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On the use of «nature-like nanotechnologies» in the buildings engineering systems of urban and rural schools

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ABSTRACT: Introduction. Recently, much attention in the publications of scientists has been paid to "nature-like technologies" in the use of RES – renewable energy sources (sun, wind, heat). At the same time, foreign business, despite the fact that these sources are low concentrated and seasonal, is actively investing in their development. In Russia, these processes have been developing slowly, and therefore, on the basis of a system analysis, it seems relevant to justify the correct vector of application of RES. The article provides evidence of the insolvency of opinions about the insufficiency of the assimilation potential of the biosphere to compensate for the economic activity of mankind. In this connection, the scientific, technical and socio-economic tasks arise for the "reengineering of the technosphere" in the structure of the life support systems of society, including educational facilities. **Methods and models.** To solve these scientific, technical and socio-economic issues, by analogy with individual residential buildings, it is proposed to use "nature-like nanotechnologies" in the engineering systems of schools, and for evaluation - the method of retro-forecasting the results of introduction of domestic innovations, which has proved its adequacy when solving the problems of fire and environmental safety of the technosphere in the regions of the South of Russia. **Results and discussion.** The results of the synthesis and "virtual implementation" of autonomous engineering systems for school buildings are presented, which allow for the decentralization of electricity, water and heat supply by generating resources (water, heat and electricity) using the "Shukhov wind-electric installations" combined with a vortex system extraction of moisture of air, with their duplication by hydro panels and solar batteries. The calculations have demonstrated that the putting into production of such domestic innovations and the «reengineering» with their help of the engineering systems of 40 thousand Russian schools will allow autonomization and proper electricity, water and heat supply, which will ensure their safe functioning in compliance with GOST 12.1.004. Moreover, after the introduction of an autonomous engineering system in the school, due to the annual savings in budget subsidies for "pedagogical services", it becomes possible to increase the monthly salary of each school teacher by 30–40 thousand rubles. **Conclusion.** The conducted studies confirm the results obtained in the synthesis of autonomous engineering systems for individual residential buildings, unequivocally determining the place of RES in the structure of resource supply systems for cities and rural settlements.

KEY WORDS: nature-like nanotechnologies, decentralization of school resource supply, safety, autonomous engineering system, reliability, fire and energy damage, quality of resources, renewable energy sources (RES).

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INTRODUCTION

In domestic publications, the term "nature-like technologies" has been used for the last 15 years [1–8], and in 2016 Corresponding Member. RAS Kovalchuk M.V. gave them the following "decoding" [9]:

"nature-like technologies" – to refer to fundamentally new methods and means of generating and consuming energy on the model of wildlife,

"nature-like technosphere" – to describe its new look, which consists in the restoration of a natural self-consistent resource turnover, which should be created by convergent nano-, bio-, information, cognitive and socio-humanitarian technologies (NBICS technologies)".

In September 2018, during forum in Sochi, the President of the Russian Academy of Sciences Academician Sergeyev S.M. proposed to replace the term "nature-like technologies" with the concept of "reengineering of na-

ture", which, according to the authors, also does not correspond to the essence of adaptive nature management in the framework of the co-evolution of the technosphere with the biosphere [10,11].

Unlike the Kyoto Protocol and other "non-scientific documents", the authors agree with Professor Kokin A.V., who proved that *"...the contribution of human economic activity remains insignificant in relation to the energy potential of the biosphere that has accumulated it over billions of years of evolution"*, and *"the ability these perturbations in from of human economic activity in terms of mass and energy, the time of its formation and development, exceeds them millions of times"* [12, 13].

Therefore, we should not talk about «reengineering of nature», which "mankind is beyond the power of", but about the reengineering of the technosphere (state district power station, boiler houses and thermal power plants, transport, industrial facilities, engineering systems of buildings and structures, etc.), whose technologies "burn oxygen" from the atmosphere and emit toxic gases, dust, liquid and solid wastes, etc. into the environment, generating the fire-energy harm [5, 6].

As noted earlier, in modern economic theories and models, as a rule, the concept of a goods (public, collective and private) is used without taking into account the dialectical unity with their opposite – harm (public, collective and private), which does not correspond to nature current developments, and, therefore, makes any technical and economic assessments of "technosphere reengineering" inadequate, incl. with the help of innovations and nanotechnologies [6, 11, 14].

