ELEMENTS OF TECHNOLOGICAL FORESIGHT IN RENEWABLE ENERGY FOR RUSSIAN INDUSTRIAL POLICY

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ABSTRACT

Starting in 2011, in the framework of Russia's industrial policy there were established 34 technological platforms in key areas: medicine and biotechnologies, information and communication technologies, photonics, aerospace, nuclear technologies, energy, transport, new materials and metallurgy, natural resource extraction, manufacturing technologies and ecology. Although being initiated in difficult post-crisis time, they represent roadmaps for enhanced development in the context of Russia's economy up to 2030. Here we discuss global technological foresight ideas in 6 areas: bioenergy, hydropower, geothermal, wind energy, solar energy and marine energy.

Key words: renewable energy, technological foresight, innovation, partnerships, Russia

INTRODUCTION

According to Organisation for Economic Cooperation and Development [1] the world spending on Research and Development (R&D) totals 1200 billion dollars US annually. National figures vary widely, for instance the R&D sum for Russia is 1% GDP, while it is 2.7% GDP for Republic of Korea. About 10 billion dollars US – 0.8% of total – are directed into renewable energy R&D. In order to channel these funds effectively, both commercially and through the government budget, technology priorities in renewable energy should be identified. Here we discuss global technological foresight ideas in 6 areas: bioenergy, hydropower, geothermal, wind energy, solar energy and marine energy.

Renewable energy (RE) is a real high technology sector with double-digit annual growth rates, attracting domestic and international investment, so it is a window of opportunity in potentially vast Russian market. The main issue here is whether the Russian technological platforms match global trends in RE advance.

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Among these directions 4 are dealing with renewable energy: 1) 'Bioenergy', 2) 'Renewable energy perspective technologies', 3) 'Small scale decentralized energy systems', and 4) 'Ocean resources'. Renewable energy (RE) is a real high technology sector with double-digit annual growth rates, attracting domestic and international investment, so it is a window of opportunity in potentially vast Russian market. The main issue here is whether the Russian technological platforms match global trends in RE advance.

R&D spending

Global R&D spending in renewable energy has peaked in 2010 at the historical high of 10 billion dollars US compared to around 5 billion dollars US in 2004. That was the time right before a sharp hike in overall investment in renewables and corresponding sharp drop in renewable energy costs. Since then R&D budgets fell to the level of 8 billion dollars US in 2016 [2].

Two big groups concerned here are governments and private corporations. Before 2015 R&D spending used to be spread evenly between these two actors – around 50% / 50%. Just recently corporate R&D began to decline and now the government R&D stands for 70% of the total figure (5.5 billion US dollars per year in absolute value in 2016). Government spending continued to grow through all the 2010's.

Geographically European Union (EU) is still the leader in renewables R&D, closely followed by China. In sectoral breakdown the most of finance goes to solar research, up to 50% of total (3.6 billion dollars US in 2016), the next is biofuels – 1.7 billion dollars US.

Research budgets in solar and wind dropped by 30-40% compared to early 2010's. The share of R&D spending in overall investment declined from 5% in 2010 to less than 3% in 2016, which is a clear indication of maturing industry. This trend has been established along with increase in installed capacity since 2011.

Technological platform #3. Bioenergy

Target: Formulate development concept and implementation roadmap for national bioenergy sector

Coordinator: Federal research center "Kurchatov Institute"

Directions:

- Adaptation and integration of bioenergy into the context of existing energy sector
- Technologies for non-food biomass production on industrial scale
- CO2 capture and transformation to biomass
- Utilization of agricultural, industrial and urban organic waste
- Fermentation of non-food biomass to biogas
- Catalysis processing of biomass into liquid fuels, alcohool and biodiesel
- Species selection and bioengineering

Technological platform #9. Small-scale distributed energy systems

Target: develop typical equipment modules and design small-scale distributed energy supply systems

Coordinators: "Agency for power balance forecasting", "Inter RAO ES" company

Directions:

