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ASSESSMENT THE ROLE OF RENEWABLE ENERGY IN SOCIO-ECONOMIC DEVELOPMENT OF RURAL AND ARCTIC REGIONS *

Sergey Tishkov [1]*, Anton Shcherbak [2], Valentina Karginova-Gubinova [3], Alexander Volkov [4], Arsen Tleppayev [5], Antonina Pakhomova [6]

[1,2,3,4] *Institute of Economics, Karelian Research Centre, Russian Academy of Science, A. Nevsky Avenue, 50, Petrozavodsk, Russia*
[5] *Faculty of Economic Sciences, Kazakh-German University, Pushkin street, 111, Almaty, Kazakhstan*
[6] *Platov South-Russian State Polytechnic University (NPI), Prosveschenia street, 132, Novocherkassk, Russia*

E-mails:[1] insteco_85@mail.ru (Corresponding author)*

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Abstract. The paper overviews Russian and foreign studies on renewable energy. In view of some economic and environmental premises, namely depletion of the traditional energy sources and growing costs of their exploitation, a new alley is being paved in scientific literature and global practices for displacing traditional energy resources and providing for a substantial contribution of renewable sources to total energy consumption. In this context, the aim of this study is to determine what role renewable energy will play in the socio-economic security of territories, to identify the potential and possible applications of renewable energy. The main tasks for the study were to: identify the socio-economic implications of the transition from traditional to renewable energy sources, study the foreign experience of implementing renewable energy policies, estimate the potential and evaluate the prospects for renewable energy with the focus on rural northern regions. The potential for renewable energy market growth in Russia was estimated, specifically for the Northwestern macroregion. To provide for socio-economic security, the energy policy being developed must have an environmental and economic orientation. Primary focus in the development of renewable energy sources should be on peripheral regions, which have no electrical grids of their own and are energy deficient.

Keywords: renewable energy; energy consumption; energy sources; socio-economic security; peripheral regions

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Additional disciplines ecology and environment; energetics and thermoenergetics.

1. Introduction

The rising interest in renewable energy is driven by several factors. The key ones are depletion of the sources of traditional fossil fuels combined with growing costs of their extraction; heavy environmental impact caused by fossil energy production and use, and the associated demand for treatment facilities and actions. Experts have estimated that with current consumption rates, primary energy sources of coal will suffice for no more than 850 years, natural gas for 270 years, oil for 180 years. The quality of the hydrocarbons' reserves will also be constantly declining (Vylegzhanin 2015; World Energy Council 2016).

An example of a negative environmental impact of fossil fuels is CO2 and methane emissions, which notably deteriorate the quality of the environment. An emerging, yet underestimated application for solar energy is agriculture. Solar-powered vegetaria can deliver products 1.5-2 months earlier than unheated greenhouses, depending on the crop. The cost of a vegetarium, on the other hand, is commensurate with a regular greenhouse. Vegetaria can be used by large agricultural producers as well as by small-scale farmers, and in private subsistence farming. Thus, the construction of solar vegetaria would enhance food security in terms of some product categories in some regions of Russia. This is of particular relevance for northern regions in the Russian periphery, away from large logistic nodes.

Novelty of this research focuses on studying the northern and Arctic regions, develop new and refine existing approaches to research and development of mathematical models of energy efficiency of the Arctic zone economy; development of methodological approach to formation of mathematical models and scenarios of energy development and socio-economic development, including economic security based on interaction of macro- and meso-level. The research limitations are that not all data was available to all countries from the sample, as primary data were collected through a variety of studies, each conducted on its own sample of countries.

2. Theoretical background

Estimating the potential of renewable energy, researchers assume that the average required energy capacity is two kW per person per day. Each square meter of the earth surface can potentially yield ca. 500 W. With the conversion efficiency of 4%, it takes ten square meters per person. Given the average population density, this amount is quite achievable (Cho 2007). Earlier studies have corroborated the statement that renewable sources of energy are essential for mitigating climate change, in particular when implementing the Kyoto Protocol and 'green credits' trading. Renewable sources can be used in the electric energy sector and as environment-friendly vehicle biofuels (Jäger-Waldau 2007; Li et al. 2018), as well as in space exploration (Komerath et al 2011; Pisacane et al 2005).

It was shown that increased utilization of renewable energy will help reduce the price of non-renewable sources, namely natural gas. E.g., each megawatt hour renewable energy may potentially save end users at least UDS 7.5-20 (Wiser 2007). At the same time, the analysis of marginal cost curves has confirmed that in some countries, such as Spain, renewable energy generation is now inefficient, wherefore its prices cannot be competitive in the electricity market (Paz Espinosa et al. 2018; Hernández et al. 2011). The general demand for a more efficient use of resources was postulated by German economists E. von Weizsäcker, A.B. Lovins and L.H. Lovins. Their ideas and approaches underlie the European sustainable development strategy (Weizsäcker et al 1997).

