Ministry of Education and Science of Georgia
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Faculty of Technical Engineering

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Non-Traditional Energy Resources of Georgia and Feasibility Study of their Use

The Author's Abstract
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Topicality of research. In the 21st century, mankind and the fuel and energy complex are facing the great challenges. According to experts, as a result of wasteful consumption of natural gas, oil and the so-called "easily exploited" other energy resources over the centuries, in the conditions of current rates of their consumption, hydrocarbon energy resources will be exhausted in the second half of the 21st century. At the same time, waste of energy resources led to the creation of serious environmental problems. All this makes new, radically different demands on the development of mankind and fuel and energy complex. It becomes evident that in a global scale, the world's energy development in the 21st century should be gradually switched from consumption of non-renewable organic resources to the use of non-traditional, renewable and practically inexhaustible sources.

The issue is particularly relevant for Georgia, which is rich in non-traditional, renewable energy resources, and they, to a certain extent, are making up shortage of hydrocarbon energy resources in the country. The fact that renewable energy resources, except for hydropower resources, practically are not still used, deserves particular attention.

it is clear that in such conditions, execution of feasibility study of non-traditional renewable energy resources in Georgia is of high topicality from both theoretical and practical standpoints. Moreover, in this regard, there is a lack of the related research works carried out in the country.

The state of scientific study of problem. The problems with using non-traditional renewable energy sources in Georgia have been studied and discussed by Georgian and foreign scientists. Among them, the emphasis should be placed on G. Arabidze, father and son O. and K. Vezirishvili, A. Mirianashvili, father and son N. and N. Meladze, I. Zhordania, N. Sulin, M. Keburia, G. Tsertsvadze, R. Khachaturyan, V. Jamarjashvili and other specialists engaged in this field. However, it is evident that their practical application is being delayed.

Goal of research. The identification of opportunities for increasing the level using non-traditional energy resources in Georgia and its scientific justification. To this end, there is foreseen to attain the following objectives: detailed analysis of the initial state of the development of each field of non-traditional energy;

- assessing the potential of non-traditional energy resources existing on the territory of Georgia and engineering-and-economical level of them;

- study of the achievements in the field of non-traditional energy throughout the world, and carrying out comparative analysis of it with the current situation in Georgia;
- assessing the impact of the use of non-traditional energy resources on the economic indicators of production, environmental and social status for conditions of Georgia, as compared to the use of traditional energy resources, as well as the technical and economic potential for optimizing its development.

Subject of research. Non-traditional energy resources existing on the territory of Georgia; including solar, wind and geothermal energy.Also, energy prospective directions, particularly, bioenergy, heat pumps, ocean and hydrogen energy.

Theoretical and methodological basis of research. Modern theory of economics and engineering on pattern in reproduction of material values. The following general scientific methods have been used in this dissertation work: analysis, synthesis, logic and computerized modeling, and expert appraisals. There have been used the works of Georgian and foreign scientists on non-traditional energy.

An information base of research. There have been used the legal and normative documents of Georgia and some other countries, data of companies engaged in this field and acting in Georgia ("KARENERGO", "SAKBURGGEOTERMIA", SPECHELIOMONTAZHI", "KEBULI KLIMATI"), works scientists engaged in this field, information material provided by statistics service, and so on.

Research novelty:

- There are justified the increasing role and importance of non-traditional energy in Georgia's economy. There is deepened a view of the role of this field in the fuel and energy complex of Georgia;
- At the current development stage, there is studied the state of all sectors of non-traditional energy of Georgia, shortcomings existing in the development, reserves and opportunities; there are specified natural resources of Georgia existing in non-traditional energy by all types, as well as the degree of their use;
- There are given substantiated author's recommendations for the development of the prospective energy fields, such as bioenergy, use of heat pumps, ocean and hydrogen energy;
- There is scientifically studied the magnitude of the total heat delivery capacity of solar, wind and thermal water resources across selected regions;
- In a given work, there have been studied the design technical and economic parameters of hydro power plants running on traditional and non-traditional resources, including the total investment required for their installation, as well as duration of useful work per year.

Author's contribution. The author formulates novelties obtained as a result of research. In this respect, he describes the measures to be taken. There is noted that Georgia must continue to exploit again rich and currently economically acceptable hydro resources, but great attention should be paid to the use of non-traditional energy resources, in order to make it technically and economically competitive with other power supplies. The author's conclusions are based on the development of those approaches, which are relied on the modern scientific-methodological achievements, and allow for identifying reserves existing in this sector. The components of scientific contribution have been reflected in the results of this research and brought to defense.

