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THE POTENTIAL OF THE RUSSIAN REGIONS CONCERNING THE TRANSITION TO RENEWABLE ENERGY SOURCES IN TERMS OF INTERNATIONAL EXPERIENCE: A CLUSTER ANALYSIS

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Goal: *To systematize the global experience of stimulating and regulating policies and the transition practices regards to renewable energy sources.*

Objectives: *To conduct a cluster analysis of stimulating and regulating policies application activity concerning conventional energy sources replacement, taking into account geographical proximity of the regions in the world.*

Methodology: *The cluster analysis is carried out by applying a hierarchical and iterative k-means method.*

Results: *In order to increase competitiveness of our country, the authors proposed a method of transition to renewable energy sources in different regions of the Russian Federation. The procedure suggested is based on the use of the cluster analysis data as well as allows estimating the feasibility of transition to renewable energy sources in different regions of the Russian Federation. The necessity for clustering is subject to selecting different stimulating and regulating policies, which affect the result of the climate change policy.*

Clustering is made following geographical reference in order to get preliminary recommendations for the effective use of these policies in different regions of the Russian Federation through using hierarchical and iterative k-means method.

Conclusions: *The conducted analysis allowed not only to identify the specifics of the choice of stimulating and regulating policies by the clusters for the purpose of conventional energy sources replacement, but also to form an idea of the four special economic zones in Russia.*

Keywords: *renewable energy sources (RES), cluster analysis, regulating and stimulating polices, green tariff, green certificates, net energy metering program.*

In a scientific community the issue of the transition to renewable energy sources (RES) is firstly considered in terms of conventional energy sources replacement and air

The current study aims to research a 5-year experience of the transition policy to renewable energy sources (RES). The study was fulfilled within the research project supported by St. Petersburg State University: Laboratory «Economic Performance and Environment» No 15.61.208.2015

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emissions reduction. A variety of new technologies and a great number of regulating and stimulating tools, allowing for the transition to renewable energy sources policy, often cause difficulties in assessing the priority scale of implementation and feasibility thereof. In our opinion, the cluster analysis can be used as one of these tools. It allows carrying out spatial agglomeration of the global transition policy regarding renewable energy sources.

The subjects of the cluster analysis are 16 macro-geographical regions of the world (Africa, America, Asia, Europe, Oceania), presenting a *set I = {I1, I2, ..., I16}*. The measurement of *i-th* characteristics of each of the 16 regions is denoted by *xij*, *vector Xj = [xij]* corresponds to each series of measurements (for the *j-th* object), expressed by proportion of countries belonging to a particular region and using appropriate stimulating and regulating policies (Table 1 and 2).

Thus, we have got a lot of measurement vectors *X = {X1, X2, ..., X13}*, which describe the policy of various countries in the transition to renewable energy sources. Within this study the cluster analysis should, on the basis of the collected and calculated statistic data contained in the set *X*, divide the regions into *m*-clusters (subsets) *π1*, *π2*, *..., πm*, so that each *Ij* belonged to the same splitting set, as well as clusters were

Table 1
Application activity of regulating tools in macro-geographical regions of the world, %

Macro-geographical regions	*Purpose of transit-ion to RES*	*Green tariff*	*RES Portfolio standards, green certificates*	*Net energy metering program*	*Certifi-cates for RES usage*	*Tender proced-ures for RES long term supply at fixed rate*	*Order for heat consu-mption*	*Order for biofuel consu-mption*
North America	43,5	21,7	8,7	43,5	4,3	34,8	8,7	17,4
Central America	28,6	14,3	0	42,9	0	57,1	0	28,6
South America	40	26,7	6,7	20	0	33,3	20,0	46,7
The Caribbian	0	0	0	0	0	0	0	0
East Asia	42,9	42,9	28,6	14,3	14,3	42,9	14,3	14,3
West Asia	36,8	31,6	5,3	21,1	0	21,1	5,3	15,8
South-East Asia	45,5	45,5	36,4	18,2	9,1	36,4	0	45,5
South Asia	71,4	42,9	14,3	28,6	14,3	28,6	14,3	14,3
North Europe	90	70	40,0	20	60,0	40,0	20,0	90
South Europe	68,8	68,8	18,8	37,5	25,0	18,8	37,5	50
West Europe	73,3	66,7	26,7	26,7	40,0	40,0	33,3	73,3
East Europe	80	60	20,0	10	50,0	10,0	0	60
East Africa	44,4	22,2	0	0	0	5,6	5,6	22,7
West Africa	50	6,3	6,3	6,3	0	12,5	12,5	12,5
North Africa	50	25	0	25	0	25,0	0	25,0
Central Africa	0	0	0	0	0	0	0	0