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2020 Volume 7 Number 4 (June)
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In some countries, the transition to renewable energy is impeded by influential business groups. In Japan, for instance, in spite of energy shortages, the introduction of renewable energy sees some resistance from the haves. While photovoltaic generation better meets their interests than windmills, solar parks are procedurally easier to deploy. Yet, the country's government policy undertakes to stick to the energy efficiency principle (Moe 2012). There are, however, some economic challenges involved in the transition to renewable energy. Thus, the analysis of data for 24 European countries covering the period from 1990 to 2007 showed that coal hinders economic growth, natural gas has no effect, but the use of oil promotes growth. Hence, abandonment of some natural resources may cause economic growth to slow down (Marques et al. 2012).

The background for research on renewable energy development in Russia is systemic studies of the energy industry at the level of countries and their individual regions (Zheng et al 2019; Pablo-Romero et al 2019; Sarma et al 2019). Energy security issues (Yoo 2003) and the environmental effect of the energy industry (Sun et al. 2019; Dhar et al. 2019; Hájek et al. 2019) have been identified. Proceeding from this identified role, the prospects for renewable energy utilization were evaluated (Proskuryakova et al. 2019; Olkkonen et al. 2016) and recommendations were given on its implementation, regarding both strategic planning and guarantee of some rate of return for investors: by improving the legislative framework, introducing grid connection cost recovery schemes and fixed feed-in tariffs (Sadorsky 2012; Wang 2019; Lanshina 2018). The transition to renewable energy is particularly promising in decentralized power supply systems, where most of the generation today is by diesel power plants with their high operating costs (Velkin 2015).

3. Material and Method

The studies on renewable energy development and the projects implemented so far suggest there is extensive potential for the use of all major types of renewable energy in Russia. The key challenge in drawing up a common methodology for the study of this process is the diversity of applicable formats and methods.
The assessment of the role of renewable sources of energy in the socio-economic development of regions included:

- comparison of traditional and alternative sources, their comparative strengths and weaknesses;
- identification of the qualitative and quantitative effects of completed projects in the renewable energy market;
- estimation of the actual and potential scope of use of renewable energy sources, including for specific most promising types, considering the resources available.

The development potential of renewable energy was estimated both as potential generation capacity and as the share in total consumption.
The results obtained in the study have enabled conclusions to be drawn concerning the current and prospective effects of renewable energy on the socio-economic security of territories.

Renewable energy sources reduce environmental charges and increase economic growth. The hypothesis is an increase in the share of renewable energy leads to a reduction in CO2 emissions. The one model was built according to the data of the European Union countries from 1990 to 2018 and other – for Belarus, Russia and Kazakhstan (World Bank Statistics, Eurostat and Enerdata, see Table 1, Figure 1, Table 2, Figure 2). We take to the data of the European Union countries, because the share of renewable is a rapidly increase in last years.

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2020 Volume 7 Number 4 (June)
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Table 1. Renewable electricity output in Belarus, Kazakhstan, Russia (% of total electricity output)

Country Name	Belarus	Kazakhstan	Russian Federation
1990	0,050599605	8,429943121	15,33814104
1991	0,046469601	8,373650912	15,69414031
1992	0,045218779	8,302197071	17,0465566
1993	0,056939075	9,850989102	18,14990447
1994	0,060515336	13,82441978	20,00717812
1995	0,080263264	12,49756229	20,42662271
1996	0,067430883	12,41742606	18,12705781
1997	0,080592547	12,49807692	18,80051466
1998	0,119189511	12,49567606	19,19112939
1999	0,07165485	12,91001726	18,99243743
2000	0,103444312	14,67344712	18,72960564
2001	0,11969836	14,21284978	19,56702383
2002	0,109615966	15,23773611	18,26085783
2003	0,10515642	13,50483826	17,07669458
2004	0,108939442	12,03525282	18,95623747
2005	0,119505184	11,57899391	18,20252976
2006	0,119455534	10,84053198	17,49382461
2007	0,157089447	10,66738035	17,52064093
2008	0,20828578	9,287039227	15,91410503
2009	0,345667632	8,739677296	17,64404648
2010	0,37254621	9,706458873	16,12058881
2011	0,428571429	9,10424318	15,80302393
2012	0,555212832	8,4	15,56373111
2013	0,844256832	8,1	17,17463022
2014	0,722614078	8,7	16,5682512
2015	0,815679831	10,3	15,85579515
2016	0,815679831	12,7	17
2017	2,2	11,3	17,2
2018	2,2	10,2	17

