus, should be also taken into account by policy-makers. This method was widely applied in studies of energy sector and particularly renewable energy domain [Zhang et al., 2013; Blaabjerg, Ionel, 2015; Froggatt, Schneider, 2015].

The STEEPV framework was used to structure identified trends and ensure that a broad range of them are covered [Saritas et al., 2015]. 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 in the energy sector.

The identification of trends was carried out using different methods including scoping, desk research, expert procedures, STEEPV (social, technological, environmental, economic, policy and values-related) trend analysis, SWOT analysis, and brainstorming. Analysis of Russian and international regulatory documents and scientific publications helped identify the initial list of trends grouped under the STEEPV structure for mapping them to the appropriate categories and to identify systemic relationships between them that were further reviewed and corrected by a few selected energy experts.

The initial list of trends was verified through an expert survey targeting 300 specialists with an equal distribution by type of organization: research centers, universities, international organizations, to government bodies, development institutions, associations of producers and consumers, development institutions, companies (including start-ups – residents of Skolkovo), technology platforms, innovation clusters and sectoral associations of producers and consumers. The response rate was 20%. The survey results were presented at the international research workshop "Global trends and uncertainties in the energy sector" held on December 11, 2015 at Higher School of Economics with the participation of 30 experts from Russia and three international experts (from Austria, Germany and Finland).

Based on the comments and discussion obtained during the workshop and the prior survey results, the final list of trends was formed. The uncertainties affecting energy sector were identified similarly to the trends. Among the selected global trends experts identified those that are most relevant to Russia (through the expert survey and at the workshop).

Global trend in the energy sector and their implications for Russia

Based on literature review key global trends in the energy sector were identified (table 1).

Table 1. List of trends in energy sector categorized by STEEPV

Social trends
Increasing differentiation among energy consumption patterns of different social groups/groups of countries
Reduction of negative effects for human health due to “clean” energy technologies
Increasing risks for population health due to accidents at energy facilities (large scale man-caused disasters)
Growing awareness of population about “clean” energy sector and industrial technologies
Technological trends
Increasing the accessible hydrocarbons resource base and improving the technologies of fossils extraction
Development of “clean” (low-waste and waste-free) and efficient nuclear energy technologies (closed nuclear fuel cycle, advanced fast neutron reactors, small nuclear power technologies (creation of mobile ground and floating small nuclear power stations, power plants up to 5 MW))
Development of low-grade heat technologies for industrial and energy facilities to increase their efficiency and reduce anthropogenic influence on climate
Development of “smart” energy technologies, including smart grid and digital infrastructure
Development of new energy storage and transportation technologies
Use of new materials in the energy sector (e.g. composites)
Economic trends
Decreasing energy-intensity of developed economies
Shift of energy demand towards Asia (primarily China and India) and Latin America
Change in the world energy balance: decreasing share of fossil fuels and increasing share of renewables
Decreasing resource intensity of the world economies
Environmental trends
Tightening environmental policies for mining and processing of fossil fuels
Increasing amount of energy generated from various types of waste in several sectors of economy, including consumer generation
Development of low-carbon energy technologies (accumulators; storage of hydrogen, materials, gas; vehicles operating with fuel cells etc.)
Rising environmental damage and increasing climate change caused by greenhouse gas emissions
Changes in the hydrological river regimes and the exclusion of agricultural lands due to hydropower plants operation

Policy trends
Development of post-crisis (after 2008-2009) economy's "green growth" policies including governmental support for the development of renewable energy, energy saving, and other low-carbon energy technologies
Renunciation or reduction of plans to use and develop certain energy sources (nuclear power, for example) in some countries
Changing governmental role in the energy sector: decentralization of the energy sector where government retains only key functions, such as regulatory, provision of security and operational management,
Decreasing influence of certain groups of countries and international organizations (i.e., OPEC, IEA) on energy markets
Value trends
Increasing quality of life due to increasing energy consumption
Increased energy saving by households and industry in developed countries
Growing consumer adoption of new technologies and their price change
Development of natural resources use culture in developing countries
Integration and development of 'sustainable development' concept of social, ecological, and economic aspects) in corporative culture

Source: authors own analysis.

Global trends may bring both opportunities and threats for the development of Russian energy sector. Most likely not all the trends will develop at the same speed (for example, the creation of fourth generation reactors will advance slowly, and the technologies for the extraction of unconventional hydrocarbons have already changed the world oil markets significantly). The main factor of uncertainty here is a technology cost, which determines its competitiveness. Some uncertainty is due to the rapid development of low-temperature superconductors, nanotechnologies and hydrogen energy technologies that may cause a breakthrough in any area of applied science from energy storage to computer technology.