References: made up on the basis of [2–7; às well as Media reports].

Table 2
Application activity of stimulating tools in macro-geographical regions of the world, %

Macro-geographical regions	*Subsidies for major construction and benefits*	*Investment or tax credit*	*Sales reduction of conventional energy, CO2, VAT or other taxes*	*Guaranteed payment for capacity*	*Government investments, credits and grants*
North America	8,7	26,0	43,5	13,0	21,7
Central America	0	42,9	57,1	28,6	14,3
South America	20,0	13,3	53,3	13,3	33,3
The Caribbian	0	0	0	0	20,0
East Asia	28,6	14,3	14,3	14,3	28,6
West Asia	15,8	10,5	10,5	10,5	36,9
South-East Asia	36,4	27,3	54,5	9,1	45,5
South Asia	42,9	28,6	28,6	14,3	57,1
North Europe	50,0	20,0	60,0	30,0	60,0
South Europe	31,3	37,5	18,8	18,8	25,0
West Europe	66,7	46,7	46,7	20,0	40,0
East Europe	40,0	10,0	60,0	0	90,0
East Africa	11,1	0	38,9	5,6	27,8
West Africa	0	6,3	0	12,5	6,3
North Africa	25,0	0	25,0	0	0
Central Africa	0	0	12,5	0	0

References: made up on the basis of [2–7, as well as Media reports].

heterogeneous (dissimilar). The computer software SPSS was used for multidimensional classification of the regions.

The policy of the transition to renewable energy sources is actively pursued in all 11 countries in North America (the United States, Barbados, Canada, Trinidad and Tobago, Costa Rica, the Dominican Republic, Grenada, Jamaica, Mexico). It intends the usage of such expensive tools as tax benefits and government subsidies (except for Canada and the Dominican Republic), policies on sales reduction of conventional energy, net energy metering programs, provision of investment and tax credits, grants. In addition, one actively applies such a quantitative (volumetrical) tool as tender procedures for a long-term supply of renewable energy sources at a fixed rate. At the same time in North America there are no usage of RES portfolio standards (except for Canada), orders for heat consumption (except for the Dominican Republic and Mexico), green tariffs (except for Canada and the Dominican Republic), orders for biofuel consumption (except for Canada, Costa Rica, Jamaica and Panama).

In the macro-geographical region of Central America the policy, concerning the transition to renewable energy sources, is fulfilled only in Nicaragua and Guatemala; whilst the regulating tools are almost not used. The exceptions are El Salvador and Panama. Continuously, they have been actively using tender

procedures for a long-term supply of RES. In 2014 in El Salvador tender conditions were reviewed, what resulted in the rare tool usage. Nicaragua and Panama use such a profitable tool as green tariff. In Panama, as in North American countries, net energy metering programs and orders for biofuel consumption are introduced. It is worth noting that tax benefits and government financing are also provided in these countries.

Analysis of the South American countries leads to the conclusion that only 8 countries out of 12 ones carry out activities which promote the transition to renewable energy sources. At the same time in Chile and Uruguay the main goals of RES usage were revised in the years 2012-2015.

