

PERSPECTIVES

Renewable energy in Russia: A critical perspective

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Email: mario.pagliaro@cnr.it**Abstract**

Partly explaining the low uptake of energy production from renewable energy sources, Russia accesses huge oil, natural gas, coal, and uranium resources and hosts advanced nuclear energy, oil, and natural gas industries. Yet, the combined effect of the exceedingly low cost of electricity generation via today's photovoltaic modules and wind turbines combined with energy storage in Li-ion battery and hydrogen obtained via water electrolysis will shortly have a profound impact on Russia's economy and manufacturing industry. The buildup of Russia's clean energy technology industry will require proper planning, rationalization efforts, and the development of creative and effective policies, which will include new educational initiatives in today's new energy technologies and energy management.

KEYWORDS

electric vehicle, hydrogen energy, lithium battery, Russia, solar power

1 | INTRODUCTION

Russia is the world's second largest natural gas,¹ the third largest oil,² and the sixth largest uranium³ and coal⁴ producer. The nation globally ranks second in oil, first in natural gas exports, and third in coal exports. The world's largest country currently hosts 700 electric power stations with a total installed capacity of 243 GW (comprised of 165 GW thermoelectric power plants mostly burning natural gas and coal; 29.13 GW nuclear power reactors, and 48.5 GW hydroelectric plants).⁵ All combined, the aforementioned plants in 2018 produced 1091.7 TWh of electricity dispatched in the form of alternating current with a single 50 Hz current frequency across the world's longest (3.018 million km) electric power lines.⁵

In 2018, Russia's thermal power plants including those of large industrial firms produced 693 TWh, hydroelectric dams gave a 194 TWh output, and nuclear reactors afforded over

204 TWh, with two new nuclear reactors entering service in the Leningrad region nuclear power station and in Rostov.⁵

Russia hosts only 143.2 million inhabitants, less than Nigeria. Its natural gas, oil, coal, and uranium reserves are immense. Why then should Russia be willing to develop electricity production from intermittent wind and solar energy, or start manufacturing electric vehicles?

The reasons, I argue in this study, are of economic and industrial nature. The ongoing rapid and massive uptake of new energy technologies enabling energy self-sufficiency via a combination of electricity production from renewable energy sources, energy storage, and digital technology,⁶ threatens to dramatically lower the abundant revenues earned by Russia from selling abroad oil, fuels, natural gas, coal, and even uranium. This picture is further worsened by the concomitant and imminent uptake of battery electric vehicles (BEVs)⁷ well beyond China where BEVs are now a large fraction of the >20 million vehicles sold every year in the Asian country.

An highly developed nation, with large and advanced steel, naval, chemical, automotive, and aviation industries, Russia simply cannot lag behind in the basic industrial sector—energy—when most world's countries achieve the key economic advantages of energy self-sufficiency made possible by almost silent industrial and technical progress in renewable energy and energy storage technologies.⁶

Putting arguments in the rapidly evolving global energy context, this study provides arguments justifying this forecast.

2 | ENERGY AND RENEWABLES IN RUSSIA

Tsarist Russia hosted an advanced oil industry with several oil refineries (export of crude oil was forbidden), but it lagged behind in electrification.⁸ By 1913, Russia hosted 327 MW of installed power, 177 MW of which were located in just three cities: the capital St. Petersburg, Moscow, and Baku.⁹ World War I and the subsequent civil war worsened matters. In the early 1920s, the overall power from all the Russian power stations had decreased to about 70 MW, producing about 500 million kWh of electrical energy.¹⁰

On 7 February 1920, the State electrification commission (GOELRO) was formed and tasked to devise a plan for electrifying the country. By December 2020, the commission presented the delegates of the eighth All-Russia Congress of Soviets held in Moscow a document of more than five hundred pages urging the construction in 10 years of a network of huge (“regional” in a country whose regions are as large as entire countries) thermal, hydropower, and combined heat and power stations.^{8,9}

By 1935, the output of electricity in Russia had reached 13.5 billion kWh from 2 billion kWh in 1913.¹¹ After World War II, Russia pioneered the use of nuclear power with the world's first nuclear power plant (a 5 MW reactor) located in Obninsk, about 100 km southwest of Moscow, connected to the power grid in June 1954.¹²