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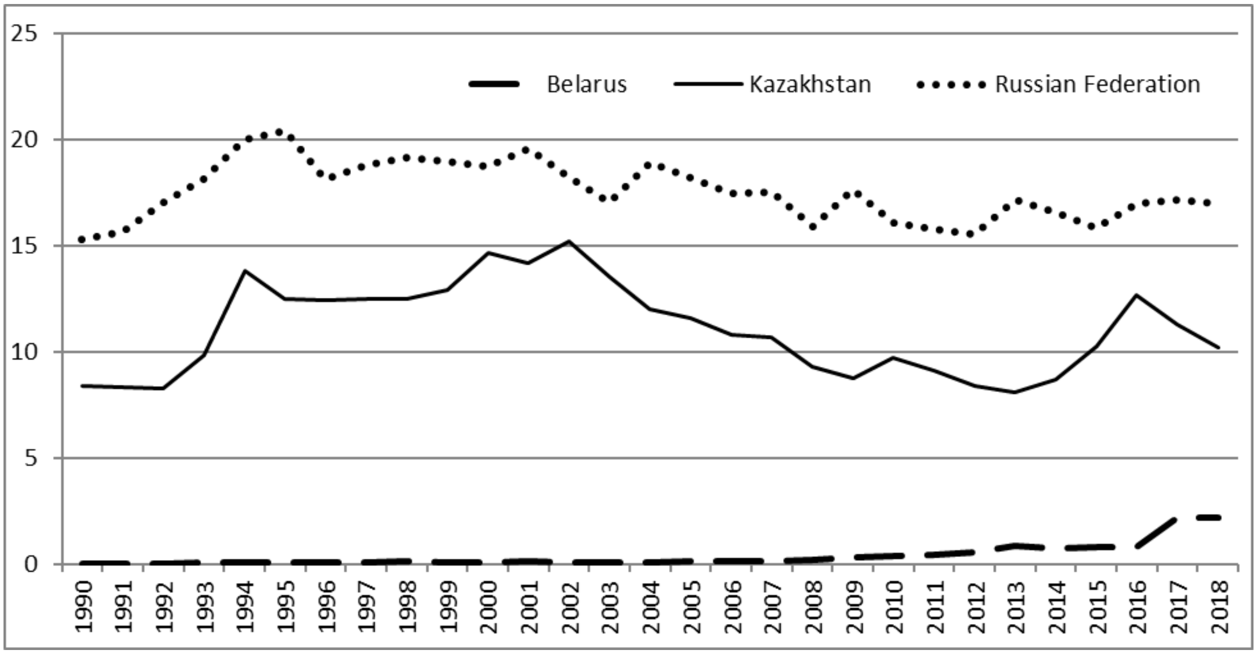

Figure 1. Renewable electricity output in Belarus, Kazakhstan, Russia (% of total electricity output)

Source: World Bank Statistics and National Agencies of Statistics

Table 2. Renewable electricity output in some European countries (% of total electricity output)

Country	Belgium	Czech Republic	Germany	Denmark	Spain	France	United Kingdom	Italy
1990	0,789564	1,864431	3,486351	3,175275	17,21625	13,369879	1,828767	16,37602
1991	0,752957	1,80603	3,168753	2,892325	17,97039	13,220198	1,656439	20,84651
1992	0,864025	2,373978	3,697964	4,398464	12,50925	15,453978	2,005662	20,55392
1993	0,723583	2,608518	3,92737	4,730088	16,16325	14,238354	1,777626	20,57976
1994	0,841031	3,050232	4,461686	4,295431	18,06068	17,058195	2,139842	21,08945
1995	0,908646	3,973586	4,866989	5,035639	14,72016	15,361125	2,066535	17,466
1996	0,746626	3,54261	4,821397	3,880034	23,79085	13,448621	1,62748	19,30801
1997	0,755192	3,414984	4,20831	6,6095	19,54617	13,264534	1,989232	18,743
1998	0,924764	3,068519	4,508169	9,546859	19,07369	12,767857	2,395321	18,32252
1999	1,0196	3,675244	5,197224	11,25128	13,26681	14,46674	2,632717	19,79325
2000	1,261281	3,132586	6,198531	15,45502	15,61373	12,967876	2,663105	18,84819
2001	1,367371	3,471455	6,512444	15,49471	21,15357	14,256372	2,497332	19,98867
2002	1,405997	3,944996	7,6427	17,28053	13,83062	11,597276	2,893173	17,4088
2003	1,426503	2,268885	7,552978	17,49015	21,67904	11,230018	2,684947	16,3708
2004	1,774685	3,271273	9,267474	23,55574	18,1347	11,242989	3,613032	18,21338
2005	2,457152	3,822729	10,15021	27,07057	14,60139	9,8606467	4,283482	16,31822
2006	3,499787	4,207808	11,32201	20,17277	17,64282	10,947576	4,602089	16,45644
2007	3,982726	3,88542	13,93801	26,2107	19,3093	11,690926	5,010293	15,48072
2008	5,285764	4,47926	14,69923	27,57265	19,98309	12,979209	5,677052	18,55119
2009	6,056388	5,701196	16,07855	27,65852	25,38125	13,127164	6,766808	24,01894
2010	6,920806	6,918136	16,72707	31,9824	32,77554	13,857359	6,812813	25,76036
2011	9,410879	8,35254	20,38328	40,25377	30,02164	11,574747	9,489053	27,59473
2012	12,81288	9,303586	23,00046	48,32742	29,58475	14,827354	11,42396	31,02039
2013	14,20939	10,82341	24,07255	45,96034	39,58358	17,045286	14,98848	38,90535