One of the most promising technology trends for the Russian energy sector is the development of mining technologies for production of unconventional hydrocarbons (collectors with low permeability, oil sands, clathrate hydrates, superviscous oil etc.) including regions with extreme conditions [Boute, 2016]. Energy center of Skolkovo Moscow Management School [2013] forecasts the production up to 70 mln tons of liquid hydrocarbons (oil, condensate and other liquid hydrocarbons) from low-permeability rocks in Russia by 2030. The extraction will be also carried out in the US, Canada, China, Argentina, Brazil and others. It is projected that unconventional gas will account for about 20% of the world gas production by 2040 (14% – shale gas, 4% - coal bed methane and 1% – biogas) [RAS Institute of Energy Studies, Analytical Center of the Government, 2014]. However, the exact volume of proven and technically recoverable fossil fuel reserves remains hard to define [EIA, 2015]. This uncertainty is complemented by uncertainty about the cost and profitability of commercial reserves extraction. However, even at existing (traditional) Russian oilfields the recovery factor reaches a very low value of 20-30% while it is up to 70% in developed countries. Increasing the extraction efficiency of fossil fuels automatically increasing the efficiency of energy sector. Energy technologies used by manufacturing companies and agriculture also vary, which directly affects the energy mix.

Another future trend is the development of “clean” and efficient nuclear energy technologies [Karakosta et al., 2013]. In its “New Policies Scenario” IEA forecasts an increase in installed nuclear power capacity in Russia from 25 GW in 2013 to 30 GW in 2020 and 44 GW in 2040 [IEA, 2014a]. The Russian researchers foresee the development of the new generation (IV) of fast neutron nuclear reactors and technologies of closed nuclear fuel cycle that will allow increasing the efficiency of nuclear fuel use (up to 50 times – EU, 2013) and reducing the amount of the remaining nuclear waste [Higher School of Economics, 2015]. Such fast reactor programmes are being developed in China, India, Japan, Russia, and Europe [EU, 2013]. It is likely that nuclear fusion technology will appear at the market in the next 30 years. The widely known nuclear fusion research program is the International Thermonuclear Experimental Reactor (ITER) with unites scientists from China, Europe, India, Japan, Russia, South Korea and the US [EU, 2013].

Recycling technologies of rejected low-grade heat at industrial facilities and power production are also among perspective trends with possible positive influence.

The growing impact of ICT in the energy sector is a mainstream trend. This applies to smart control systems (e.g., cyber-physical devices and systems of Industrial Internet of Things), and the digitalization of infrastructure, which collects data and integrates these systems on a completely new level with the use of cloud computing and big data (e.g. smart grids) (*Panajotovic et al.*, 2011; *Moyer and Hughes*, 2012). These solutions, in turn, require new provisions to ensure data security and protection against new types of cyber threats [Ryabov, 2015].

Development of low-carbon energy technologies (accumulators; hydrogen storage, materials, gas; fuel cell vehicles, etc.) pose some uncertainties due to their rapid development and may cause a breakthrough in any area of applied science from power generation to energy storage. Stationary and portable super accumulators suggest more advanced solutions in energy storage. The prominent example is the projected Tesla manufactory that will produce Li-ion batteries the capacities of which exceed cumulative operating capacities of the plant (Skoltech, 2016). New solutions in this area will help address the instability in power generation by RES.

Low-temperature superconducting transmission and distribution cables, when it will be possible to use them for long distances, will provide completely new possibilities of high-speed power transmission. The use of new materials, e.g. composites, for transmission lines insulation or as suspension insulators, has a range of advantages such as increased reliability of operation, light weight, high intrinsic safety, absence of micro cracks, etc. [Kudryavtsev, 2016].

The upcoming revolution in data storage and proceeding is associated with photonics. Such technologies imply the use of light instead of electricity and foresees the market of 20 bln USD by 2030 (Skoltech, 2016).

The above mentioned trends contribute to faster and more efficient deployment of renewable energy technologies, that become more efficient and cheaper every year. Some of the recent developments in photovoltaic (PV) are flat solar collectors, thin-film solar cells, and perovskite solar cells [Higher School of Economics, 2015]. The production of the latter caught up to silicon cells in 2015, and new type of PV combining silicon and perovskite is expected to be produced in 2017 with efficiency of 25%.