In accordance with the 2003 law “On electric power industry”, the electricity market in Russia is open (since 2011) to full competition in generation by ensuring third party access to the grid. The energy market regulator is the “NP Market Council” whose main task is to ensure the correct functioning of the national wholesale electricity and power capacity market. All companies in the wholesale electricity market must become member of the NP Market Council (which by mid May 2018 had 415 members).¹³

Since mid-2013, the development of renewable energy in Russia is regulated by a decree entitled “On Procedure for Incitement of Use of Renewable Energy Sources at Wholesale Power Market.”¹⁴ The law establishes a system for which renewable energy developers of projects with an output between (at least) 5 MW and 25 MW can bid in annual tenders



FIGURE 1 The Yelshanskaya 25 MW photovoltaic park in the Orenburg region supplies power to the grid since 1 July 2019. Using only components made in Russia, the plant is expected to produce 30.5 million kWh annually. [Image courtesy of Hevel Energy Group, Reproduced from hevelsolar.com]

for capacity supply contracts with Russia's Administrator of the Trading System.

Winning suppliers are paid both for the capacity they add to the energy system, and for the energy they supply, based on long-term 15-year contracts with fixed tariffs. The incentives are subordinate to purchase 55%, 50%, and 20% of wind, solar and hydro project equipments from within Russia (in 2016, these figures were further increased to 65%, 70%, and 45%).

To avoid a rise on electricity prices, yearly limits control the increase of newly added renewable generation capacity. According to a resolution of May 2013, auctioned power between 2014 and 2020 cannot surpass the 5871 MW threshold (3600 MW wind, 1520 PV, and 751 MW small hydro).

Between 2013 and 2016, slightly more than 2 GW of renewable capacity was awarded in the annual tenders. The 2017 auction saw a total of 2.2 GW across wind, solar, and small hydro awarded in a single tender. The 2018 auction had 1.08 GW of capacity distributed across 39 projects.¹⁵

Finally, in 2019 the competitive tender for new renewable energy capacity from 2019 to 2024 was set at slightly more than 313 MW, most of which comprised of new hydro power capacity (about 230 MW), followed by wind (78 MW) and only 5.6 MW new photovoltaic power (Figure 1), to be connected to the grid in 2022.¹⁵

The effects of the newly installed wind, solar, and hydro-electric power capacity on power generation became noticeable in 2018 when production of wind energy in Russia rose by 69.2%, and that from PV by 35.7%. Combined, wind and solar PV output crossed the 1 TWh threshold.⁵

Perhaps even more importantly, the amount of yearly hours during which wind and solar PV parks in Russia in 2018 supplied energy at their nameplate capacity was, respectively, 1602 and 1283 hours.⁵

Russia's almost unlimited land available for development, the latter long functioning times, and the low and decreasing cost of both PV and wind power generation systems create

the conditions for significant penetration of wind and solar PV in Russia's energy mix via utility-scale PV and wind parks coupled to storage in large Li-ion battery and solar hydrogen systems.

In other words, the combined effect of today's low-cost power generation and storage via, respectively, photovoltaic, wind turbine, Li-ion battery, and solar hydrogen technologies will shortly have a profound impact on Russia's energy and mobility industries. In the following, I analyze first the consequences of BEV massive uptake driven by the newly achieved low cost of Li-ion batteries, and then of stationary storage in Li-ion battery energy systems and in solar hydrogen, namely hydrogen derived from water via electrolysis driven by renewable electricity.

3 | ELECTRIC VEHICLES IN RUSSIA

Today's BEVs are already competitive with internal combustion engine (ICE) vehicles even without subsidies because the cost of Li-ion batteries manufactured and marketed in China was below \$100/kWh already by late 2018.¹⁶ As put it by the managing director of a reputed lithium battery consultancy based in Britain during a US Senate hearing on the supply chain for EV batteries and energy storage held on early 2019:

We are in the midst of a global battery arms race, in which so far the US is a bystander. The advent of electric vehicles and energy storage has sparked a wave of battery megafactories that are being built around the world.