The only acceptable way to solve such problems, in our opinion, is the method of retroforecasting sacure life-activity [15], which has proven itself in the socio-economic assessment of the "virtual implementation" of decentralized autonomous engineering systems in individual residential buildings, and its fundamental difference lies in the forecast vector, which rushes from the "current" to the "past", and its phase space is built not on "imaginary data", the dispersion of which is large, but on "historical", i.e. on statistically reliable events in the past, which are established by experts and documented, i.e. on data with practically "zero variance" [11, 15].

METHODS, MODELS AND TOOLS

Currently, as follows from the statistical analysis performed by the National Research University Higher School of Economics, the number of school-age children (from 7 to 18 years old) studying in 16.8 thousand urban and 22.6 rural schools (Table 1) is about 16.9 million people. (Fig. 1). At the same time, about 1.1 million teachers are involved in the learning process (Fig. 2) [16].

A system analysis of the functioning of educational facilities, in particular the engineering systems of school buildings and auxiliary facilities (sports grounds, etc.), made it possible to identify the processes of "turning consumed resources" (of electricity, water, gas, heat, etc.) "into a collective harm" (fire-energy, environmental, etc.) with the help of electrical, gas and other devices used in the educational process. It is essential that the quality of the resources centrally consumed by educational facilities

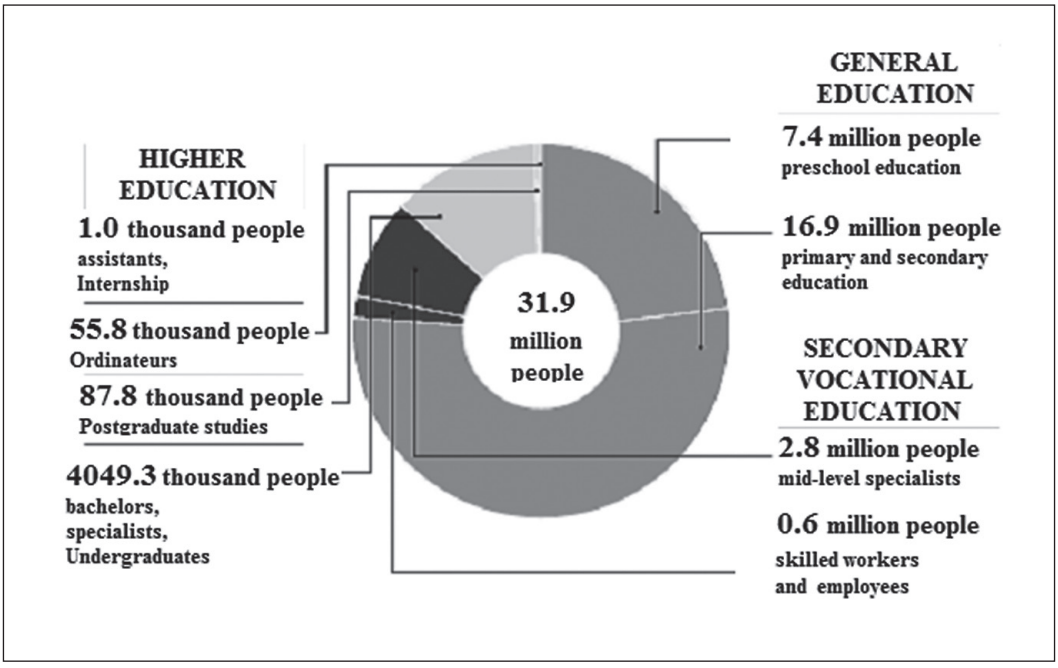

Fig. 1. **The number of students and students by type of education**

Table 1
Number of objects of education

Objects of education	2001	2006	2011	2018	2019	2020	2021
Total	68804	63174	50793	41958	41349	40823	40346
State, including:	68169	62448	50128	41103	40498	39966	39462
in cities and towns	22694	4321	19505	17111	17004	16907	16812
in the countryside	45475	40705	30623	23992	23494	23059	22650