The athor has made 4 publications, two in the Journal of the Akaki Tsereteli State University, and two presentations at the International Scientific Conference.

Volume and Structure of Dissertation. The proposed work comprises 103 printing page, containing 27 drawings and tables. It includes Introduction, four chapters, 13 paragraphs, conclusions and references. The list of references includes 92 sources.

Content of Dissertation

In the first Chapter "Non-Traditional Resources of Georgia", the dissertation reviews non-traditional resources of Georgia, their amount and qualitative indicators.There is presented a table illustrating possible economic and energy's benefit from non-traditional energy resources (solar, windand geothermal energies) based on the already mentioned and available data by region (see Table 1,4): (data illustrated by this table are average data on the resources existing in the region; data of some one point of the region may exceed data of the entire region).

Table 1.4

Heat delivery capacities of Georgia's solar, wind and thermal water resources by selected regions.

Regions	Total annual solar radiation (kWh/m^3)	Total duration of wind equal or over 3 m/sec annually by regions	Heat delivery capacity of thermal water resources (MW)
Tbilisi	2107	4436	7,32
Imereti	1350-1400	7127	21
Kakheti	1349	3000	2,55
Kvemo Kartli	1400-1450	4131	-
Mtskheta-Mtianeti	2147	4591	0,04
Abkhazia	1451	3395	164,95
Guria	1426	5223	-
Adjara	1308	6243	-
Samtskhe-Javakheti	1400-1600	6740	5,83
Shida Kartli	1350-1450	5000	2,14
Samegrelo	1451	4280	102,1

In accordance with data in Table 1.4, there is presented the average declined radiation histogram on the area of 1 square meter of every region during the year ((see Fig. 1,5). 1

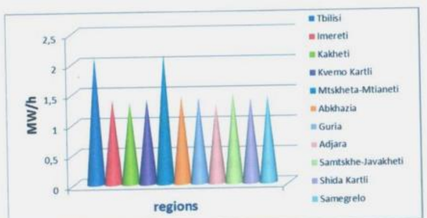

Fig 1.5. The average declined radiation on the area of 1 square meter of Georgia's region

There is given the amount of electricity generated by 1 KW of installed capacity of wind, for each region.

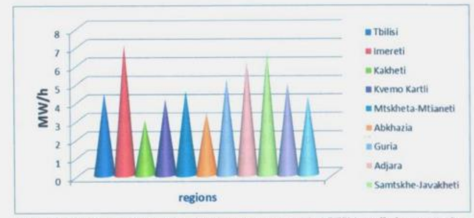

Fig. 1.6. The annual generation of wind generator with 1 KW installed capacity by Georgia's regions (MW/h).

Histogram 1.7 illustrates the total capacity of deposits of thermal waters, with account for daily flows and temperature.

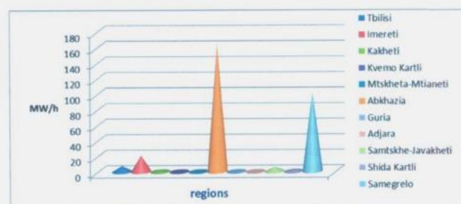

Fig. 1.7 Thermal water flows capacities in Georgia's regions (MW)

The analysis of table and histogram on non-traditional energy resources of Georgia's regions, has shown that in each region, there must be developed that alternative energy sector, whose resources and qualitative indicators are better in comparison with other regions.

Chapter 2 "Analysis of the Current State of the Use of Non-Traditional Energy Resources" providesa table on draft technical and economic indicators of power plants running on non-traditional and traditional energy resources (see Table 2,2), for comparison and conclusions: for comparison, there are selected data on hydro power plants and compared with other power plants running on non-traditional or traditional resources. There is shown installation of 1 KW capacity of solar power plant requires the largest investment - $13715, which is 8 times higher the amount required for installation of 1 KW-capacity hydro power plant ($1616), besides, working hours of solar power plant during the year make up only 1048 hours that is 5 times lower than working hours of HPP (5194 hours per year), and it turns out that investment in solar power plants is 40 times more unprofitable to the investor than investment in hydro power plant. Calculations have shown that the wind power plant is much more competitive than the hydropower plants, they both need almost the same amount of the investment for installing 1 KW capacity (HPP - $5144, WPP - $4251). These data allow for concluding that development of a particular type of renewable and non-traditional offers tremendous opportunities in our country. Table 2.2 shows that start-up of thermal power plant requires the least of the investments on 1 KW capacity ($956,6). In addition, in comparison with all other power plants it is characterized by the longest working hours during the year (7608 hours), but it has negative environmental impacts. Economic study has shown that the operation of HPPs and TPPs is profitable to the investors, but this study also reveals the competitiveness of wind power plantrelative to them.