Since my last testimony only 14 months ago, we have gone from 17 lithium-ion battery megafactories to 70. In gigawatt hour-terms, we have gone from 289 GWh to 1549 GWh, that's the equivalent of 22 million pure electric vehicles worth of battery capacity in the pipeline.

The scale and speed of this growth is unprecedented, and it will have a profound impact on the raw materials that fuel these battery plants. The scale of investment will also drive the cost of lithium-ion battery production down below \$100 kWh this year.¹⁷

The consultant provided also figures for the US import dependency for the main minerals used to manufacture Li-ion batteries in 2018: 59% for nickel, 92% for lithium, and 100% for cobalt and graphite.¹⁷

In Russia, the price of electricity is extremely low, and the grid is ubiquitous. Shifting mobility from internal combustion engine to electric vehicles therefore is an economically convenient opportunity starting from companies and cities operating large vehicle fleets.

The State-owned company managing the 6500 Moscow's bus fleet already operates 300 electric buses, by late 2020 more than in any city in Europe.¹⁸ All bids to purchase the e-buses required as mandatory condition the localization of the manufacture process within Russia. Indeed, the first 300 electric buses were commissioned to the two largest Russia's automotive manufacturers (Kama and Gorky automobile plants: KamAZ and GAZ): 200 in Spring 2018 and 100 as of April 2019.

The first electric buses started to circulate in Moscow streets on September 2018. Less than one year later, there were over 180 of them deployed on 13 e-bus routes, carrying more than 80 000 passengers every day.¹⁹ Starting in 2021, Moscow's public transport company will only purchase electric buses, discontinuing purchase of diesel ICE buses.¹⁹

The electric bus supplied by Kamaz, which won the first bid to supply 200 electric buses, makes use of lithium batteries using the lithium titanium oxide (LTO, lithium titanate) cathode technology. The LTO cathode ensures high frost resistance (a key requirement in cold regions), extended service life, and fast charging, which eliminates the need for high storage capacity, lightens the bus, and increases the passenger capacity. Perhaps not surprisingly, the same company is currently building in Moscow a 500 vehicle/year production plant and a R&D innovation center for electric buses.²⁰

Every 1000 battery electric buses, about 500 barrels of diesel are displaced every day,²¹ making the e-bus powered by electricity stored in Li-ion batteries (and shortly in solar hydrogen fueling hydrogen fuel cells) the first electric vehicle to become ubiquitous across the world, entirely replacing buses powered by diesel or natural gas fuels burned in internal combustion engines.²²

With 1.8 million passenger cars sold in 2018 and more than three million vehicles produced yearly, Russia is one of the 12 largest automobile markets worldwide.²³ Around 400 000 workers are employed in automotive manufacturing facilities and special economic zones, where tax and customs benefits are granted to manufacturers and public financing of infrastructure construction is provided.

As shown by the ongoing mass scale electric bus adoption in Moscow, Russia's automotive industry has in EVs powered by electricity stored in Li-ion batteries the first real opportunity to emerge as a leading automotive manufacturer refocusing production from ICEs to battery electric vehicles, so far mostly produced in China.