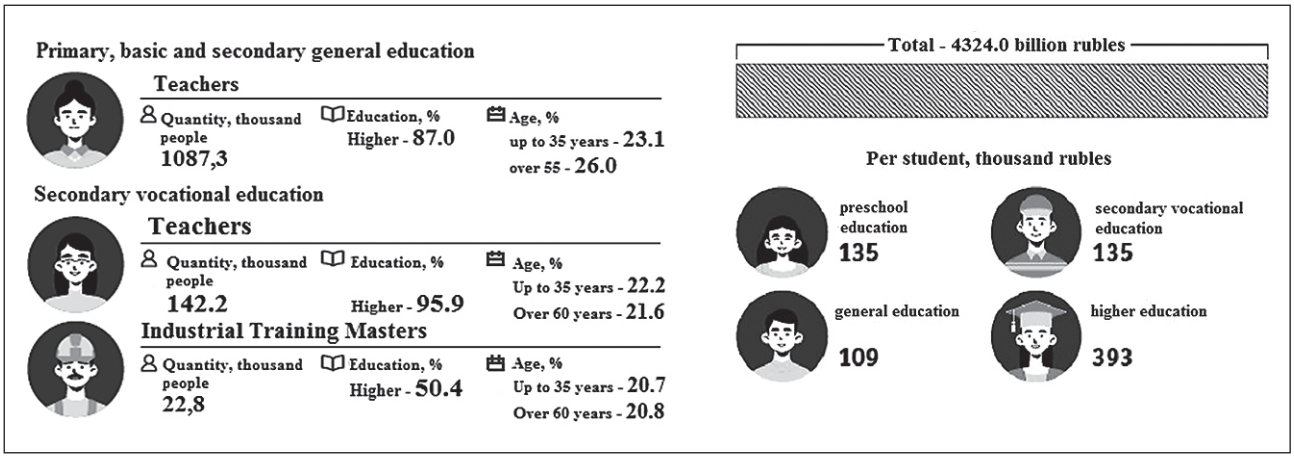

Fig. 2. **Number of teachers and costs per student, by type of education**

(of water, electricity, heat, gas), especially in rural areas, does not meet state standards, and in comparison, with autonomous systems, it is ten times worse [17].

American scientists have come to the conclusion that the installation of solar batteries on the roofs of schools can provide up to 75% of the required electricity, which will reduce emissions from educational facilities by 28%, because in this case, schools can be disconnected from the centralized electricity and heat supply by thermal power plants, which running on coal and natural gas, emissions from which pollute the atmosphere [18].

Thus, according to the US Department of Energy, schools with 12 years of education spend more than 6 billion dollars a year on electricity, and this is the second largest expense item after wages [19].

In our country, averaging the "regional unevenness" of teachers' remuneration, which is included in current costs, the "cost of teaching services per student" in a secondary school per year (Fig. 2) is 109.0 thousand rubles [16].

At the same time, the average percentage of expenses for the maintenance of a school for 445 students, which, according to our calculations taking into account different regions, is optimal (Table 2), is 55.1% of state subsidies, and each student accounts for 54.2% of the "cost of a pedagogical service" [20–22].

On April 12, 2022, United Russia deputies submitted a draft law to the State Duma that would exclude the term "educational service" from the legislation, because the wording "service in the field of education" discredits the mission of a teacher. "*I believe that the very concept of education as a service is erroneous and does not correspond to our national traditions. The teacher does not provide a service. He participates in the personality formation of students, influences their worldview, system of values, views. These views of yesterday's schoolboy or a student then carry through their whole lives*," – had wrote Andrei Turchak, Secretary of the General Council of United Russia [23].

It took almost 30 years to understand the harm of «foreign market theories of education» and return to the pedagogical heritage of Russian scientists Lesgaft P.D. and Makarenko A.S. which is based on the doctrine of the unity of the physical and spiritual growth of an individual. They considered physical exercises as a means of not only physical, but also intellectual, moral and aesthetic development of the schoolchildren, while emphasizing the importance of a reasonable combination, mutual influence of mental and physical education [24, 25].