A significant threat for Russia is the growing share of infrastructure deterioration, which reaches 70%. Hundreds of power plants require replacement, repair, or maintenance of basic equipment due to the lack funding. The solution may be found in the shift towards active modernization actions in the energy sector, including replacement of equipment or key components and maintenance of turbines.

Of particular threat among social and economic trends to the Russian energy sector, there are increasing risks for the population associated with accidents at power plants; lower resource consumption by developed economies (due to lower amounts of hydrocarbon export); the changing geography and routes of oil transportation, as well as low oil market prices and reduced investment in its exploration. Reasonable opportunities for the energy sector development are provided by scaling up “clean” energy technologies, enhancing the consumer adoption of new energy technologies and their prices. The development of energy-water-food nexus technologies require extended inter-sectoral governance measures [Higher School of Economics, 2014].

Substantial opportunities for Russia are associated with a shift in energy demand towards Asia and Latin America. Growing China and India economies in 2040 are estimated to account for 30% and 20% in global energy consumption respectively [Exxon mobile, 2015]. This trend requires increasing availability of energy efficiency and energy conservation technologies, which, however, will not be able to revert the growing global energy consumption (except for the OECD32 economies). At the same time, such opportunities also pose a challenge to keep a competitive advantage as a resource supplier to external markets.

Due to the depletion of conventional oil and gas reserves in the developed countries, the production is shifting to regions with unstable political and economic situation, and the regions involve in armed conflicts. This increases the risks associated with the instability of production and lack of secure energy supply. Energy security, thus, turns into a factor of uncertainty. Increasing competition and the diversification at the energy markets may partly compensate this effect, but it is unclear at the moment to what extent.

The global climate change associated with greenhouse gas emissions at the same time represent the most important uncertainty factor for the sector. The inability of modern science to reliably predict and model climate changes in and natural disasters results in the limited capacity to formulate consistent policy measures to address these issues [Kovalev, 2015]. The uncertainty of climate models is enhanced by the insufficient understanding of the mechanisms of generation and sources of greenhouse gases. For example, large hydropower plants, traditionally regarded as "low emitting", are a significant source of methane, known for its greenhouse effect. Toughening of environmental standards associated with climate change poses a challenge to Russia that has to adapt the national legislation to the regulations of countries that import Russian energy [Bernauer, 2013; Higher School of Economics, 2014].

Renewable energy sources: drivers of change for the new energy wave

Diversification of energy sources

Diversification of energy sources is closely related to the concept of energy security, which, in turn, constitutes an important consideration of national energy planning. Energy security has caught increasing attention of researchers and decision-makers [Loeshel et al., 2009]. The IEA defines energy security as “*the uninterrupted availability of energy sources at an affordable price*” [IEA, 2015d]. Long-term energy security is addressed through assuring timely energy supply to satisfy the needs of the economy in a sustainable way. Short-term energy security focuses on the ability of the energy system to react promptly on sudden changes within the supply-demand balance. Insufficient energy security is therefore associated with physical unavailability of energy, non-competitive or overly volatile prices [IEA, 2015d].

Thus, energy security and diversification of energy mix are the important drivers for renewables’ deployment. As Russian budget heavily relies on fossil fuels export, it is highly affected by global oil and gas prices, which imply the need for energy mix diversification enabling the economy insulation from fossil fuels prices’ “rises and swings”. Such a trend can be globally observed both in countries that are net exporters and net importers of fossil fuels. For example, Germany imports about 71% of fossil fuels it uses in primary energy consumption [BMWi, 2014]. To decrease this value in long-term, the country adopted “The Energy Concept” in September 2010 aiming to increase the relative share of renewable energy from roughly 10%

in 2010 to 60% in 2050. The share of renewables in electricity supply is supposed to grow up to 80% by 2050 [BMWi, 2012]. Certain achievements have already been made: 30% of gross electricity generation in 2015 was based on renewables: a marked growth compared to 24% in 2013 and 6% in 2000 [BMWi, 2016].

At the same time, some of the OPEC members invest in renewables developments as well. For example, Saudi Arabia is working on a long-term program to become a leader in solar and wind power, aiming to export electricity instead of fossil fuels by 2040 [Vedomosti, 2015]. The Qatar Solar Energy company, the first vertically integrated PV manufacturer in the Middle East & North Africa (MENA) region, announced the plan to produce 2.5 GW of solar energy annually, aiming to produce 2% of power output by renewables by 2020 [Qatar Solar Energy, 2016]. These cases demonstrate that ensuring energy security at a higher level requires rearrangement of the current energy mix in order to decrease the share of fossil fuels.