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2020 Volume 7 Number 4 (June)
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2014	17,08064	10,77841	26,1301	55,90045	40,10526	16,455905	19,26285	43,39161
2015	20,80002	11,40457	29,23177	65,50592	34,94989	15,857667	24,84005	38,67923
2016	17,9	12,7	29,9	60,44681	39,3	18,4	25,4	37,9
2017	18,8	12,4	34,2	70,6113	32,8	17,2	30,1	35,7
2018	23,3	11,9	36	68,85025	38,6	19,9	34	39,9

Table 2. (continuation) Renewable electricity output in some European countries (% of total electricity output)

Country	Netherlands	Norway	Poland	Portugal	Romania	Sweden
1990	1,119942	99,79196	1,095116	34,71526	17,74402	51,00011
1991	1,256991	99,80102	1,136158	33,12365	25,68174	44,30088
1992	1,287909	99,81727	1,238073	18,57003	21,5924	52,33321
1993	1,4347	99,80371	1,175453	30,45499	23,01716	52,92433
1994	1,575119	99,64299	1,338395	37,14495	23,66149	43,02873
1995	1,730999	99,66215	1,42657	28,30075	28,16623	47,57878
1996	2,125891	99,49951	1,461818	45,86106	25,68052	38,40159
1997	2,331172	99,57735	1,512754	41,67936	30,65724	48,27755
1998	2,555013	99,61608	1,799376	36,36107	35,31105	49,18289
1999	2,890913	99,56087	1,679988	20,09135	36,06784	48,27433
2000	3,315817	99,71511	1,628787	29,66891	28,45535	57,24673
2001	3,525405	99,5203	1,936391	34,09504	27,70393	51,56162
2002	4,140403	99,58308	1,941768	21,32092	29,32128	48,49693
2003	4,092214	99,39908	1,49991	38,05378	24,05151	43,38265
2004	5,243346	99,35063	2,102262	27,47005	29,23415	44,94933
2005	7,450886	99,47175	2,4762	17,88343	34,02117	51,29416
2006	8,146065	99,31613	2,66913	32,36578	29,2837	49,6008
2007	7,210574	99,13454	3,420235	34,58291	25,94977	52,0269
2008	8,86176	99,40296	4,271217	32,19791	26,51641	54,30905
2009	9,531097	96,57044	5,742418	36,96496	26,9358	58,41996
2010	9,387943	95,73265	6,931103	52,80773	33,48785	55,30176
2011	10,81228	96,49442	8,053679	46,4751	26,31494	55,9446
2012	12,11446	97,95491	10,43776	42,50044	25,39558	59,06775
2013	11,97511	97,70227	10,40531	58,31915	34,42155	54,0335
2014	11,32105	97,65553	12,51861	60,7402	41,60609	55,83769
2015	12,44208	97,70987	13,8024	47,52637	39,74697	63,26275
2016	12,8	97,8	14	55,5	42,2	57,2
2017	15	97,8	14,5	41	38,3	57,5
2018	15,7	97,9	13	52,2	41,3	55,3

