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Management of Energy Enterprises: Energy-efficiency Approach in Solar Collectors Industry: The Case of Russia

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ABSTRACT

In the last few years, the development and management of some types of renewable energy industries in Russia is proceeding at a rapid pace, mainly due to government support programs. At the same time, many renewable energy technologies designed for use at the enterprises, primarily in the residential and commercial sectors, have not yet been widely disseminated. In particular, this applies to solar collectors. In this article, we study the factors, preventing the wider distribution of solar collectors in the residential sector from the viewpoint of the theory of energy-efficiency. The focus of research is the informational barriers. The obtained results allow us to draw several practical conclusions about the directions for improving regional energy-efficiency programs currently being implemented in most of Russian regions.

Keywords: Solar Thermal Energy, Solar Collectors, Barriers of Energy Efficiency, Survey
JEL Classifications: O33, Q42, Q47, Q48

1. INTRODUCTION

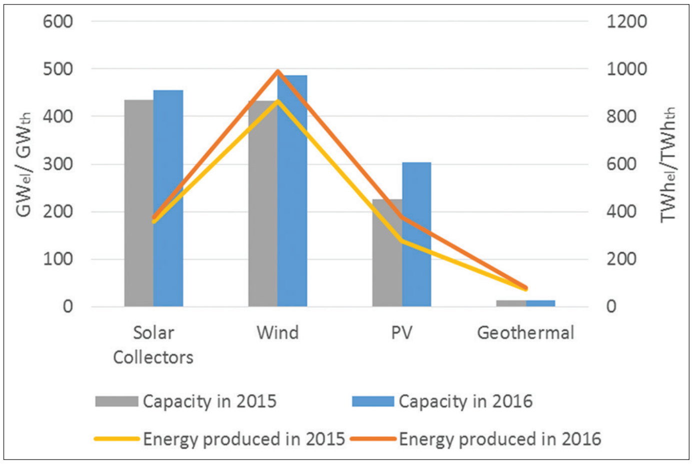
In recent years, solar thermal collectors (STC) have been widely used in all regions of the world for water heating, building heating and cooling, as well as in high-temperature industrial processes (Farijana et al., 2016; Tarsitano et al., 2017). According to the cumulative volume of installations this type of renewable energy is comparable with wind energy, and in terms of the amount of energy produced, it is significantly ahead of photovoltaics and geothermal power engineering (Figure 1).

The annual rapid growth in the cumulative capacity of solar collectors in the world has not ceased for 10 years and amounted to about 40 GW in 2016, while the total installed capacity of the installed collectors reached 456 GW (Figure 2). It is enough to yield 375 TWh of energy annually and prevent emission of 130 million tons of CO_2.

More than 70% of the total cumulative capacity of solar collectors is installed in China (Figure 3), however this largest market shows a decline over the last three accounting years (2014-2016). Other leading countries in terms of the installed cumulative capacity of solar collectors are the United States (4%), Turkey (3%), Germany (3%), and Brazil (1.9%). They are followed by India, Australia, Austria, Israel, Greece, Italy, Japan, Spain, Mexico, France, Poland, Palestine, South Korea, South Africa and Switzerland, which, combined, represent < 10% of total cumulative installed capacity (Figure 4).