"*It is necessary,*" Lesgaft P.D. wrote, "*that mental and physical education go in parallel, otherwise we will disrupt the correct course of development in those organs that will be left without exercise*." Just like Sechenov I.M., Lesgaft P.D. argued that movements and physical exercises are a means of developing the cognitive abilities of schoolchildren, and therefore, "*systematic exercises are needed in the simple and*

Table 2
The amount of standard costs for maintenance of educational facilities

№, p. p	Object of education	The size subsidies, thousand roubles	Salary, thousand roubles	School maintenance costs, (thousand rubles)				
				Exploitation	Current repair	on 1 student	in % on 1 student	in % of the subsidy
1	St. Petersburg: school for 825 students	89925.0 (825 • 109)	53087.0	33040.9	3797.1	33.05	30.3% (33.05/109)	40.9%
2	St. Petersburg: school for 210 students	22890.0 (210 • 109)	7052.7	13036.9	2800.4	75.42	69.2% (75.42/109)	69.2%
3	Novosibirsk: school for 800 students	87200.0 (800 • 109)	53362.0	30350.1	3487.9	42.87	39.3% (39.3/109)	38.8%

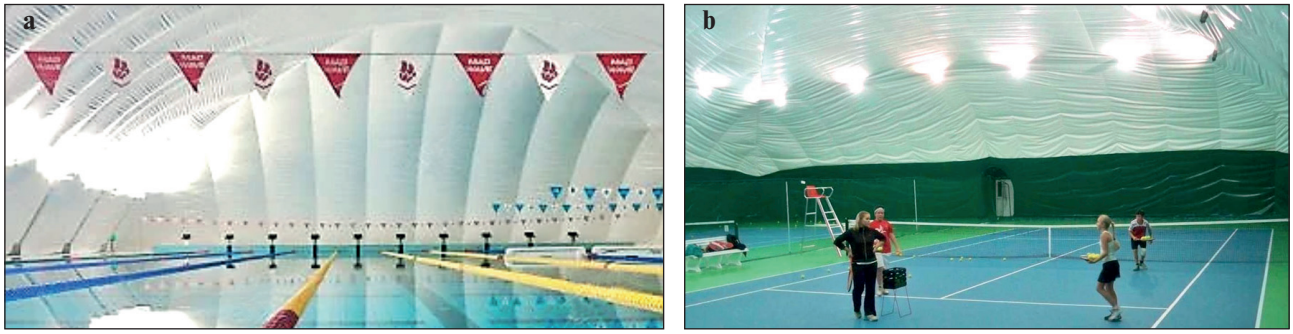

Fig. 3. **Swimming pool (a) and tennis court (b) from ASS**

complex games, swimming, skating and skiing, in wrestling matches, in hiking and excursions", and Makarenko A.S. has proved that labor lessons are also must be included in this list. In other words, a cyclic change of natural and humanitarian subjects with sports disciplines (such as volleyball, basketball, tennis, wrestling, etc.) and labor lessons is necessary [24, 25].

Given that such a harmonious development of schoolchildren requires additional engineering structures and significant material costs, in particular, for the construction of a swimming pool and a tennis court (Fig. 3), for example, using air support structures (ASS). We include into a final assessment for the effectiveness of reengineering of schools the costs for construction in the amount of 3.0 million rubles. for one school, i.e., 118.4 billion rubles for 39,462 public schools [26].

By analogy with individual houses [17], we calculate an autonomous duplicated system of electricity, heat, water supply for a school for 450 students, which is smaller than a typical "Soviet school" (Fig. 4) and accordance with the project (Fig. 5) has the following parameters [27]:

heating season – 168 days,

energy consumption for heating – 325090 W (kcal/h),

Fig. 4. **School building according to the standard project 65-426/1 for 960 students**

energy consumption for ventilation – 217710 W (kcal/h),

energy consumption for hot water supply – 71640 W (kcal/h),

estimated electricity consumption – 112 kW,

cold water supply – 9.04 cubic meters. m per day (1.4 liters per second).