Source: World Bank Statistics and Eurostat

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2020 Volume 7 Number 4 (June)
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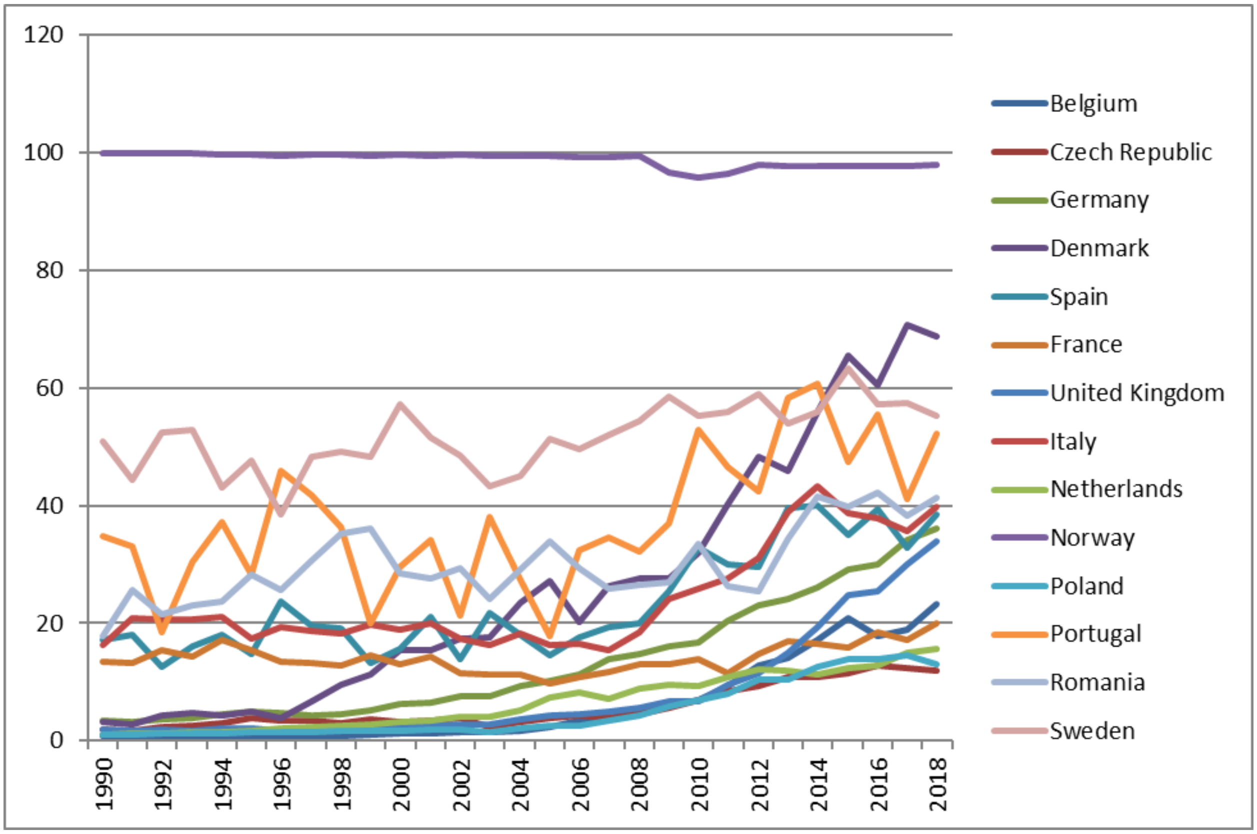

Figure 2. Renewable electricity output in some European countries (% of total electricity output)

Source: World Bank Statistics and Eurostat

To investigate the relationship between CO2 emissions per capita, fossil fuel energy consumption, renewable electricity and GDP per capita, we apply model proposed Ito (2017) and the long-run model is given by the following equation:

CO2emmisions = f(FuelCons, Renewable electricity, GDP) (1)

Making the log linear form of the both sides of the Equation (1), we obtain the following Equation (2):

$$lnCO2_{it} = \beta_0 + \beta_1 \, lnFuelCons_{it} + \beta_2 lnRW_{it} + \beta_3 lnGDP_{it} + \varepsilon_{it} \, , \qquad (2)$$

where:
ln denotes the natural logarithm;
β_1, β_2 and β_3 parameters are the long-run elasticities of CO2 emissions per capita to Fossil fuel energy consumption (% of total), share of Renewable electricity (% of total electricity output) and GDP per capita;
lnCO2it is a logarithmic meter corresponding to CO2 emissions (metric tons per capita);
$lnFuelCons_{it}$ is a logarithmic meter corresponding to the Fossil fuel energy consumption (% of total);
lnRWit is a logarithmic meter corresponding to the share of Renewable electricity (% of total electricity output);
lnGDPit is a logarithmic meter corresponding to the GDP per capita.

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2020 Volume 7 Number 4 (June)
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4. Results and Discussion

According the econometric analysis, the panel unit root tests are provided for all of the parameters of equation (2). Keeping in mind the basic idea behind cointegration, it is necessary to determine the order of integration of each variable before proceeding to using cointegration techniques. The results of the panel unit root tests for all of variables of equation (2), using the Levin, Lin & Chu test, ADF Fisher, and PP Fisher tests, are presented in Table 3.