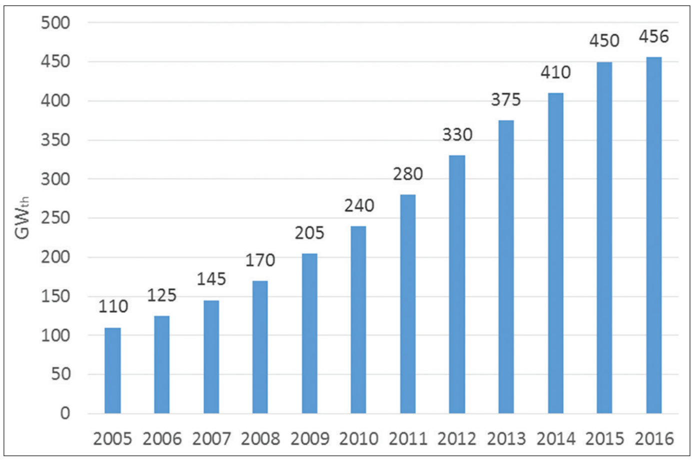
According to the latest statistics available, the most common type of solar collectors in the world at the moment are vacuum collectors that are capable of heating water up to the boiling point even at a negative ambient temperature. They are followed by flat solar collectors, which have a simpler device than vacuum ones and lower cost, but also show less efficiency. Solar water heaters of the simplest type, which are a conventional tank made of heavy-duty rubber or plastic, treated with an inhibitor of ultraviolet light, account for slightly more than 6% of the total cumulative power of solar collectors. The least common in the world are solar air collectors, in which air passes through the heat sink due to natural convection or under the influence of a fan (figure 5). The detailed classification of modern solar collectors can be found in (Farijana et al., 2016; Ruschenburg et al., 2013; Shmitt 2016).

Figure 1: Cumulative installed capacity and energy generation of various renewable energy sources in 2015-2016



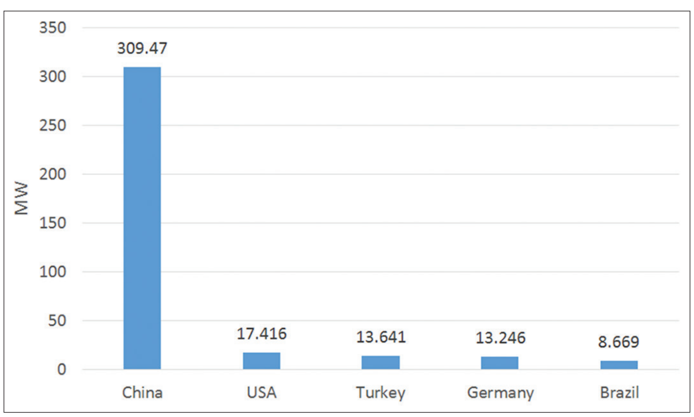
Source: Authoring based on data in (Mauthner et al., 2016; Weiss et al., 2017)

Figure 2: Global solar thermal capacity in operation in 2000-2016



Source: (Mauthner et al., 2016; Weiss et al., 2017)

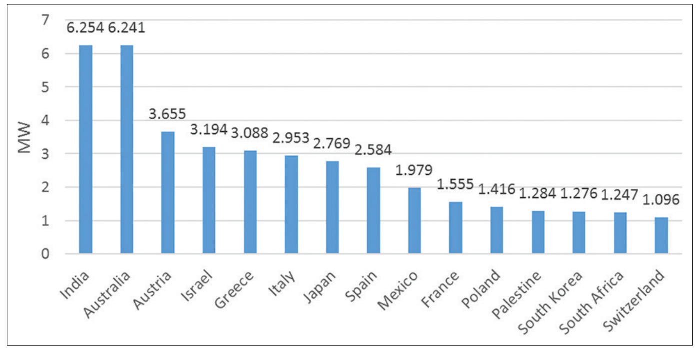
Figure 3: Top-5 countries with biggest solar thermal capacity (MW_{th}) in 2016



Source: Authoring based on data in (Mauthner et al., 2016; Weiss et al., 2017)