If we use "Shukhov wind turbines" of maximum power (7 kW) instead of a rotor in "Samara Vortex Springs"

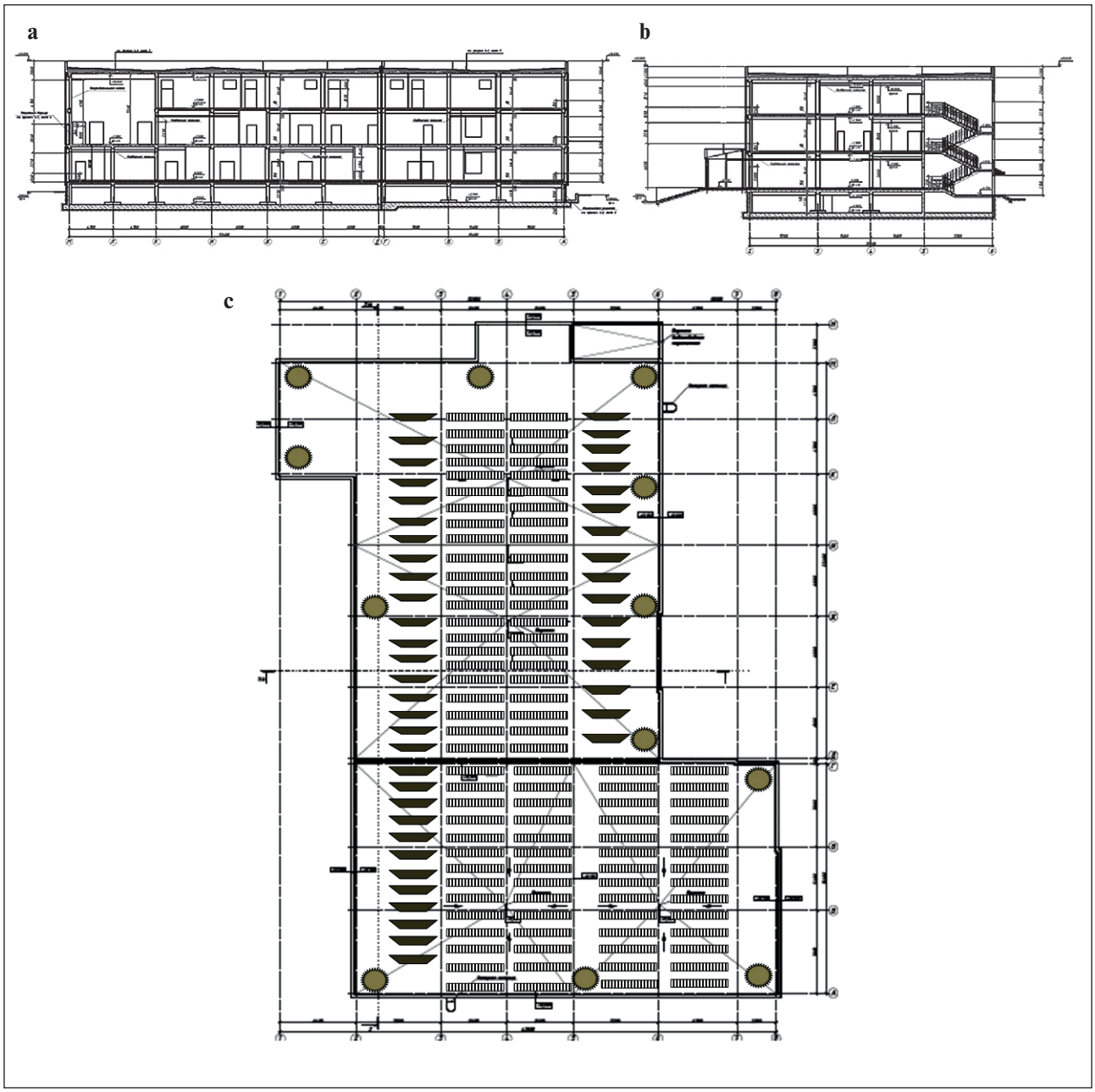

Fig. 5. **Layout of the roof of the school for 450 places with wind turbines (●), hydropanels (▬) and solar batteries (▥)**

[28, 29], which are placed along the perimeter on the roof of the school (Fig. 5b) in the amount of 12 installations, costing 1 each, 0 million rubles each, we will get the required volume of water supply with high-quality cold water (9.6 cubic meters per day) and high-quality electricity in the amount of 84 kW.