- Combine standard generation units, local grids, control and automatisation, storage
- Minimize deployment and dissemination costs, reduce manufacturing expenditures
- Formulate roadmap for market, institutional and scientific ambient conditions
- Formulate strategic plan for R&D and innovation implementation in the field of small-scale energy systems

Transition from centralized power supply to combination of diversified energy systems tailored to consumer demand and local conditions

Technological platform #18. Ocean resources

Target: develop the set of breakthrough technologies to exploit marine resources

Coordinator: Federal scientific center "Concern MPO Hydrodevice"

Directions:

- Connect government-private partnerships and scientific research
- Present focus on gas and oil extraction on sea shelf
- Robotic systems for surface and submarine applications
- Ship-based energy supply facilities for coastal urban areas (including nuclear energy)
- Special opportunities for tidal energy development in Okhotsk Sea (Tugur project, 20 GW)

Vast mineral, bio- and energy resource potential in 3 oceans. 5 million km2 - national exclusive economic zone in Pacific Ocean

Technological platform #19. Perspective renewable energy technologies

Target: Accelerate deployment of power and heat generation technologies, based on renewable energy (RE) sources

Coordinator: "Rushydro" joint-stock company

Directions:

- Develop strategic research program. Coordinate technology platform members activity.
- Facilitate operation of RE generators in existing power grid
- Approval of "green energy" tariffs for RE generation
- Standardization for equipment, construction and operation
- Life-cycle monitoring and management for RE projects
- International cooperation in RE development. Russia joined International Renewable Energy Network Association (IRENA) in September 2014

National RE targets in Russia

First national target indicators for renewable energy were established in 2009. According to federal program "Energy Efficiency and Energy Sector Development" 6.2 GW of new generation capacity based on renewable sources should be installed in Russia by 2020. Thus RE share in national energy balance could reach 2.5%, comparing to 0.8% at present. Deployment of 6.2 GW renewable energy capacity corresponds to annual investment of $2 billion dollars US/yr. Average figure for RE investment in Russia in 2005-2014 is estimated at $100 million dollars US/yr – that is 10 times less the announced level [3].

MATERIALS AND METHODS

In order to achieve renewable energy development targets Russia's industry has to pursue global research and development (R&D) trends in this sector. We have assessed global technological foresight issues in 6-7 areas: bioenergy, hydropower, geothermal, wind energy, solar energy and marine energy.

Technology assessment. New and renewable energy (NRE) technologies: we mainly use standard cost-benefit analysis approach. Research and development phase (R&D) requires special treatment, comparison with analogues is useful. In the deployment phase we look at: 1) capital expenditure, 2) operation and maintenance costs 3) overall energy costs at different locations. On the demand side we try to assess: a) potential applications for the new technology b) the size of the market niche. Special consideration: national energy pricing system. General conclusion should be derived on the competitiveness of particular energy technology. Comparison with traditional energy supply.

1. Global hydropower R&D

Investment cost – 1100-1700 USD/kWh. Installed capacity – 816 GW in large hydro plus 280 GW in small hydro, (less than 25 MW), total equal to 1096 GW. Levelised cost of electricity (LCOE) - 5 centsUS/kWh [4].

- No major improvements in machinery
- Computer automatisation in monitoring, diagnostics, protection and control technologies
- maximize the energy produced from existing projects through modernisation
- New sites for small hydro projects
- hybrid systems wing-hydro and hydrogen production
- Pumped storage and grid balancing
- Improvements in efficiency. Reductions in equipment costs. Reductions in operating and maintenance costs. Improvements in reliability and availability

2. Global wind R&D

Investment cost – 1400-1700 USD/kWh. Installed capacity – 487 GW. Levelised cost of electricity (LCOE) - 6 centsUS/kWh [4].