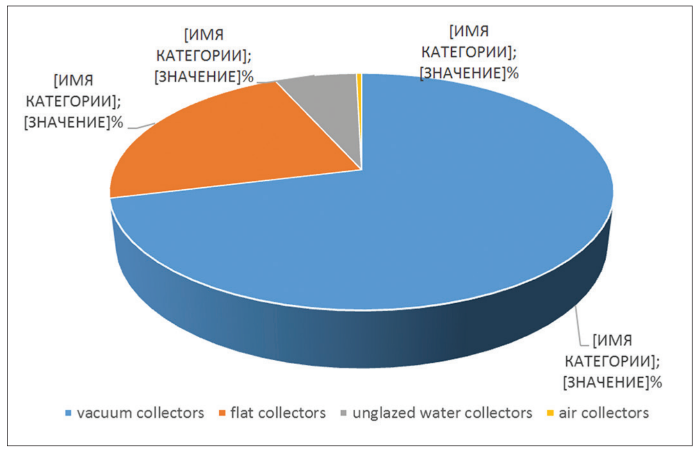
The main practical application of solar collectors, which already can be called "traditional", is water heating for use in individual households (Weiss et al., 2017). So, by the end of 2014, the residential segment of the solar collector's market was 63%. However, in recent years, many countries are actively introducing large-scale heating systems for apartment buildings and tourist facilities (hotels, motels, boarding houses).

Figure 4: Countries with more than 1GWth solar thermal capacity in 2016



Source: Authoring based on data in (Mauthner et al., 2016; Weiss et al., 2017)

Figure 5: Distribution by type of solar thermal collectors by the end of 2015



Source: (Mauthner et al., 2016)

This sector represented only 28% of the cumulative capacity installed by 2014, but more than half of the new installations (Mauthner, 2014). In 2015, this process continued, and the best examples were China and Poland, where the commercial segment grew at the fastest pace, while the share of solar thermal installations for individual use declined. In China, solar collectors for multi-family homes and hotels accounted for 61% of the total installed capacity in 2015. In Poland, the main driver of the market were large systems in public buildings. Also, the use of solar collectors in combination with other technologies, such as heat pumps and other hybrid renewable energy systems for households became more popular (Poppi et al., 2018).

In 2016 megawatt-scale solar thermal systems demonstrated the biggest growth: Comparing with 2015 with 21 new large-scale STC installations, 37 megawatt-scale STC with the total capacity of 350 MWth were put into operation in Europe. They were used primarily for district heating networks.

In addition, solar heat is increasingly used in industry for heating and evaporation of water, cleaning, drying, boiling, pasteurization, thermal separation and power supply for other production processes. Technologies of solar power engineering in recent years have become most widespread in the food (Meier et al., 2006; Sharma et al., 2017), textile (Ramos et al., 2013) and mining industries, automobile industry (Zahler and Iglauer, 2012), pharmaceutical industry (Haagen et al., 2015) as well as in the processing of metals (Farijana, 2016). According to data for March 2016, there are 188 thermal solar industrial facilities with a total capacity of 106 MW in operation in 32 countries worldwide (Mauthner et al., 2016). Leaders for the use of thermal solar energy in the industrial sector are Austria, Chile, China, the United States and India. While the share of the industrial sector in thermal solar energy is small compared with the share of residential and commercial sectors, experts estimate the long-term potential of these sectors as roughly the same.

The share of Russia in the world market of solar collectors is still very small and comparable with the share of such small countries as Latvia, Lithuania and Estonia (Figure 6). At the end of 2015, the cumulative power of all types of solar collectors installed in Russia was 13 MW. This corresponds to a collector surface area of about $18,500^2$ meters.

The development of solar thermal energy is not currently a priority of Russian state policy in the energy sector and is not supported by any state programs or incentives as other renewables (Ratner and Nizhegorodtsev, 2017a; Abayev et al., 2018). Regional energy efficiency programs provide several modest opportunities to support the development of this technology, in which significant funds are spent on the popularization of energy-efficient products, services and technologies among the population (Orlov et al., 2013; Ratner and Ratner, 2016). But a wider introduction of solar collectors could significantly improve the energy efficiency of the housing and communal sector, commercial buildings (tourist facilities, offices) and public (schools, hospitals, clinics, etc.) buildings (Chua et al., 2013; Peruzzi et al., 2014; Salata et al., 2016; Cao et al., 2016; Yang and Athienitis, 2016). In the absence of government support programs, the development of solar thermal energy can only occur purely due to market forces. Presumably, the low degree of distribution of this technology is due to the poor awareness of potential consumers about the capabilities of this technology and its high initial cost. These assumptions were the basis for the research hypothesis of our large-scale empirical study on identifying and assessing the diffusion barriers of solar collectors as energy-efficient technology.