The necessary "addition" of 33 kW to the consumed electricity and duplication of electricity and water supply (similar to individual residential buildings) should be carried out using domestic solar batteries (for example, SilaSolar 330W PERC 5BB in the amount of 100 pieces, with a total cost of 1.5 million. rub.) and hydropanels (for example, UNISORB in the amount of 40 units, with a total cost of 1.3 million rubles), which are located on the roof of the school, and atmospheric water generators are installed in the dining room, in the corridors and in the halls of the floors (for example, T-88 "Soyuz" in the amount of 10 units, with a total cost of 1.2 million rubles) [28].

Thus, the one-time cost of equipment for one school of such a duplicated system will amount to 16 million rubles. And it remains to evaluate the volumes and terms

of financing the proposed autonomization and its contribution to the existing generation and delivery of electricity, water and heat to educational facilities, as well as the method for implementing the proposed decentralization of school resource supply.

If we consider only urban educational facilities, of which there are 16812 today, then the installation of such autonomous engineering systems for providing school resources (AESS) in them will require 268.9 billion rubles. In this case, we get the following volumes of resources produced with the help of nanotechnologies in schools during the year:

drinking water supply – 56 billion liters or 55.5 million cubic meters. m.;

hot water supply – 703 million liters or 0.7 million cubic meters; m.;

power supply – 687.3 million kW/h;

heat supply – 289.9 thousand Gcal (for the heating season of 6 months – 0.0342 • 6 • 50 = 10.26).

To equip the remaining 22650 rural schools, which, as a rule, have an order of magnitude smaller number of students, occupied space, and consumption of resources, another 22.35 billion rubles will be required and the total amount of resources produced by AESS per year will be:

drinking water supply – 5.6 billion liters or 5.6 million cubic meters. m;

hot water supply – 70.3 million liters or 0.1 million cubic meters. m.;

power supply – 68.7 million kW/h;

heat supply – 29.0 thousand Gcal.

Savings in budget costs for the maintenance of buildings and structures of schools can be estimated at 54.2% of the average "cost of a pedagogical service per student":

109000 rubles • 16893700 accounts • 0.542 = 998.046 billion rubles per year

We list the advantages of this approach for schoolchildren and our state, built taking into account the processes of self-organization:

firstly, schoolchildren and teachers are provided without interruption with high-quality electricity, heating, cold and hot water, and schools save on paying for it;

secondly, schoolchildren and teachers really participate in solving the problem of "reengineering of the technosphere" with the help of "nature-like nanotechnologies", saving budgetary funds on payment for electricity, water and heat, which should be directed to the depreciation of equipment and its current maintenance, including AESS (50%), and the rest (50%) – to increase the salaries of teachers;

thirdly, the state ensures the growth of the share of alternative energy in the overall balance, stimulates the production of solar batteries and hydropanels, wind turbines, drinking water generation devices and other devices included in the AESS, which increases the gross domestic product (GDP) and the number of high-tech jobs.

What hinders the implementation of such an approach?

Firstly, the lack of a systematic approach to alternative energy, as evidenced by our data on the erroneous vector of its development, "laid in 2009" by the Government of the Russian Federation [30].

Secondly, the lack of systemic support in the production of domestic innovations in wind energy, and in the generation of drinking water, and in the production of "budget" hydropanels, and in the production of solar batteries.

Thirdly, and this is the main reason – in the absence of political will and an appropriate regulatory framework, to "direct business in the right way", to ensure the well-being and safe life of the people, and not to increase the fire and explosion hazard from "thoughtless gasification of the village" and poor-quality electricity, water, heat supply of the residential sector and households, with "super profits" of resource-extracting and resource-supplying companies [17, 31].

For retroforecasting of the introduction of AESS in Russian schools, we had presented a selection of the necessary parameters from statistical studies of the Higher School of Economics [32] and calculate the necessary parameters for the reengineering of Russian schools from 2009 to the present (Table 3) i.e., since the adoption of the erroneous decision of the Government of the Russian Federation [15, 30].