- Large-scale integration of wind turbines into electric grids
- Forecasting power performance, decrease uncertainty in power output
- Extreme environmental conditions, safety, power performance and noise
- Storage techniques
- More efficient generators and converters from electronics industry
- Electric load control and improved power quality

3. Global solar thermal R&D

Investment cost – 5000-7000 USD/kWh. Installed capacity – 5 GW. Levelised cost of electricity (LCOE) - 22 centsUS/kWh [4].

- Parabolic trough technology using high temperature fluid (HTF) or direct steam generation (DSG).
- Central Receiver Systems (CRS) using: molten salt, pressurised air receiver and dish Stirling systems.
- improvement of modular components - concentrators, heliostats or modular receivers
- storage systems for high pressure steam and pressurised, high temperature air - significant drop in electricity costs
- Energy / exergy loss optimisation

4. Global photovoltaic (PV) R&D

Investment cost – 1300-1700 USD/kWh. Installed capacity – 303 GW. Levelised cost of electricity (LCOE) - 10 centsUS/kWh [4].

1. Target - very low cost (while optimising efficiency):

- Improved oxide cells.
- Organic solar cells.
- Nano-structured materials.

2. Target - very high efficiency (while optimising cost):

- Multi-junction cells for use in concentrators

- New conversion mechanism concepts
- New resource for crystal silicon production
- Cost reduction in thin-film technologies
- Long-term stability up to 25 years lifetime

R&D in materials science, device physics and chemistry, electronics, robotics, building technologies, electrical transmission systems and storage.

5. Global bioenergy R&D

Investment cost – 1600-2600 USD/kWh. Installed capacity for electricity generation – 112 GWe. Levelised cost of electricity (LCOE) - 5 centsUS/kWh [4].

- Develop biorefinery concept for biomass feedstocks
- Biological conversion for ethanol, biogas
- Anaerobic digestion for biogas
- Municipal solid waste incineration - electricity and heat
- Production of bioethanol and biodiesel from sugar, oil-based crops and lignocellulosics.
- Biohydrogen
- Availability of cheap feedstocks: short rotation forestry, grasses, straw, sewage
- Increase the energy density by pelletising.
- Improvement of the efficiency of conversion processes while reducing their costs

6. Global geothermal R&D

Investment cost – 2900-3300 USD/kWh. Installed capacity – 14 GWe. Levelised cost of electricity (LCOE) - 7 centsUS/kWh [4].

- Development of deep (>3,000 m) geothermal resources
- Development of hot dry rock formations
- Increased geothermal co-generation of power and heat
- Reduction of costs of geothermal well drilling, logging and completion
- Direct geothermal systems, including geothermal heat pumps and space heating
- Life-cycle analysis, sustainability of geothermal power generation
- Improved conversion efficiency cycles, exergy optimisation
- Induced seismicity on geothermal sites

7. Global ocean/marine energy R&D

Investment cost – 2000-5000 USD/kWh. Installed capacity – 0.5 GW. Levelised cost of electricity (LCOE) - over 20 centsUS/kWh [4].

- Tidal stream current systems based on underwater turbines (transfer of turbines and rotors from shipbuilding industries).
- Salinity gradient (efficient membranes).
- Ocean thermal energy conversion (OTEC)
- Resource potential assessment and monitoring
- Wave energy systems.
- Improvement of power take-off systems.

Fig. 1 illustrates the relative position of 7 renewable energy macro-technologies based on the learning curve – technology assessment tool. The picture is qualitative (there are no concrete units on axis) but it properly reflects the level of maturity and structure of renewable energy sector. Green dot just below the horizontal red line represents solar PV electricity generation technologies demonstrates the key achievement of renewable technologies in 2010's – utility scale solar PV has reached profitability even without any subsidies, it's production cost dropped below grid parity [5].