Table 3. Panel unit root results

Variables	Test Statistics		Panel data 1 – EU countries		Panel data 2 – Belarus, Russia and Kazakhstan	
			Level	First Difference	Level	First Difference
lnCO2	Levin, Lin & Chu t	Statistic	2.438	-7.278	-0.835	-3.835
		Prob.	0.993	0.000	0.202	0.000
	ADF - Fisher Chi-square	Statistic	17.734	134.559	4.368	21.564
		Prob.	0.933	0.000	0.627	0.002
	PP - Fisher Chi-square	Statistic	22.661	296.535	6.620	33.777
		Prob.	0.750	0.000	0.357	0.000
lnFuelCons	Levin, Lin & Chu t	Statistic	2.052	-7.387	-0.762	-2.260
		Prob.	0.980	0.000	0.223	0.012
	ADF - Fisher Chi-square	Statistic	8.622	145.579	4.708	34.130
		Prob.	0.999	0.000	0.582	0.000
	PP - Fisher Chi-square	Statistic	10.204	286.086	7.586	69.541
		Prob.	0.999	0.000	0.270	0.000
lnRW	Levin, Lin & Chu t	Statistic	1.378	-7.846	2.348	-2.640
		Prob.	0.916	0.000	0.991	0.004
	ADF - Fisher Chi-square	Statistic	11.090	81.445	4.666	25.880
		Prob.	0.998	0.000	0.587	0.000
	PP - Fisher Chi-square	Statistic	21.756	153.196	5.820	52.998
		Prob.	0.793	0.000	0.444	0.000
lnGDP	Levin, Lin & Chu t	Statistic	-2.269	-9.856	0.108	-2.942
		Prob.	0.012	0.000	0.543	0.001
	ADF - Fisher Chi-square	Statistic	13.679	142.515	1.260	15.055
		Prob.	0.989	0.000	0.974	0.019
	PP - Fisher Chi-square	Statistic	12.569	162.261	0.878	23.757
		Prob.	0.995	0.000	0.990	0.000

Source: Computed by this study

The results in Table 3 point out that the hypothesis that the levels of all variables under study contain a unit root is accepted at the 1% significance level. The test results indicate that the first difference variables are stationary. Thus, the results allowed the test for panel cointegration between the GDP, RW, CO2, FuelCons. In Table 4, the results of using the Pedroni panel cointegration tests are presented.

Table 4. Pedroni panel cointegration tests

Variables	Test Statistics	Panel data 1 – EU countries		Panel data 2 – Belarus, Russia and Kazakhstan	
		Statistic	Prob.	Statistic	Prob.
within-dimension	Panel v-Statistic	1.105	0.135	0.546	0.292
	Panel rho-Statistic	-0.719	0.236	-0.258	0.398
	Panel PP-Statistic	-3.564	0.000	-0.954	0.170
	Panel ADF-Statistic	-2.847	0.002	-1.398	0.081
	Weighted Statistic				
	Panel v-Statistic	0.772	0.220	0.475	0.317
	Panel rho-Statistic	-0.893	0.186	-0.163	0.435
	Panel PP-Statistic	-3.853	0.000	-0.993	0.160
	Panel ADF-Statistic	-2.714	0.003	-1.380	0.084
between-dimension	Group rho-Statistic	-0.160	0.436	0.546	0.707
	Group PP-Statistic	-4.609	0.000	-0.868	0.193
	Group ADF-Statistic	-2.988	0.001	-1.153	0.124

Source: Computed by this study

The cointegration reveals that there is a long-run relationship between the variables for EU countries (which is indicated by the panel PP, panel ADF, group ADF and group PP statistics in Table 4) and unclear results for panel – Belarus, Russia and Kazakhstan. According table 4, panel 2 have a cointegration relationship by only ADF-Statistic.

In Table 5, the findings of the use of the FMOLS and DOLS panel cointegration techniques are presented.

Table 5. Results of model

	Methods	lnFuelCons			lnRW			lnGDP			R-squared
		Coefficient	t-Statistic	Prob.	Coefficient	t-Statistic	Prob.	Coefficient	t-Statistic	Prob.	
Panel data 1 – EU countries	Panel Fully Modified Least Squares (FMOLS)	1.483	13.792	0.00	-0.0612	-5.672	0.00	0.0275	1.662	0.097	0.96
	Panel Dynamic Least Squares (DOLS)	1.309	10.870	0.00	-0.046	-4.05	0.00	-0.004	-0.246	0.806	0.98
Panel data 2 – Belarus, Russia and Kazakhstan	Panel Fully Modified Least Squares (FMOLS)	5.856	2.859	0.005	-0.050	-1.307	0.195	0.124	5.520	0.000	0.85
	Panel Dynamic Least Squares (DOLS)	7.190	3.212	0.002	-0.061	-1.237	0.221	0.136	5.050	0.027	0.94

Source: Computed by this study

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According results, for European countries the fossil fuel energy consumption contribute the the CO2 emissions and renewable electricity contributes to reductions in emissions. For Belarus, Russia and Kazakhstan fossil fuel and per capita GDP lead to an increase in the emissions. For European countries, coefficient of FuelCons suggests that a 1% increase in fossil fuel energy consumption will lead to an increase in the CO2 emissions per capita of 1.5% and the coefficient of RW suggests that a 1% increase in share of renewable energy will lead to a decrease in the CO2 emissions per capita of 0.06% for FMOLS estimation (DOLS estimation shows 1.3 and -0.05 respectively), the GDP per capita don't influence on emissions (coefficient is statistically insignificant). According results, for Belarus, Russia and Kazakhstan the coefficient of GDP suggests that a 1% increase in per capita GDP will lead to an increase in the CO2 emissions per capita of 0.12% and the coefficient of FuelCons suggests that a 1% increase in fossil fuel energy consumption will lead to a increase in the CO2 emissions per capita of 6% for FMOLS estimation (DOLS estimation shows 0.14 and 7 respectively), the renewable electricity don't influence on emissions (coefficient is statistically insignificant).