Advancements in energy technology

Advanced technology base assures country's international competitive advantage, while its absence makes it hard to catch-up with the leaders [Kim, 2015]. A well-developed technology base in renewable energy allows to expand a country's technology portfolio to production of related equipment, decreasing dependence on foreign exports and induce spillovers to other sectors [Peters et al., 2012]. For developing countries international technology transfer is considered to be one of key element in efforts to ensure low carbon growth and clean development mechanism introduction [Lema, Lema, 2013].

According to the research conducted in MIT, Russian economy has an Economic Complexity Index (ECI) of 0.548, which makes it the 38th most complex country in the world [OEC, 2016]. Russia exports 132 products with revealed comparative advantage, with top exports in Crude Petroleum, Refined Petroleum, Petroleum Gas, Coal Briquettes and Raw Aluminum. Despite some limitations of the calculating model, we may conclude that as Russia is already advanced in extractive industries, it should be fairly easy to extend the competences to renewables. The mains limitations are the use of database Comtrade covering only product export without services and calculation of ECI based only on export data without internal markets, etc.

Overall, renewables constitute a rapidly developing and a highly prospective market. Technological advances of renewables may be induced both by technology-push (e.g., direct government subsidies or regulations) and market-pull (e.g. application of market-based stimuli as tradable permits or feed-in tariffs) policies [Peters et al., 2012]. The efficiency of the former can be proved, for example, by rising patent activity illustrating technological and innovation progress. According to the World Intellectual Property Organization [WIPO, 2014], the number of patents filed over the last five to six years within biofuels, solar thermal, solar PV and wind energy, exceeds the number of patents filed during the previous 30 years in the same fields. IRENA [2013] also claims that patents alone may spur technological progress.

Cost-effective energy access in remote areas and for off-grid users

Renewable energy sources may contribute to the development of the geographically remote regions that have no access to the power grid and those regions, where extending the power grid or central heating are not economically viable. According to the World Bank [2015], about 1.1 billion people (around 15% of world population) globally live without the access to electricity. This number is continuously declining due to the development of such regions, due to poverty elimination and other developments. Without access to the central grid, power supply is executed via autonomous power generating units. In such situations typically, diesel generators are used, which drive the cost of produced electricity [Elistratov, 2014]. Apparently, there is no unified approach on ways to provide electricity to those regions due to their climatic and geographical characteristics and renewable energy potentials. Solar PV and wind remain the most popular sources to address power scarcity due to their advanced stage of development (compared to other options). Their combinations, such as solar-geothermal plants [Inhabitat, 2012], or wind energy-hydrogen fuel cells [Fuel Cells Bulletin, 2011] may also be considered.

Moreover, the cost of energy production from renewable sources has been rapidly decreasing and is already comparable with traditional energy resources. Solar power is projected to become the cheapest source of electricity in many regions of the world in the short run [Mayer et al., 2015]. After equipment installation and the end of the recoupment period maintenance costs are very low and fuel cost is zero. However, other kinds or arising challenges should also be taken into consideration. Energy storage and its transportation to consumers, who are often located in other regions (in case of industrial production) can appear to be quite costly for countries if the decision is made to produce electricity at a distance from its actual consumption.

Environment protection and climate change

The evidence of global warming is recognized worldwide. Rising temperatures are accompanied by change in climate and weather patterns: natural disasters (e.g., droughts and floods) are happening more and more often. Greenhouse emissions such as carbon dioxide (CO_2), methane, and others, induced by the use of fossil fuels to generate electricity and heat, are the main reason of temperature increase. The empirical study carried out by S. Shafiei and R. Salim [2014] proves that use of renewables significantly contribute to mitigation of climate change. To monitor and limit the amount of emissions at the level that does not lead to unavertable climate change consequences, the United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992. As of December 2015 it includes 196 parties from all over the world.

Russia is one of the largest CO_2 emitters in the world: measured per USD 1000 of GDP at PPP the country's carbon intensity was 0,78 tons in 2012. The country is an Annex I country of the UNFCCC and Annex B party of the Kyoto Protocol [UNFCCC's agreement of 11 December 1997] that makes it responsible for CO_2 emission reductions and reporting on that. Additionally, in December 2015 the new Paris agreement was drafted by UNFCCC to enter into the force in April 2016 and to provide a framework to govern the greenhouse emissions as of 2020 [UNFCCC, 2015].