In South American countries, green tariff (except for Uruguay, Argentina, Peru, Ecuador), net energy metering program (except for Chile, Uruguay and Brazil), orders for heat consumption, subsidies for major construction and benefits (except for Chile, Uruguay and Brazil), investment and tax credits (except for Argentina, Brazil) are almost not used. South American countries have no experience in the usage of such regulating tools as portfolio standards for renewable energy sources and green certificates. The transition to renewable energy sources in South America is performed mainly through tender procedures (Argentina, Peru, Chile, Ecuador, Uruguay and Brazil) and orders for biofuel consumption (Uruguay, Argentina and Peru, Ecuador, Brazil). Such expensive tools as government investments, credits and grants (Peru, Brazil, and others) have been widely practiced in the region.

Analysis of the Caribbean allows to conclude that they ignore the policy of the transition to renewable energy sources (except for Haiti - the government makes investments and provides for loans and grants to support the development of RES production and sales).

In East Asian countries, the transition to the usage of renewable energy sources is realized only in Japan, China and Mongolia. In Japan at the national level one actively uses all regulating tools, besides orders for heat and biofuel consumption, and in China – except for the net energy metering program and green certificates. Such tools as tender procedures, net energy metering program, RES portfolio standards, green certificates and green tariff, subsidies for major construction and benefits, government investments, credits and grants are most widely used in East Asian countries.

RES portfolio standards, green certificates, orders for heat consumption (except for Israel and the United Arab Emirates), net energy metering program (except for Jordan and Syria), tender procedures (except for Syria, Israel, Kuwait and Jordan), orders for biofuel consumption (except for Jordan and Turkey) were used not so actively by the countries of West Asia in the years of 2012-2015. The transition to renewable energy sources is effected by introducing a green tariff (Israel, Jordan, Turkey, Armenia, Syria, the United Arab Emirates) and reducing sales of conventional energy, CO2 emissions, as well as providing tax benefits, government investments, credits and grants.

South East Asia most actively uses subsidies for major construction, carries out activities, which allow to reduce the usage proportion of conventional energy and CO2 emissions, provides for government investments and grants, introduces a green tariff, regional programs on enhancement of biofuel use (Indonesia, Philippines, Vietnam, Singapore Malaysia). The countries of South Asia are characterized by active provision of subsidies for major construction and benefits, government investments, credits and grants, and introduction of green tariffs (India, Maldives, Pakistan, Bangladesh and Nepal).

Such regulating tools as RES portfolio standards, green certificates (except for Lithuania, Norway, Sweden) and net energy metering program (except for Denmark and Latvia since 2014) are almost not used in the countries of North Europe. Programs on enhancement of heat consumption occurred to be not in demand. The policy of the transition to renewable energy sources is carried out through the active introduction of green tariffs (Denmark, Estonia, Finland, Ireland, Norway, Latvia, Lithuania), the use of green certificates (Denmark, Finland, Ireland, Norway, Sweden), tender procedures (Denmark, Ireland, Latvia, Norway since 2014) and the regional programs on enhancement of biofuel consumption (in all countries). Reduction of conventional energy share in this region is effected through subsidies and benefits for major construction of RES generating facilities, implementation of various projects which allow to reduce CO2 emissions, provision of tax benefits, government investments and grants.

The countries of South Europe actively apply a green tariff, net energy metering program (Italy, Malta, Albania, Cyprus, Greece), RES portfolio standards, green certificates (except for Albania, Slovenia and Bosnia-Herzegovina), tender procedures (only in Albania, Slovenia, Cyprus), programs on enhancement of heat (only in Albania since 2014) and biofuel consumption (Croatia, Cyprus, Italy, Greece). Besides, in South Europe one actively provides for subsidies and benefits for major construction of RES generating facilities, investment or tax credits, holds activities on reduction of conventional energy sales and CO2 emissions.