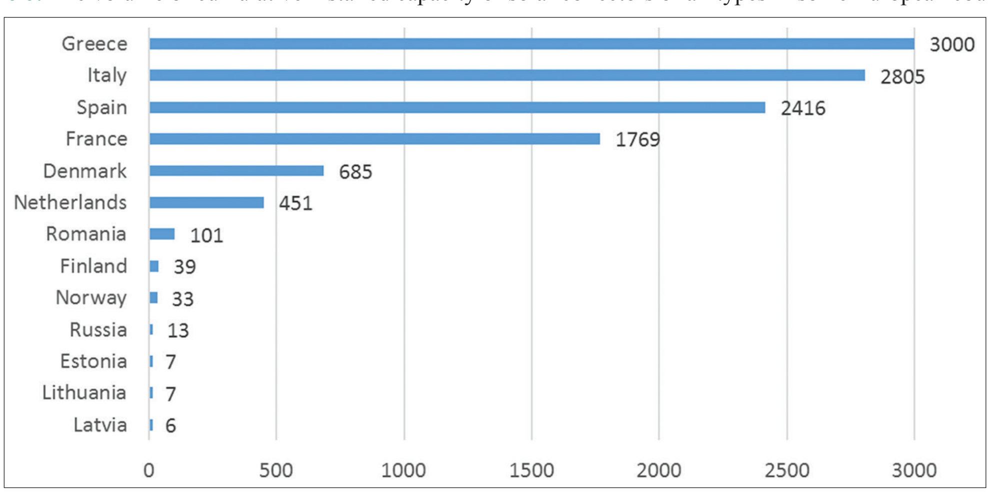
2. METHODOLOGY

We performed the research based on a specially developed survey, which included multiple-choice questions and range-based questions, using interviews. The investigation of the diffusion barriers of solar collectors was carried out as part of a bigger scale study of barriers to the diffusion of energy-efficient technologies and renewable energy technologies, described in detail in (Ratner and Nizhegorodtsev, 2017b). Over 650 people from three different regions (Krasnodar region, Krasnoyarsk region and Primorsk region) participated (Figure 7).

The choice of regions was dictated by several factors. First, there's a wide representation of companies responsible for solar collector installation in all three regions, both for domestic and foreign equipment, that have significant portfolios of successful projects.

Secondly, these regions have significant differences in their energy systems, which also leads to different heat and electricity rates. This can affect the intensity of stimuli for transitioning to more energy efficient technologies. The third factor which may potentially affect the supposed regional differences in the level of heat pump technology diffusion and the level of social awareness is the informational policies of the regional authorities, which

Figure 6: The volume of cumulative installed capacity of solar collectors of all types in some European countries



Source: Authoring based on data in (Mauthner et al., 2016) is implemented under the framework of regional programs and projects for increasing energy efficiency.

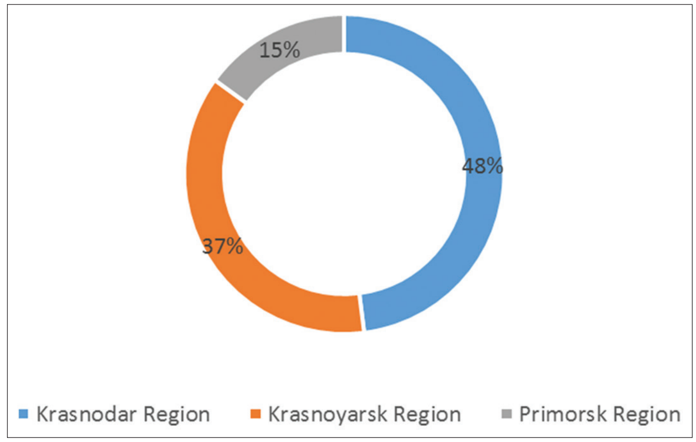
Figure 7 shows that the largest share of survey participants are Krasnodar region residents (48%, 315 people), with 37% (252 people) of participants from Krasnoyarsk region and 15% (100 people) from Primorsk region. Primarily the middle-class participated in the research, with participants having higher or middle education, primarily working specialists and students. Pensioners and housewives didn't have a significant representation in the survey. The gender and age ratios of survey participants are shown on Figure 8.