Thus according to the panel data model, the increase in the share of renewable energy in the long run reduces the CO2 emission by the example of European countries. For countries of panel 2, renewable electricity don't influence on emissions due to low share of renewable energy in total electricity output compared to Germany or Portugal.

Our empirical findings are as follows: (i) renewable energy consumption contributes to reductions in emissions for European countries, but we don't find relation for Belarus, Russia and Kazakhstan; (ii) fossil fuel energy consumption lead to increase the CO2 emissions in alll countries in the long run.

Owing to modern techniques, a majority of agricultural enterprises (animal, poultry, breeding farms) can fully satisfy their heat and power demand using their own biogas. In addition, biogas can serve as an alternative fuel for farm machinery.

The biogas production technology should also be applied at large municipal wastewater treatment facilities. The raw material in this case is sewage. Biogas (methane) is a greenhouse gas which, formed under natural conditions, is harmful for the environment, imposing extra burden on the economy (Chang 2017). Since wastewater has to be treated anyway, the use of biogas can help treatment facilities reduce their energy costs and sometimes get extra revenues from selling biogas and its end products out to the market.

Biogas production also proves beneficial in municipal landfills. Methane collection can be organized there. In the process, municipal wastes will be recycled, new energy resources will be generated, greenhouse emissions will be reduced, and environmental improvements will be achieved. Such landfills are quite common in a majority of developed countries, including the USA, China, Japan, the Netherlands, Belgium, and many others. Thus, in the subarctic city of Oulu (Finland), the municipal landfill Oiva Roina has been reconstructed, so that in addition to waste processing it now extracts gas and generates power. Gas is extracted by specialized pumps connected to pipelines running through the body of the landfill. There is a 200 kWh power station in the landfill premises with four power generators operating on methane, 50 kWh installed capacity each. This capacity suffices to cover all energy demands of the company. Excessive gas is sold to nearby enterprises. This recycling technology has proven efficiency and could be applied in Russian municipal waste landfills, considering how pressing the waste recycling problem is today in a majority of large settlements across Russia.

The results are consistent with previous studies. In particular, data from African countries for the period 1980-2014 and 1980-2011 confirmed respectively the existence of a short-run (Adams et al 2019) and a long-run (Adams et al 2019; Inglesi-Lotz et al 2018) relationship between the renewable and non-renewable energy and CO2 emissions. The study also found a unidirectional causality running from renewable energy consumption to CO2 emissions (Inglesi-Lotz et al 2018). The existence of a link between the use of non-renewable energy and

CO2 emissions was also confirmed in an earlier study of the Tunisian economy (Cherni et al 2017). At the same time, data from the MENA region (Middle East and North Africa) showed that a transition to renewable energy consumption can only slightly explain changes in CO2 emissions. The reason for this is the weak distribution of renewable energy in the MENA countries (Charfeddine 2019).

Renewable energy development plans should take into account the resources available in a territory. Take the case of Northwest Russian regions. Northwest Russia has good premises for the development of the renewable energy sector, and many regions implement pilot projects, get expert reviews for projects and search for instruments to implement them. An important application for renewable energy sources is the conversion of district boiler houses from coal and heavy oil to biomass, viz. wood wastes, peat, etc. With heavy oil prices in Russia growing constantly, wood residues as feedstock for heat production are gradually becoming competitive. Hence, forest resources in northern regions of Russia (especially Republic of Karelia and Arkhangelsk Region) can be utilized to produce renewable fuels, such as chips and pellets. Boiler houses in all districts of Karelia are getting re-equipped to be converted to local fuels. Some boiler houses in the region are already powered by local fuels such as chips and peat. They are situated in Suojarvi, Veshkelitsa, Porosozero, Harlu, Essoila and many other towns and villages.

Finnish experience deserves special attention. A Finnish company has developed an integrated solution for the heating and hot water supply of private houses where a solar power installation is integrated in the utility system. The main element of this system is a heat accumulator combined with a solar collector. Where needed, the system can be supplemented with a diesel or gas boiler so that the heat and hot water supply of the house is provided by the integrated solar energy-diesel/gas system. In this system, the water heated in solar collectors is supplied to the heat accumulator and then distributed among consumers, with additional heating by a diesel or gas boiler if necessary. The boiler ensures that even when solar energy is in deficit, e.g. in wintertime, the consumer gets adequate heating and hot water supply.