There has been studied the annually growing volume of the converters of alternative energy, which in 2015 reached 785 GW of installed capacity (see Fig. 2.4), where the WPPs bear a significant proportion, 433 GW, wind power installations are in second place – 231,8 GW, a large share belongs to bioenergy – 106,4 GW, and relatively small share belongs to geothermal energy – 13,2 GW, and the share of ocean energy is minimal – up to 0,5 GW.

Table 2.2

The design technical and economic parameters of power plants running on non-traditional and traditional energy resources.

Power plants	Location	Installed capacity	Power generation	Including for 1 KW capacity (USD)	Including for 1 KW capacity (USD)	Number of used hours
Solar	Tbilisi Airport	350 KW	367 KW/h.	4,8	13715	1048
Wind	Gori municipality	20,7 MW	88 man KW/h	35,0	1690	4251
TPP	Gardabani	230 MW	1750 a mln KW/h	220,0	956,6	7608
HPP	Kazbegi districts (Tergi HPP)	26,3 MW	136,6 mln KW/h	42,5	1616	5194

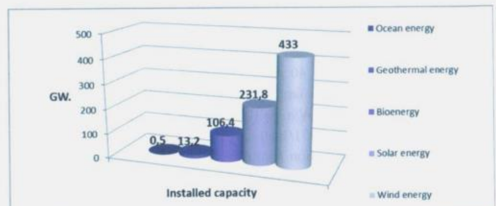

Fig 2.4 The 2015 estimates of the installed capacities of alternative energy throughout the world

The third Chapter "Basic Directions of Non-Traditional Energy Development"refers tothe level of development and areas of non-traditional energy in Georgia and throughout the world. There are given the calculations of profitability of solar photovoltaic vacuum-tube collector and geothermal energy for domestic and commercial use, and experiments have been also conducted.

There have been calculated data of three distribution companies in Georgia,the average annual expenditure per family for electricity used in the household sector and by registered consumer (1582,3 KW/h). We put forward our thought regarding the prospects for the future, which is strengthened by the following calculations: if one of the largest distribution companies in Georgia – the Emergo-pro Georgia, installs, for their own expense or by state subsidies, small solar power plants for each such consumer, for example 22 solar battery pack with 80 KW capacity each, with its "smart" bilateral electricity meters, the total cost of which will be (1760*6) 10560 GEL, and in addition to this the cost of the meter, controller, converter, iron structure and cost of installations 350 GEL, i.e. 10910 GEL in all. The installed capacity of each of them will be (80*22=1760W) 1,76 KW. In Georgia, the average annual number of solar period hours is 1800, power capacity generated by such solar battery pack will be (1800*1,76) 3168 KW/h. Each such consumer, who paid annually 1582,3*16,931) 267,90 GEL, made a profit for Energo-pro Georgia - (1582,3*(16,931-7,534)) 148,69 GEL (thermal power plant sells 1 KW/h of generated electricity for 7,534 tetri). The duration of service of solar batteries is 40 years, and over this period of time, the distribution company would have earned a profit (148,69*40) 5947,6 GEL. In 40 years, each solar battery pack will generate (3168*40) 126720 KW/h, the family will consume (40*1582,3) 63292KW/h, i.e. 126720-63292) 63428KW/h will return into the network, the cost of which will be (63428*16,931/100) 10739 GEL. By means of "smart" bilateral meters, the distribution company can control consumer, for whom they installed solar battery pack, and let him to pay instead of 16,931 tetri, lower tariff, for example 12 tetri, i.e. such consumer, during the period of 40 years, will pay (63428*0,12) 7611,36 GEL instead of (40*267,9) 10716 GEL, and such consumer will save (10716-7611,36) 3104,64 GEL. A profit of the distribution company will be (10739+7611,36-10910) 7440,36GEL that is 97440,36- 5947,6) 1492,76 GEL more than under standard conditions, i.e. by investing 10910 GEL, each consumer in the domestic sector saves up to 3000 GEL, the distribution company makes a profit about 1500 GEL on each installed solar battery pack per 1,76 KW capacity, a profit per 1000 such

consumers will be (1500*1000) 1500000 higher. If the number of such houses will enable us to replace gradually the electricity generated by thermal power plants in 2015 (in 2015, thermal power plants purchased 649 mln m^3 of natural gas), in 40 years we will have in the atmosphere (40*649 mln. m^3/1000*1,9=49324000 kg)49324tons' lighter greenhouse emissions. Also, our calculations give us reason for motivating foreign and local businessmen, funds, banks to invest in energy sector.