We assume that the respondents' living conditions (apartment or private house) could have been a significant factor that affects the respondents' awareness and attitude towards the researched technology, since while building or reconstructing their own houses, respondents would have had to make their own decisions in regards to a wide range of issues, including those related to heating and cooling systems, as well as water heating. Problems during installation and integration of new energy-saving equipment into an existing energy or heating system are known as the infrastructural barrier (Weber, 1997; Kollmuss and Agyman, 2002; Sherriff, 2013; Ratner and Iosifov, 2017; Prentis, 20116). It can be assumed that respondents who live in apartments will evaluate the infrastructural barrier higher than those who live in their own houses. This assumption, however, is only valid if the respondents are well-aware of the capabilities and limitations of solar collectors in the first place. Hence, the respondents living conditions were one of the questions in the survey but didn't serve as a factor for preselecting the survey respondents. The final selection had 63% of respondents living in apartments and 23% in private houses (Figure 9).

To determine potential barrier to information diffusion (Blumstein et al, 1980) on solar collector technology, the survey contained questions meant to identify information sources used by respondents. The majority of respondents in our selection use non-specialized mass media sources of information, as well as friends and acquaintances (Figure 10). Only 5.9% of respondents noted their professional activities as a source of information. This percentage corresponds to specialists in construction work and educators of colleges and universities that participate in energy saving propaganda. This structure of information source preference allows to view the respondents as classic recipients of external informational influence and use their responses to evaluate the overall efficiency of national and regional informational campaigns for energy saving and energy efficiency.

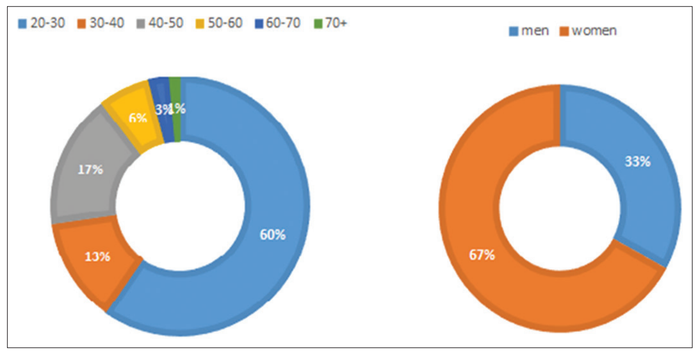
Other questions of the questionnaire were aimed at determining the level of awareness of potential consumers about the possibilities of solar collector technology, as well as the identification of links between the level of awareness of the respondent and their personal characteristics. In the first stage all the responses of the respondents were processed using descriptive statistics. At subsequent stages of processing, more sophisticated methods of mathematical statistics were used, in particular, parametric t-test and non-parametric correlation and cross-tabulation tables (Lehmann, 2006).