Figure 4 demonstrates the change in the level of CO_2 emissions calculated per USD 1000 of GDP in Russia. It raised in 1990-1998 due to the economic growth but afterwards the country managed to decouple its economic growth from emissions: GDP grew by 87.4%, while CO_2 emissions increased only by 8.6% in 1998-2000. Since 2008 a slight increase in emissions per USD1000 of GDP can be observed due to "a modest recovery in economic growth" [IEA, 2014b].

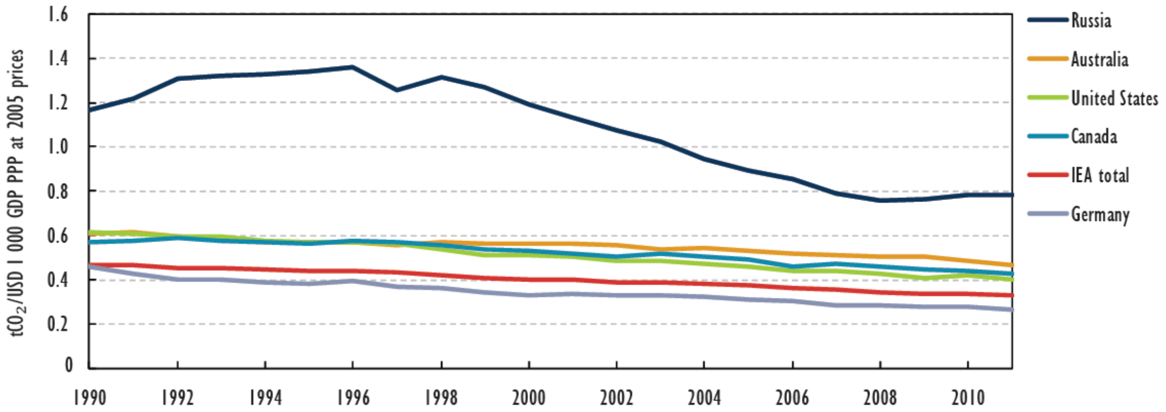

Figure 4. Energy-related CO_2 emissions per USD 1000 of GDP PPP in Russia and selected IEA member countries (1990-2011)

Source: IEA, 2013.

Increasing renewable (and, possibly, nuclear) energy share in TPES will lead to decreased carbon intensity of the Russian economy and level of CO_2 emissions emitted to the atmosphere.

A shift to the green development path: incentives for Russia

The Russian energy sector will shortly face a choice to continue focusing on fossil fuels or to start integrating renewables. The considered pros and cons for both are summarized in the table 2.

Table 2. The comparison of the fossil fuels and renewable energy sources future.

Why not fossil fuels?	Why renewables?
• Conventional fossil fuels to be exhausted in ~50-100 years; their extraction becoming more expensive • Non-conventional fossil fuel resources require additional study and investments • Demand for fossil fuels will be slowly decreasing • Falling prices for fossils in the future (e.g. due to decreasing demand) • Ageing equipment needs replacement • Tightening environmental policies • In general fossil fuels constitute the limited solution for the energy supply challenge	• RES continuously address the growing demand for new solutions and foster technological innovations in the energy sector • Due to diversification of energy mix they increase the energy security and limit the dependence on hydrocarbon prices • Provide cost-effective electricity and heat access in remote areas • Falling prices for RES equipment and almost zero-costs for equipment maintaining • Cut emissions including GHG • RES provide long-term solution for energy supply

Source: authors own analysis.

To sum up, the world is already shifting towards renewables deployment and those countries will have a greater success in this field, who will be among the first ones. Low oil and gas prices offer Russia a unique incentive to shift to greener energy sources, including renewables. This shift will allow the country to:

- diversify its economy to limit its dependence on hydrocarbon prices;
- cut emissions including greenhouse gases;
- foster technological innovations in the energy sector and decrease energy intensity of the economy;
- cut costs (including government subsidies) associated with expensive exploration and extraction of fossil fuels;
- develop remote and isolated regions;
- provide households and industrial enterprises with affordable energy solutions.

Most of these incentives are reflected in the draft Russian Energy Strategy 2035 – the main document of energy sector development that is being finalized by the Ministry of Energy. Its central idea is the transition to innovation-based development of the Russian energy sector, which will provide *“the conditions for the development of the Russian economy including its diversification, higher level of technological development and lower infrastructure constraints”* [Ministry of Energy of the Russian Federation, 2014].