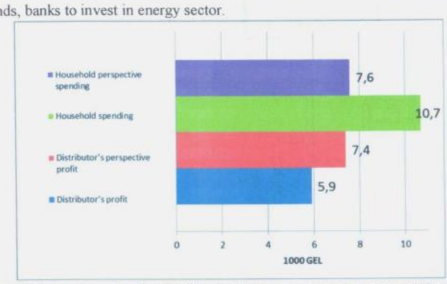

Fig. 3.4 Prospective and real profit of the distribution company and amounts paid by the family for electricity really and in case of istalling solar photovoltaic batteries in 30 years (thousand GEL)

We had out experiment aiming at quantifying the savings in utility bills obtained annually by hot water supply system of living space by using the solar vacuum tube collector.

The experimental method was as follows: within 24 hours, we observed what volume of water and at what temperature was heated by solar water heater.

The observations were carried out within the year in Kutaisi on a 230-l water heater installed in a five-person family, which was operated by means of a SR500automatic controller of solar water heater.

The connecting circuit of the controller to a solar water heater is given in Fig. 3.6, which illustrates that the SR 500 controller is connected to the electric heater installed in a water heater, condutor with heating capacity, sensors and electromagnetic valve, by means of which it runs the memorized functional commands.

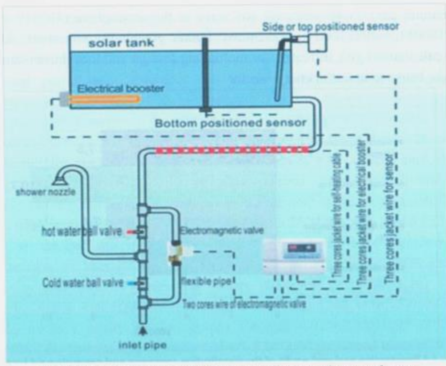

Fig. 3.6 The connection circuit of the controller to a solar water heater

The solar water heater received the following commands: sisplaying on the screen the water level, temperature and date. The function of filling by time mode was turned on. The tank was filling every night at 4 o'clock. There was given command to set temperature at 90 ^{0}C, and if the temperature was lower than required, the 750-KW capacity electric heater must be installed in a water heater must be turned on.

Within 24 housr, there is calculated 200 l of the 45 ^{0}C-temperature hot water per capita. The temperature of cold water in the pipeline in summer is 15^{0}C,and in winter - 10 ^{0}C. 1 kcal thermal energy is required for heating 1 l of 1^{0}C-temoerature water. data on saving energy in a particular case of using solar energy for water heating purposes, are given in Table 3.7.

Table 3.7

Observations on solar water heater operation

Months	Temperature of obtained water (^{0}C)	Energy saved within 24 hours (KW/h)	Energy saved within a month (KW/h)
January	23	3	90
February	30	4,7	141
March	55	10,5	315
April	65	11,6	348
May	73	13,5	405
June	85	16,3	489
July	92	17,9	537
August	92	17,9	537
September	71	13	390
October	58	10	300
November	37	6,3	189
December	18	1,9	57
Total			3798

3798 KW/h of energy had been saved in one year for water heating in an appartment building at the expense of solar energy. If we take into account that in Georgia,up 300 KW/h of energy costs0,1693 GEL, this one family saves annually (3798*0,1693) 643 GEL from the family budget. The production costs of a water heater set will be returned (1900/643=2,95) in 3 years, Operational period is 20 years, i.e. by investing 1900 GEL, the family saves (17*643) up to 11000 GEL. In order to generate the same amount of energy by using natural gas in 20 years, about 8 tons (20*2019/9,45*1,9) of greenhouse gases will be emitted into environment.