To determine the "speed" of the deployment of the proposed autonomization of schools, incl. determining financing for the production and installation of AESS in the regions, we use the "model of organizing 85 regional public-private partnership enterprises" (PPP) for the production of AESS equipment and its transfer to city and district branches/sites of the PPP enterprise for the assembly and installation of "specified AESS", consisting [11, 17, 33]:

- from "Shukhov wind-electric generators" with vortex generators - sources of atmospheric water;
- from UNISORB hydropanels;
- from solar batteries;
- from inverters-meters-detectors;
- from battery charge controllers-detectors;
- from devices for generating cold and hot water from air (GHGW);
- from domestic multi-split systems-detectors;

Branches/sites of the same 85 PPP enterprises located in cities and regional centers of the regions provide the projects of specified of AESS for "binding" already to the school (SAESS – with a specific number of hydropanels and HGW devices, with Shukhov wind-electric generators, combined with vortex generators – sources of atmospheric water, and with a specific number of solar batteries with inverter-detectors and controller-detectors of battery charge, as well as with domestic multi-split

Table 3
Statistics and calculation of the parameters of objects and subjects of education in the Russian Federation

Years/ Options	Subsidy for 1 school-children (thousand rubles)	Number of school-children (thousand people)	Number of city schools	Number of city AESS	Number of rural schools	Num-ber of rural AESS	ASS costs (million rubles)	AESS costs (million rubles)	Savings with AESS (million rubles)	Savings in scho-ol with AESS (million rubles)	Supple-ment to teacher's salary at AESS (rub.)
2010	112.0	13374.2	19904	1659	31728	2644	12908.0	35662.1	67655.5	15.724	31120
2011	108.0	13655.7	19505	3284	30623	5196	25440.0	70493.7	135224.2	15.946	30641
2012	104.0	14570.8	19106	4876	29518	7656	37596.0	104495.0	211599.0	16.885	31470
2013	99.9	15485.9	18707	6435	28413	10023	49376.0	137665.8	292930.1	17.798	32146
2014	100.8	15626.7	18308	7961	27308	12299	60779.9	170006.3	379277.7	18.721	32734
2015	101.7	15767.5	17909	9453	26203	14483	71807.9	201516.5	471758.6	19.709	33326
2016	99.9	16260.2	17510	10912	25098	16574	82459.8	232196.2	567776.1	20.657	33737
2017	98.0	16752.9	17111	12338	23992	18574	92735.6	262045.4	669217.8	21.649	34109
2018	99.5	16682.5	17058	13760	23743	20552	102935.7	291758.4	756595.2	22.051	34486
2019	101.0	16612.1	17004	15177	23494	22510	113060.2	321335.2	846254.8	22.455	34858
2020	105.0	16752.9	16908	16586	23072	22650	117707.2	345406.0	935660.1	23.847	36546
2021	109.0	16893.7	16812	16812	22650	22650	118385.4	349200.7	998040.7	25.291	38257

systems-detectors, depending on the number of places in the school).

In this case, we will obtain the following additional production plans for each of the 85 PPP enterprises in the regions [11, 17] from 2009 (from the moment of putting into production and production of complexes) to 2021:

1. For 12 years, 16812 SAESS complexes (from 1659 to 1409 per year) must be produced and installed for urban schools, and 22650 SAESS complexes (from 2644 to 140 per year) for rural schools, i.e. 464 complexes at each of the 85 PPP enterprises in the regions (from 51 to 18 per year), which, with 247 working days a year, will be from 1 complex per week to 1 complex per two weeks. Therefore, we will clarify the cost of the corresponding "average specifications" for urban and rural schools.

For a city school, the average cost will be 16.79 million rubles. with the following specification:

– 12 "Shukhov" vortex wind-electric generators with vortex generators – sources of atmospheric water – 12.0 million rubles;
– 40 sets of 4 UNISORB hydropanels – 1.3 million rubles;
– 100 solar batteries – 1.5 million rubles;
– 20 inverter detectors – 0.57 million rubles;
– 20 charge detector controllers with rechargeable batteries – 0.27 million rubles;
– 10 HCHG devices – 1.15 million rubles;
– 10 domestic multi-split systems-detectors – 0.9 million rubles.