The Government Order No. 861-R [Government of Russia, 2013a] and Decree No. 449 “On stimulating the use of RES for power generation at the wholesale market” [Government of Russia, 2013b] of May 28, 2013 established the first mechanism in the regulatory framework for RES access to the wholesale market. The Government Order №47 “Encouraging the use of renewable energy in retail electricity markets” of January 23, 2015 determined the supporting mechanisms in electricity retail market for biogas, biomass, landfill gas etc. including long-term tariff regulations and their limiting values [Government of Russia, 2015].

The National Technological Initiative (NTI) was announced by the Russian President on December 4, 2014. NTI is a long-term program of public-private partnership aimed at developing seven prospective high-tech markets that will determine the growth of global and national economy in the next 15-20 years. One of the planned outcomes of this initiative is to make Russian companies become global leaders at selected markets (including energy) by 2035. EnergyNet (energy market) is "*based on technological solutions that provide the intelligence and the distributed nature of energy networks (smart grid)*" [RVC, 2015]. Undoubtedly, RES will shape key products for this market.

Additionally, on July 22, 2015, the Russian Federation became a member of the IRENA and received direct access to best practices in RES research, development and deployment [IRENA website]. According to the organisation's research, wind power, biomass, and small hydro plants have the largest potential in the Russian renewable sector [IRENA, 2015]. Atlas of renewable energy resources in Russia, designed by experts from Lomonosov Moscow State University, Institute of Energy of the Higher School Economics and Joint Institute for High Temperatures, additionally includes solar PV as a prospective market with 20743243 bln kWh of annual gross potential [Reencon-XXI, 2015].

Conclusion

After the world economy experienced a downturn of 2008-2009, countries have re-orientated towards green growth, whereby environmental concerns are integrated with economic targets. The business community is trying to seize the opportunity by taking the advantage of first comers.

An overview of world energy trends shows that developed and emerging economies are mostly focused on significant increases in energy efficiency, self-sufficiency in energy resources, and the diversification of energy mix by increasing the share of renewables and unconventional hydrocarbons. In this regard, renewables are seen as a prospective and easily accessible energy source in medium and long-term future, and RES capacities are expected to cost less and develop faster than other energy sources. RES advantages over fossil fuels are nearly zero emissions, zero cost of energy resources, low equipment maintenance costs, and infinity of reserves.

Countries exporting energy resources have to keep and further increase the volume of their export in order to retain traditional and enter new geographic and product markets. In case of consistent implementation of these trends, external risks for Russia will increase substantially in the West (the need to restore supplies to the EU) and in the East (the need to accelerate market entry to the Asia-Pacific countries). Thus, the main external challenge for the Russian energy sector is the radically tightening competition at international energy markets. The main domestic challenges are the overdue comprehensive modernization of the Russian energy sector (including infrastructure and energy efficiency); technological catch-up with the developed countries; increasing the recovery factor at traditional oilfields; diversification of energy mix by increasing the share of renewables.

Today the Russian economy is predominantly based on hydrocarbons. However, the energy sector will shortly face a choice between preservation of existing structure, technologies and processes and the transition to a more efficient and "green" development path to address the existing challenges and constraints. Renewables are able to lift a range of existing barriers, diversify the country's economy by creating a new high-tech sector, strengthen energy security by limiting the dependence on hydrocarbon prices, lower emissions, foster innovation activity of the energy and adjacent sectors, assist the development of remote and isolated regions, and partially replace deteriorated facilities.

Despite the substantial technical, environmental and economic potential renewable energy technologies in Russia are at early stage of development. Of all RES solar and wind power, biomass and small hydro plants have the highest potential in Russia. The preconditions and plausible future scenarios of their development are yet to be explored.

Overall, the trends and uncertainties identified may have both positive and negative impacts on the development of the Russian energy sector. In particular, this applies to social, economic trends and trends in environmental protection. In this regard, the experts noted the need to develop research and innovation policies that will minimize the negative consequences.

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Elena Kyzyngasheva
National Research University Higher School of Economics (Moscow, Russia). Laboratory for Science and Technology Studies, Research Assistant;
E-mail: kyzyngasheva@gmail.com

Liliana Proskuryakova
National Research University Higher School of Economics (Moscow, Russia). Laboratory for Science and Technology Studies, Leading Researcher;
E-mail: lproskuryakova@hse.ru; Tel. +7-495-7729590 ext. 12495