Figure 7: Geographical spread of survey participants



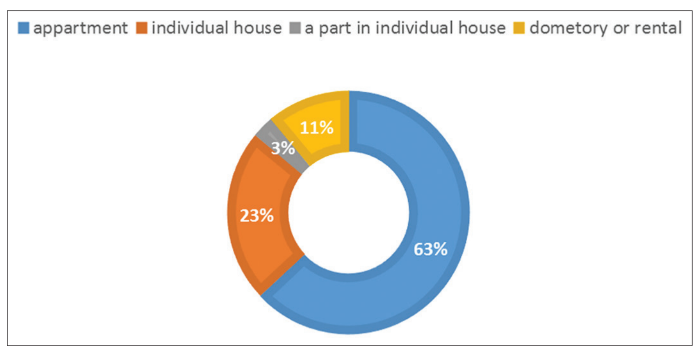
Source: Developed by authors

Figure 8: Gender/age structure of survey participants for the research of solar collector diffusion barriers



Source: Developed by authors

Figure 9: Respondents' living conditions

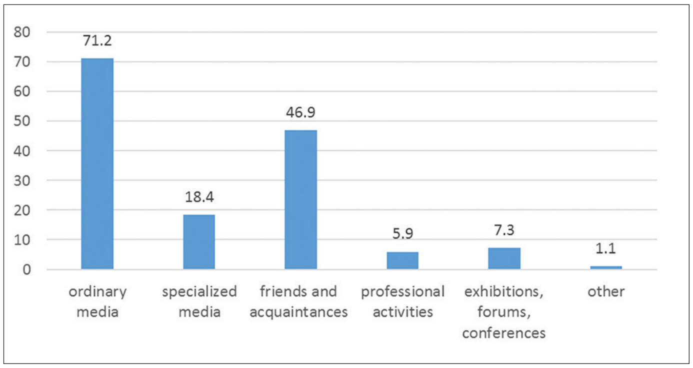


Source: Developed by authors

3. RESULTS AND DISCUSSION

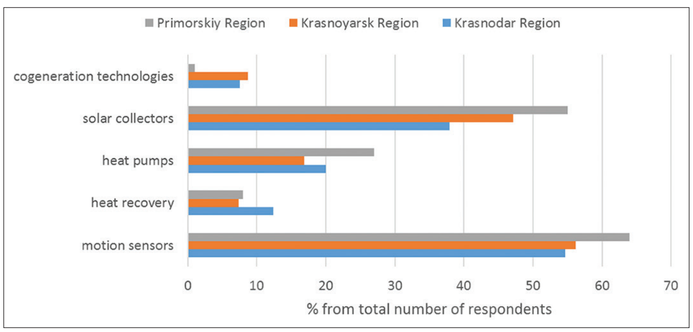
The research results have shown that the respondents' awareness level of the solar collector technology is rather low in all regions but is higher than that of other energy saving technologies developed in recent years, such as heat pumps, cogeneration and heat recuperation (Figure 11). It's of note that the lowest awareness level of the three researched regions is exhibited in the Krasnodar region, which is a region with a high share of individual houses, a developed tourism infrastructure and the best climate conditions for implementing this energy-saving technology. The results of processing the survey responses using the t-test for equality of the average showed the relationship between the use of specialized media, social contacts, professional activities and exhibitions/forums as a source of information on new energy-saving technologies and respondent's knowledge of solar collector technology (Table 1). As expected, respondents using additional (or alternative) sources of information to regular media have a higher level of awareness of the technology of solar collectors.

Figure 10: Information sources used by respondents to obtain information on energy saving technologies (frequency of answer in percent of overall respondent count)



Source: Developed by authors

Figure 11: Respondents' awareness level of different energy-saving technologies



Source: Developed by authors

To assess the extent of the relationship between the respondents' level of awareness of the solar collector's technology and the type of housing, cross-tabulation and Pearson's χ^2 statistics were used in the work, both calculated in the usual way and using the maximum likelihood method (Lehmann, 2006). The results of the calculations showed the presence of a statistically significant association at the level of P = 0.01 (the P-level of Pearson χ^2 is 0.0034, the P-level χ^2 of the maximum likelihood is 0.0029). An analysis of the two-way cross tabulation table (Table 2) allows us to conclude that respondents living in multi-apartment buildings and dormitories or in rented accommodation are better informed about solar collector technology than respondents living in individual houses or part of an individual house. This result can be explained by the fact that respondents living in multi-apartment buildings and rented dwellings experience a higher financial burden when paying utility bills, and therefore are more interested in finding ways to reduce it.