The countries of West Europe are characterized by significant changes in the transition policy to renewable energy sources. Thus, for example, in 2014 in Belgium, France, Germany, the Netherlands and Portugal the most demanded tool as regards to the transition to renewable energy sources –a green tariff - was revised and abolished. Revision (France) and abolishment (Portugal) touched the criteria in providing for loans concerning RES projects, and subsidies. In the Netherlands net energy metering program was canceled. Successful reduction in the usage share of conventional energy sources in the countries of West Europe is achieved through green certificates (Austria, Belgium, France, the Netherlands, etc.), programs on enhancement of biofuel consumption (except for Andorra and Switzerland), reduction of conventional energy sales, air emissions, as well as the provision of government investments, credits, grants and tax benefits (Austria, France, Germany, the Netherlands, Belgium up to 2014). RES portfolio standards, green certificates and tender procedures (Belgium, Portugal) are used not so widely.

In the countries of East Europe the climate change control policy is primarily based on increasing use of renewable energy sources. One should note that a green tariff is actively applied in all macro-geographical regions of Europe. The key objectives regarding the transition to renewable energy sources are achieved primarily by enhancement programs on biofuel consumption (except for Belarus, Kazakhstan and Moldova), net energy metering programs, RES certificates (except for Belarus and Moldova), reduction of air emissions and provision for tax benefits, government investments, credits and grants. Some countries are trying to achieve a higher level of RES usage through other tools (RES portfolio standards, green certificates, tender procedures for a long-term supply of renewable energy sources at a fixed rate.

The transition to renewable energy sources is also carried out in the countries of East Africa (Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, Sudan, Tanzania, Uganda and others). These countries use a green tariff, implement activities which reduce the need for conventional energy sources and air emissions, as well as carry out the policy of tax benefits, government investments and others.

West African countries use a limited range of tools as regards to the transition to renewable energy sources, preferring a reduction in sales of conventional energy sources, what, in turn, allows to bring down CO2 emissions, and the provision for tax benefits. However, in Cape Verde and Burkina Faso net energy metering program, tender procedures, investment or tax credits are used, as well as in Ghana and Mali – RES portfolio standards and the enhancement programs on heat and biofuel consumption.

The policy of the transition to renewable energy sources was held in Egypt and Sudan, in two countries out of four ones in North Africa, but only until 2014. Central Africa ignores this policy, except for Cameroon, where we have introduced the programs on reduction of conventional energy sales, CO2 emissions and provision for tax benefits were introduced.

So, on the basis of the data acquired, the cluster analysis of the application of regulating and stimulating tools for the transition to renewable energy sources was carried out. At the first stage, the method of hierarchical clustering was applied. It is based on the successive grouping of smaller clusters into larger ones or division of larger clusters into smaller ones. We have stated that the closest policy of the transition to renewable energy sources is proceeded in West Africa and the Caribbean, in East and North Africa, North and West Europe, and so on.

The difficulty of using a hierarchical clustering method of the regions as regards to the degree of application of regulating and stimulating tools while the transition to renewable energy sources is caused by inflexibility of classifications obtained. Therefore, at the next stage of the cluster analysis, a non-hierarchical method was applied. It is based on the separation of the regions studied by splitting an initial set. In the process of splitting, new clusters regarding the transition to renewable energy sources were formed prior to the stop rule.