For a rural school, the average cost will be 2.955 million rubles. with the following specification:

– 1 "Shukhov" vortex wind-electric generator with a vortex generator – sources of atmospheric water – 1.0 million rubles;
– 4 sets of 2 UNISORB hydropanels – 0.48 million rubles;
– 10 solar batteries – 0.2 million rubles;
– 5 inverter detectors – 0.25 million rubles;
– 5 charge detector controllers with rechargeable batteries – 0.1 million rubles;
– 5 HCHG devices – 0.575 million rubles;
– 5 domestic multi-split systems-detectors – 0.45 million rubles.

2. The total annual volume for each regional PPP enterprise will be from 51 to 18 SAESS worth from 35.6 to 23.4 billion rubles. per year (Table 3), and the total production of SAESS complexes for 39,462 schools over 12 years will amount to 349.2 billion rubles.

3. The specification, installation, commissioning and ongoing maintenance of AESS in 39,462 schools over 12 years in 85 subjects will require 69.84 billion rubles, and the average annual volume of branches / sites of one PPP enterprise will be 68.47 million rubles. Consequently, the additional staffing for one head PPP enterprise in the region, similarly assuming that SAESS is considered a high-tech product in accordance with the Decree of the Government of the Russian Federation [34], will be 71 specialists (342.4 million rubles / 4.8 million rubles). rub.). At the same time, the additional number of its branches / sites, whose design and installation activities are also considered high-tech, will average 15 specialists (69.84 million rubles / 4.8 million rubles), i.e. 1 staff unit,

on average, per one branch / site in the constituent entity of the Russian Federation.

Thus, the total number of high-tech jobs in 85 constituent entities of the Russian Federation will increase by 7310 units and, taking into account the production of complexes for 10.0 million individual houses in the regions of Russia, will amount to 118574 [11].

Taking into account that the «speed of production and implementation» of AESS is from 4333 to 1409 complexes per year, and the average savings in budget funds for "pedagogical services per student" will be 54.2%, the calculation of the "economic efficiency" of the autonomization of engineering systems was carried out Russian schools (Table 3).

Adding to the annual costs, the cost of building a swimming pool and two tennis courts in each school, with the use of air support structures and automatic control of their functioning in the amount of 3.0 million rubles, we get the total amount of such modernization in the amount of 467.59 billion rubles.

Thus, if, as a result of a systematic approach to alternative energy, the Government of the Russian Federation would adopt a Decree on the deployment of autonomous engineering systems in schools, as well as on support for the production of domestic innovations in wind energy, in the generation of drinking water from the atmosphere, the production of "budget" hydropanels and solar batteries in 2009, then by 2021 almost all Russian schools would have been transferred to a decentralized resource supply of electricity, heat and water, by saving budget funds for education, and from 2022, fully paying back almost 500 billion rubles costs, get annual budget savings in the same amount! At the same time, every year in schools, after the introduction of SAESS, each teacher could increase the salary by 31,000 rubles. per month, and from 2021, such an allowance would reach 38.0 thousand rubles per month due to saved budget funds (Table 3).

CONCLUSION

An analysis of the directions and rates of development in the world, "the so-called renewable energy sources", showed that these installations, being unstable, low-concentration and periodic sources, can be used in individual residential buildings and schools as autonomous engineering systems (AESS) of electricity, water and heat supply. It is shown that domestic innovations and nanotechnologies in the engineering systems of buildings of educational facilities, in particular, the integration of "Shukhovskaya" and vortex wind turbines, hydropanels and solar batteries make it possible to create and replicate AESS for schools, by saving budget allocations for education, while raising teachers' salaries. at least 2 times.

At the same time, it is essential that, due to the duplication of AESS, all state and municipal schools can be provided with electricity, water and heat with quality, reliability and safety parameters that are several orders of magnitude higher than the existing centralized resource supply systems for cities and towns, than to create a fire explosion-proof conditions in schools for students and teachers are not worse than 0.999999, as required by the state standard [35].

Thus, mass alternative energy in Russia is really possible and effective with the help of nanotechnologies in engineering systems not only in individual residential buildings, but also in school buildings.

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Belozerov V.V. – general scientific guidance; analytical review of «nature-like approaches», including the results of own research; adaptation of the retroforecast method to RES; findings.

Belozerov Vl.V. – participation in the simulation of SAESS; development of the structure and design, installation and commissioning functions of the branches of PPP enterprises; calculations using the retro forecast method and the design of sections.

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