A study of the relationship between the place of residence and the respondent's knowledge of solar collector technology, also carried out using cross-tabulation tables, showed the presence of a statistically significant relationship at the level of P = 0.05 (the P-level of Pearson χ^2 is 0.0113, the P-level of χ^2, the maximum likelihood, is 0.0094). From the frequency distribution of the answers presented in Table 3, we can conclude that the highest level of awareness is observed among respondents living in megacities (47.89%) and their suburbs (44.44%).

A study of the relationship between the age and the respondent's knowledge of solar collector technology, performed by calculating

Table 1: The results of t-test

Grouping variable (factor)	Dependent variable	t-statistics	P-level of t-statistics
Using ordinary mass media as a source of information about technology	Awareness about technology	0.86	0.38
Using specialized mass media as a source of information about technology		1.65	0.1
Friends and acquaintances as a source of information		1.66	0.09
Professional activities as a source of information		-3.8	<0.01
Exhibitions, forums and conferences as a source of information		-2.63	<0.01

Table 2: Cross-tabulation between the type of living facilities and the awareness of responder about solar collector's technology

Awareness of solar collector's technology	Type of living facilities				Row totals
	Apartment	Individual house	A part of individual house	Dormitory or rental	
No (code 0)	212	101	15	39	367
Column, %	51.33	67.33	71.43	53.42	
Row, %	57.77	27.52	4.09	10.63	
Total, %	32.27	15.37	2.28	5.94	55.86
Yes (code 1)	201	49	6	34	290
Column, %	48.67	32.67	28.57	46.58	
Row, %	69.31	16.90	2.07	11.72	
Total, %	30.59	7.46	0.91	5.18	44.14
Totals	413	150	21	73	657
Total, %	62.86	22.83	3.2	11.11	100

Source: Calculated by authors with STATSTICA 10.0 software

Table 3: Cross-tabulation between the place of living and the awareness of responder about solar collector's technology

Awareness of solar collector's technology	Place of living					Row totals
	City more than 3,00,000	City from 1,00,000-3,00,000	Suburb of a city more than 3,00,000	Town<1,00,000	Rural area	
No (code 0)	247	23	20	26	51	367
Column, %	52.11	69.70	55.56	60.47	71.83	
Row, %	67.30	6.27	5.45	7.08	13.90	
Total, %	37.60	3.5	3.04	3.96	7.76	55.86
Yes (code 1)	227	10	16	17	20	290
Column, %	47.89	30.03	44.44	39.53	28.17	
Row, %	78.28	3.45	5.52	5.86	6.90	
Total, %	34.55	1.52	2.44	2.59	3.04	44.14
Totals	474	33	36	43	71	657
Total, %	72.15	5.02	5.48	6.54	10.81	100

Source: Calculated by authors with STATSTICA 10.0 software

the rank correlation Kendall statistics, showed a weak statistically significant negative correlation ($\tau = -0.06$) between the analyzed characteristics of the respondents. This indicates that with aging, the level of awareness of respondents about the technology of solar collectors decreases.

4. CONCLUDING REMARKS

The main contribution of our study in the literature is the identification of significant information barriers for the dissemination of solar collector technology in the residential sector in Russian regions, which is currently the most promising in Russia due to the absence of state incentives for large-scale solar thermal installations for district heating purposes and industrial applications.

In addition, the obtained results allow us to draw several practical conclusions about the directions for improving and increasing the effectiveness of regional energy saving programs currently being implemented in the regions under the study. As can be seen from the results of the survey of respondents, the change in the content of information campaigns on the promotion of energy saving and energy efficiency in the direction of increasing consumers' awareness of energy efficient technologies, goods and services available on the market is a top priority.

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