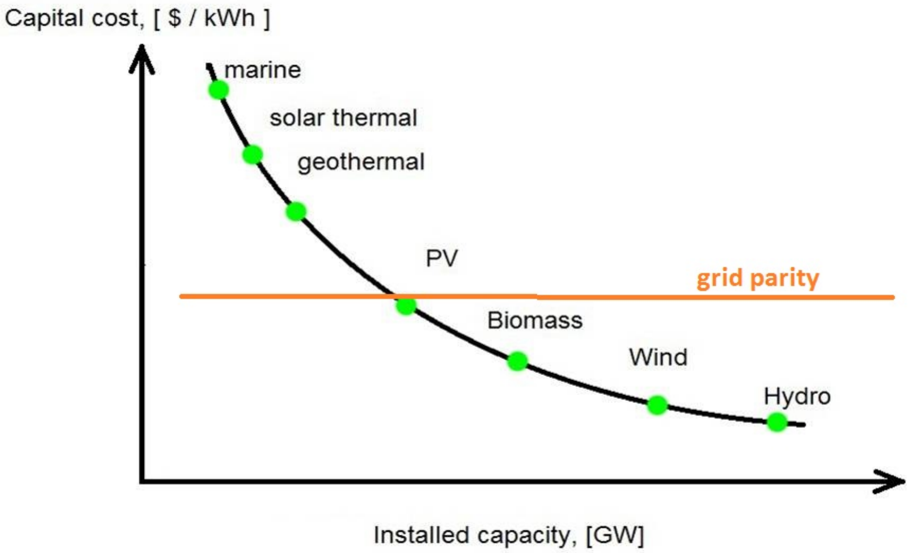

Fig.1. Technology assessment tool: learning curve

Towards the low carbon future

Implementation and scale-up of the set of renewable energy technologies, described above, leads towards less carbon oriented energy system. Early signs of so called 'grand transition' to this new system emerge in the area of energy investments.

Share of fossil fuels in the whole energy investment declined sharply in 2014 - 2016 approaching just 50% (it was around 70% ten years ago) [6]. Growth shifted to renewables, networks and storage and energy efficiency. They are gaining the share at the expense of fossils.

The share of renewables increased from 16% to 17%, networks from 12% to 14% and efficiency investments met 12% of the total in 2015, up from 10% in 2014.

Energy efficiency investment reached 221 billion dollars US in 2015, representing 12% of total spending last year and an increase of 6% from the previous year.

Upstream oil and gas investment revealed a 44% cut between 2014 and 2016. In absolute value energy investment in the global economy totaled 1 830 billion dollars US in 2015, down 8% from the previous year, mostly because of cuts in upstream oil and gas.

Electricity generation spending reached 420 billion dollars US, with renewables accounting for the about 70% of the total, or 288 billion dollars US.

Spending on all renewable energy sources, including biofuels for transport and solar thermal heat installations, totaled 313 billion dollars US, as part of a broad reorientation in investment toward low carbon energy sources.

In China, the largest energy investor by size, new energy investment is dominated by spending on renewables, networks and energy efficiency. Thus, 25% less of coal power capacity has been commissioned in 2016 compared to 2015.

Given the time lag, 5 -7 years ahead in mid-2020's we should experience establishment of the new structure of energy balance globally and in particular countries as well. There will be corresponding economic and social consequences.

CONCLUSIONS

Renewable power generation continued to grow strongly, reaching almost 22% of the global mix, compared to 18% in 2007. Investment in new renewable power capacity topped 270 billion dollars US globally in 2016 and is likely to remain at high levels.

Investment levels in renewable energy in Russia should be raised significantly. Average figure for RE investment in Russia in 2005-2014 is estimated at 100 billion dollars US /yr – that is 20 times less the required level, announced in governmental outlook. In order to achieve renewable energy development targets Russia's industry has to pursue global research and development (R&D) trends in this sector.

Key component in investment is R&D (research and development) spending. The share of R&D spending in overall investment declined from 5% in 2010 to less than 3% in 2016, which is a clear indication of maturing industry. This trend has been established along with increase in installed capacity since 2011.

Here we have identified global technological foresight issues in 6 areas: bioenergy, hydropower, geothermal, wind energy, solar energy and marine energy.

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