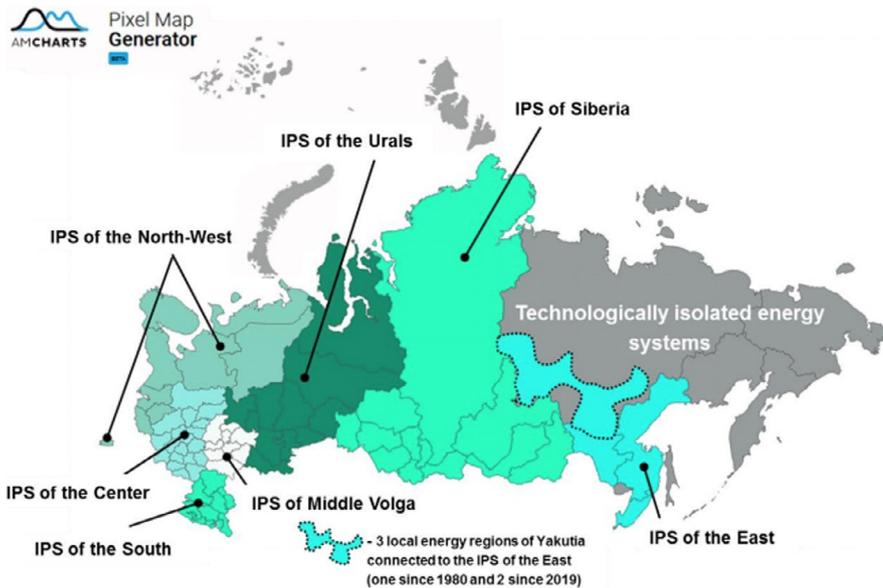


FIGURE 2 The seven integrated power systems of Russia's unified power system. The geographically isolated energy systems are Chukotka Autonomous Okrug, Kamchatka Territory, Sakhalin, and Magadan Oblast, Norilsk energy Districts of Taimyr and Nikolaev, western energy systems of Sakha (Yakutia) [Image courtesy of eclareon, Reproduced from Ref.30]

Along with lithium, nickel, iron, cobalt, and graphite are the main minerals used to produce Li-ion batteries. Russia is the world's largest nickel manufacturer and seventh largest graphite manufacturer.²⁴ Significant increase in graphite production is expected during the next several years due to two ongoing investment projects (Dalgrafit and Uralgraphite).

When it opened in Novosibirsk in 2011 as a joint venture between a Chinese lithium battery manufacturer and State-owned Rusnano technology group, the lithium-ion battery plant using the safe and reliable lithium iron phosphate (LFP) cathode technology was “the world's largest.”²⁵

The plant was expected to produce “up to 500 000 lithium batteries per year, to supply electric vehicles and larger bus batteries, in addition to a variety of energy storage applications, and emergency power supplies.”²⁶

According to market analysts based in Britain, the company “saw downtimes between 2014 and 2016” due to “continuous ruble devaluations that pushed up the cost of imports,”²⁷ including that of battery-grade lithium carbonate from abroad needed to manufacture the battery cathodes.

It is instructive thus to learn that Russia's government-owned nuclear company “pursuing its goal of applying lithium-ion battery technology in the Russian economy “lately signed an agreement outlining the acquisition of up to a 51% ownership in a Atacama lithium project in northern Chile... after sealing a nonbinding agreement in July with Bolivia's energy ministry to cooperate in developing lithium deposits and making lithium products.”²⁷

Russia, in other words, is trying to secure supply of strategically important lithium to manufacture batteries on the multi-gigawatt-hour scale required for mass producing electric vehicles (a 1 GWh storage capacity is enough to equip 20 000 electric cars with a 50 kWh battery pack each).

4 | STATIONARY STORAGE SYSTEMS

As shown by the first 100-500 MWh energy storage systems (ESS) based on containerized Li-ion batteries so far deployed in Australia, California, Hawaii, and numerous regions of China, intermittent renewable power produced at low cost by utility-scale PV and wind parks coupled to ESS becomes of higher quality than power produced by state of the art gas-fired thermoelectric power plants.²⁸ Higher quality here means precise frequency of alternate current, reliability, and immediate availability.

In brief, as the ongoing solar energy PV revolution unfolds across the world,²⁹ the potential of PV and wind power in Russia will be fully untapped when the country will access ESS based on the Li-ion battery at affordable cost. By then, for example, in place of the diesel-fired thermoelectric power units currently used to supply Russian citizens in sparsely populating areas of the country connected to local grids, Russia will use renewable power generation plus storage in ESS.

We briefly remind that the unified energy system of Russia (UES) is divided into seven integrated energy (or power) systems (IES or IPS of the South, Center, Middle Volga, North-West, Urals, East, and Siberia) and a huge area of geographically isolated energy systems (Figure 2), representing a total of 71 regional power systems and different owner structures.³⁰

With an excellent performance of 1283 hours in terms of kWh/kW_p in 2018 for the first 834 MW of PV power installed in Russia,⁵ generating power at overly low generation cost of today's PV technology is now achieved also in Russia.