As regards municipalities, the development of their economies is directly dependent on distance to the region's capital city, the only exception being centers of innovation. In Karelia, the latter are represented by the borderland towns of Kostomuksha and Sortavala.

Since the beginning of reforms, Karelian economy has seen a substantial decline, most importantly in industry and agriculture. Employment levels in a majority of municipalities dropped 4-6-fold, and it is only in Kostomukshsky and Sortavalsky Districts that the socio-economic situation is slightly better, owing to the presence of customs and transport infrastructure, active foreign economic contacts, and AO Karelsky Okatysh. The latter, situated in Kostomuksha, accounts for roughly one fifth of the Karelian economy, while a majority of rural municipalities remote from Petrozavodsk contribute no more that 1%. At the same time, the population loss was smaller than the production decline, wherefore the share of unemployed has increased markedly in the periphery.

Reforms have induced economic renovation of Karelia, but little of it has happened in rural areas. The peripheral position and poor infrastructure of rural areas make their industrial revival unlikely. Regional authorities, struggling to save budgetary funds, shut down pieces of infrastructure, leaving the population deprived not only of social facilities, but even of energy supply. One possible solution is to engage renewable energy sources, particularly in agricultural cooperation arrangements.

Conclusions

Green economy and renewable energy have lately been studied as a full-fledged research area both globally and in Russia. In particular, there is an ongoing search for engineering and process solutions for utilizing solar energy and promoting bioenergy; potential applications for green economy techniques are being investigated (Statista 2018). The task to promote alternative energy has been formulated within the UN Sustainable Development Concept, Renewable Energy Development Strategy 2020, a number of other international regulatory documents.
All the countries leading in renewable energy utilization have for a long time been offering targeted support to the developments. The incentives for renewable energy development fall into three main groups: price-, cost-, and quantity-based. Price-based instruments include fixed prices per unit energy or price markup set in law, capacity charges (feed-in tariffs, net metering). These support measures were first introduced in the USA in the 1970's, but became widespread only in the 1990's. At the moment, price-based instruments are the most popular, applied in more than 50 countries. Cost-based instruments include various subsidies, tax abatements, partial reimbursement of investments in renewable energy developments. Quantity-based instruments include renewable energy quotas or green credits, as well as assistance in tendering. As a rule, quantity-based instruments are applied to more mature technologies for renewable energy use.

Furthermore, renewable sources of energy have a substantial environmental-economic potential and contribute to the country's innovative development. Finnish experience, for instance, proves that installations utilizing renewable energy can operate even in the north. To activate the use of renewable energy in Russia, foreign experience needs to be adapted and a systemic approach should be employed in implementing the energy saving and energy efficiency policies. The possible incentives for renewable energy development, given the existing potential and scientific developments, can take the form of support measures of all the three major types: price-, cost-, and quantity-based. However, since the threats for the energy security and, hence, the socio-economic security are higher in northern peripheral regions, they should be treated preferentially within the incentive mechanisms.

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Sergey TISHKOV is Secretary for Science in the Institute of Economics, Karelian Research Centre, Russian Academy of Science. Research interests: innovation development, spatial development, regional innovation system, environmental risks, energeefficiency of economy.
ORCID ID: orcid.org/0000-0002-6061-4165

Anton SHCHERBAK is the Researcher in Institute of Economics, Karelian Research Centre, Russian Academy of Science. Research interests: sustainable development, regional innovation system, environmental risks, energeefficiency of economy.
ORCID ID: orcid.org/ 0000-0002-2259-9953

Valentina KARGINOVA-GUBINOVA is the Researcher in Institute of Economics, Karelian Research Centre, Russian Academy of Science. Research interests: sustainable development, risk management, environmental risks, energeefficiency of economy.
ORCID ID: orcid.org/ 0000-0002-8630-3621

Aleksander VOLKOV is the Junior Researcher in Institute of Economics, Karelian Research Centre, Russian Academy of Science. Research interests: sustainable development, spatial development, regional economic system, human capital, environmental risks.
ORCID ID: orcid.org/0000-0003-0451-8483

Arsen TLEPPAYEV is the Associate Professor, Faculty of Economic Sciences, Kazakh-German University. Research interests: Energy consumption, internet usage, digitalization, economic growth, environmental risks.
ORCID ID: orcid.org/0000-0001-9754-3383

Antonina PAKHOMOVA is the Professor, Platov South-Russian State Polytechnic University. Research interests: energy potential, recycling, fish waste, biowaste, biogas, bioenergy.
ORCID ID: orcid.org/0000-0002-4261-3097