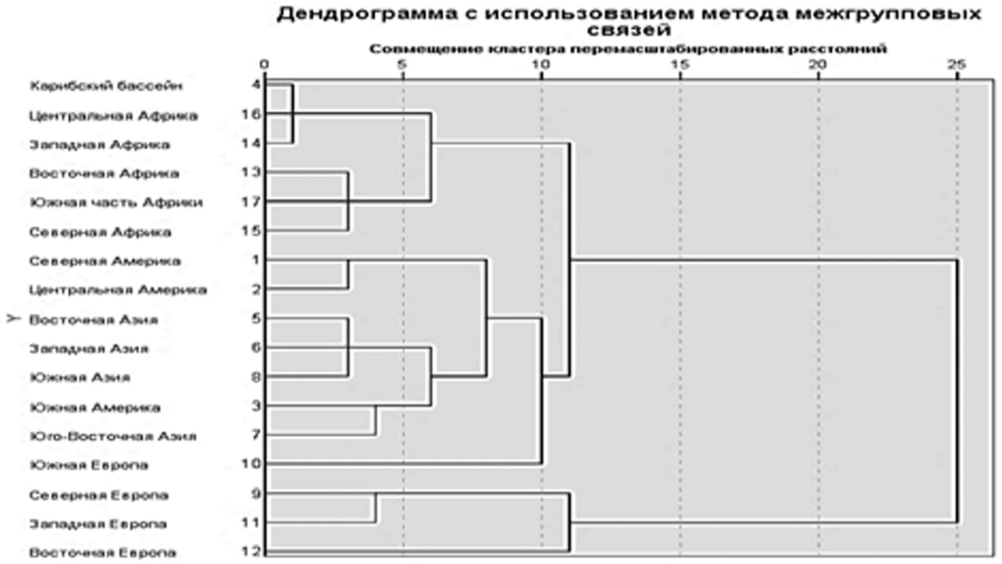

Figure 1: Cluster dendrogram on method of close neighbor

Figure 2: Mining model of the transition to RES

The calculations make it possible to identify five clusters. The first one includes East, South East and South Asia, as well as South Europe. The second - North, Central and South America, the third - East Europe, the fourth - the Caribbean, West Asia, East, West, North, Central and South Africa, the fifth - North and West Europe (Figure 2).

Russia has a great potential in the field of renewable energy sources, as there are significant opportunities to introduce a variety of advanced technologies in our country.

However, policy-making concerning the transition to renewable energy sources, in relation to Russia, must be based on basic principles and priorities clearly defined and accepted at the highest state level, which can be set using the results of the cluster analysis. The data acquired allow concluding of the feasibility to establish four special economic zones (SEZ) in Russia.

On the basis of separation of macro-geographical regions into five clusters it was specified that in order to improve the competitiveness of Pskov, Leningrad and

Figure 3: The first special economic zone of the Russian Federation regards the transition to RES

Figure 4: The second special economic zone of the Russian Federation regards the transition to RES

Murmansk regions as well as the Republic of Karelia, it is reasonable to take into account the experience of the fifth cluster concerning the transition to renewable energy sources (which actively uses a green tariff, implements programs on promotion of biofuel consumption, provides for investment and tax credits) (Figure 3).

It is reasonable to take into account the experience of the transition to renewable energy sources of the third cluster (which actively implements a green tariff and promotion programs of biofuel consumption) for such regions as Novosibirsk, Omsk, Tyumen, Kurgan, Chelyabinsk, Orenburg, Samara, Astrakhan, Belgorod, Volgograd, Rostov, Smolensk, the Republic of Altai and Kalmykia, as well as the Altai Territory (Figure 4).

Figure 5: The third special economic zone of the Russian Federation regards the transition to RES

For the Jewish Autonomous and Amur region, Primorye and Trans-Baikal territories, as well as the republics of Tuva and Buryatia, it is worthwhile taking into account the experience of the transition to renewable energy sources of the first cluster (which actively promotes a green tariff, conducts tender procedures on a long-term supply of renewable energy at a fixed rate, uses RES portfolio standards. (Figure 5).

For Dagestan and the Chechen Republic, Stavropol and Krasnodar territories it is advisable to take into account the experience of the transition to renewable energy sources of the fourth cluster (government investments, credits and loans are the most actively provided here). (Figure 6).

The obtained clusters represent a new additional way of economic and dynamic development of our country, which allows for selection of various regulating and stimulating activities for the state policy in different regions of the Russian Federation

Figure 6: The fourth special economic zone of the Russian Federation regards the transition to RES

in order to increase the competitiveness, the level of infrastructure and household welfare.

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