The results of a recent study aimed at identifying the optimal renewable energy technology and the highest renewable

energy regional potential revealed that even in Krasnoyarsk Region which “seems to be a territory with a northern climate, the actual potential of solar power in the region, which combined with other renewable sources of energy relevant to each municipal entity, outlines a solution for thinly populated, agricultural and remote areas.”³¹

Today, large manufacturers of solar modules in China already commercialize PV modules of 600 W nominal power obtained starting from large (such as 210 mm) silicon wafers. Supplied with a linear performance warranty guaranteeing performance for 25 years, such modules are made of 1/3-cut solar cells in monocrystalline silicon using several busbars to ease the electricity flow.³²

5 | SOLAR HYDROGEN

Solar hydrogen produced via water electrolysis using abundant solar and wind power³³ is also in Russia the complementary energy storage technology that will be rapidly adopted to power heavy duty electric vehicles and provide electricity and low temperature heat to buildings.

For instance, using technology developed by a France's train manufacturer, Germany in late 2018 became the world's first country to launch on a commercial route two electric trains powered by electricity generated onboard by fuel cells converting hydrogen stored at 350 bar.³⁴

Showing how the hydrogen fuel cell technology can be scaled and used to retrofit existing fleets, the train dimensions were similar to that of conventional diesel-powered trains (with no significant changes in weight/point of gravity), while avoiding adding equipment in passenger areas.³⁴

To date, the trains have been running for over one year on a nonelectrified route in Lower Saxony demonstrating the full economic and technical viability of the technology. A few months after the debut, the Lower Saxony railway company ordered 14 hydrogen fuel cell trains to the same manufacturer followed by another 27 trains order from a subsidiary of Rhine-Main Transport Authority, in each case to replace diesel trains on regional lines.

It may not come as a surprise, that in Autumn 2019 Russian Railways reached an agreement with the country's largest train manufacturer and with the government-owned nuclear energy company for the production of the first Russia's trains using hydrogen fuel cells (to be first deployed in the Sakhalin region).³⁵

In state-of-the-art hydrogen fuel cells, platinum in very low amount is the noble metal currently used as catalyst at both electrodes. With over 25 tonnes of platinum mined annually, Russia is the world's second largest platinum manufacturer after South Africa.

The hydrogen fuel cell technology, and in particular the proton-exchange membrane (PEM) technology, is now a

mature industrial technology in several countries including Canada and China. In the first seven months of 2019, China alone increased the installed capacity of fuel cells by 643% to almost 46 MW,³⁶ with 1176 hydrogen fuel cell electric buses manufactured in China practically from zero between 2018 and 2019.

A large number of research institutes are engaged in Russia with research and development activities in the field of H₂ fuel cells,³⁷ and their role, including that of the OOO National Innovation Company New Power Engineering Projects (2006-2010), was recently recounted.³⁸

Soviet Union was leading the field of alkaline fuel cells. Russia currently hosts several electrolyser manufacturers. The largest, PJSC Uralkhimash, produces in Yekaterinburg electrolysers with a capacity of 300-400 cubic meters of pure H₂ per hour.³⁸

Along with electricity, H₂ fuel cells generate low temperature heat in the form of water at 70-80°C, which is ideally suited to provide sanitary hot water to buildings.

The energy density of hydrogen is so high (120 MJ/kg for H₂ vs 43 MJ/kg for diesel fuel) that it is enough to store the excess PV energy generated during Summer as electrolytic H₂ under pressure in today's safe and easily handled reservoirs in composite material to provide off-grid buildings with power and hot water for the whole year even in Sweden. In the latter north European country experiencing 220 days of rain each year, the first off-grid homes of a public housing company powered only by solar hydrogen produced with PV energy are currently being completed.⁶

6 | OUTLOOK AND CONCLUSIONS

The reason for which Russia will shortly emerge as a leading country in new energy technology based on renewable power generation and energy storage in Li-ion battery and solar hydrogen, I argue in this study, is of economic and industrial nature.

As countries increasingly replace thermoelectric power generation with solar and wind power, the demand of gas-fired turbines has gone from over 71.6 GW to less than 30 GW in 2018,³⁹ and this regardless of *increased* energy consumption. Under these conditions, and with BEVs now replacing ICE vehicles at quick pace, becoming a leading country in clean energy technology for Russia's economy becomes an inevitable option.

Aware that solar PV generation is the cheapest way to generate electricity, governments across the world in 2018 auctioned 81 GW of PV power out of about 100 GW installed globally. In 2019, the amount of power contracts through a competitive procurement rose to 90 GW out of 114 GW installed.⁴⁰ In 2018, only seven countries installed between 1

and 5 GW of PV power, but by 2022 the number of such countries is expected to almost triple to 19.⁴⁰

The country currently lags behind in solar cell, Li-ion battery, wind turbine, and hydrogen fuel cells manufacturing but it excels in practically all fields of science, with numerous milestone achievements in the areas of physics, chemistry, mathematics, aerospace, medicine, and engineering. As put it by Hargittai, “there is no other city in the world that has so many memorials honoring scientists as Moscow.”⁴¹

According to Russian scholars writing about Li-ion battery manufacturing in Russia, “the current level of competences, technologies, and production volumes in the Russian Federation does not meet the needs of modern and future markets”.⁴² Yet, neither “competences” nor “technologies” can be a problem to scale-up Li-ion battery manufacturing in a country excelling in virtually all fields of today's science and advanced technology in fields far more complex than battery technology such as avionics, aerospace, and nuclear energy.

To unleash its potential in clean energy technology manufacturing, Russia needs to develop its own national solar cell, Li-ion battery, and hydrogen fuel cell industries, reinvesting part of the huge revenues coming from oil and natural gas sales abroad into developing the national clean energy technology industry.

One single example renders said potential. Russia's sole solar cell and PV module manufacturer was established in 2009 by government-owned Rusnano technology group in Novocheboksarsk. In 2018, the company (Hevel) started shipments of its new heterojunction solar modules replacing thin film modules not only to Russia's customers, but also to customers in Sweden, Thailand, Kazakhstan, and other countries.⁴³ By mid 2019, the company completed the expansion of its heterojunction solar module production capacity from 160 to 260 MW annually.

Though minuscule in volume in comparison with the yearly output of just one of the single top ten PV manufacturers (all based in China, with the first alone having delivered more than 11 GW of solar modules only in 2018),⁴⁴ the new production line yields also 460 W bifacial modules comprised of 144 half-cut bifacial cells.

On 1 July 2019, Hevel connected to the grid a 25 MW solar park in Yelshanskaya (Figure 1). All components of the power plant, including the inverters and support structures, were produced in Russia. Alone, the plant produces over 30 million kWh every year, saving the equivalent of 4 million m³ of natural gas.

The competing dynamics of oil price, economic growth, and oil extraction costs require that by 2025, even keeping the oil fraction in the global energy mix at the 2015 low level of approximately 33%, more than 11 additional million barrels per day will have to be added to current oil production levels.⁴⁵ Furthermore, this exceptional amount of extra oil

should be available at low extraction costs. In brief, driven by socioeconomic and energy global drivers, mankind has in the switch to producing energy from renewable energy sources the only alternative to an energy crisis that would drive social and economic unrest.⁴⁵

In this context, the widespread uptake of decentralized solar energy systems in the built environment on a truly global scale is now a realistic objective for all world's countries.⁴⁶ Even in Moscow's huge (962 ha) Kuzminki-Lyublino urban park, for instance, 228 out of 505 existing lamps are ready to be replaced by solar street LED lights equipped with Li-ion batteries.⁴⁷

The buildup of Russia's clean energy technology industry will require proper planning, rationalization efforts, and the development of creative and effective policies, which will include new educational initiatives in today's solar energy science and technology,⁴⁸ and energy management.⁴⁹

Addressing the delegates of the 1920 All-Russia Congress of Soviets Ulianov (Lenin) said: “*Communism is Soviet government plus the electrification of the whole country*”.⁵⁰ One century later, with Russia fully electrified since decades and renewable energy technologies soon to power vehicles, buildings, and industries, Lenin's insight into the future might be reformulated as follows: “*Russia's economy is its clean energy industry on the scale required by being the world's largest country*”.

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CONFLICT OF INTEREST

The Author declares no conflict of interest.

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