There are given calculation data on the justified economic and environmental profitability of using energy generated by the gethermal well installed in Samegrelo for the household or water-heating purposes: in Tsaishi dsitrict, there are located 15 former operating wells, to date, water from them is pouring for nothing. Their overall flow is24564 m^3, water temperature - 78-98 ^{0}C, overall thermal capacity - 69,8 MW/h. Flow and temperature of this water are completely adequate for using geothermal water in the heating systems and for hot water supply.

If we assume that losses of potential thermal energyofwater from well during transportation of geothermal waters to water collectors, and then to the appartment buildings, by using the modern thermal insulation, are estimated at 10%, the useful kinetic thermal energy will be up to 63 MW/h.

Heating of 1 m^2 area of a building located in Zugdidi, according to European standards, requires 100 W/h capacity. To meet the needs of a 4-person family for hot water within 24 hours, we calculate 100 W of thermal energy per hour, i.e. we'll be able to provide (63 MW/h/12,4 MW/h) more than 5000 such buildings with hot water and with heating in winter. During that season, when heating is not required (63 MW/h/ 2,4 MW/h), more than 26000 families can be provided with hot water.

Based on current electricity tariff in of Tbilisi on the Lisi Lake geothermal water deposits (each consumer pays monthly 3 GEL), for heating of 5000 buldings and hot water supply, the population will pay annually (5000*3*12) 180000 GEL. When burning, 1 m^3 of natural gas generates 9,45 KW/h of energy. To obtain 63 MW, up to6700 m^3 of natural gas would have been burned per hour. More than (6700*24*365*0,54) 31,6 mln GEL of natural gas is spending annually. Calculations show that the use of energy of geothermal waters of Zugdidi-Tsaishi in the household sector allows the population for saving about 30 mln GEL, annually.

Up to (6700ə ^{3}*24*1,9) 3000 tons of greenhouse gases would have been emisitted into environment within 24 hours that allows for protecting the atmosphere from the emissions of up to 1 mln ton of greenhouse gases.

In the fourth Chapter " Prospects for Development of Innovative Energy Fields", we have studied the technical-economic indicators of such alternative energy sources, as biomass, hydrogen, ocean flow, gradient and ground swell, hydrogen and thermal pump energies. There is given calculation of selecting the capacity of thermal pump and economic efficiency for the greenhouses existing in the Imereti region of Georgia: let's calculate the heat load required for the glass greenhouse with the so-called (Finnish roof" located in the Imereti region, whose parameters are as follows: with the height to the roof H=2 m; the total height - R=5 m; the width of the roof slope S=5 m; the length L=50 m; the width W=8 m. Calculation has shown that the inside surface area of the greenhouse glass is756 m^2. Based on the NASA RETScreen Interbational, the accepted difference between the outside and inside temperatures is 16 ^{0}C. Heating of greenhouse will require(756*16*10,76) 130153 BTU, which is equivalent to (130153/3413) 38 KW/h of energy.

To keep out desired temperature within three months in winter, we would need (38*24*30*3) 82080 KW/h capacity, the cost of which will be (82080*21,45) 17600 GEL. If we use a thermal pump with thermal efficiency

2,5 for obtaining the same capacity, when the difference between the outside and inside temperatures is 16 ^{0}C, the electric energy consumption will be 17606/2,5) 7040 GEL.

By using a thermal pump in during the winter, we save more than 10 000 GEL for heating greenhouse. For heating the same area with natural gas, we would spend (82080/9,45*0,54) 4700 GEL that is2300 GEL less than by using a thermal pump (see Fig. 4.4). However, from the combustion of natural gas, up to (82080/9,45*1,9) 17 tons of greenhouse gases emit into environment.

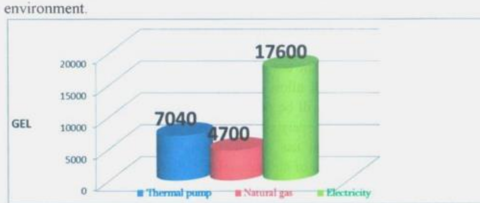

Fig 4.4 Tariff paid for heating during three months of winter

Based on the results of carried out feasibility study, the following conclusions have been made:

1. For replacing TPPs with power plants, the long-term investments are profitable to the State and environment, since the country meets its commitments to reduce greenhouse emissions, and the atmospheric pollution is reduced; power plants are also profitable to consumers, since they spend smaller financial resources for electricity and breath cleaner air; they are profitable from business standpoint, since businessmen gain higher profit than from electricity generated by thermal power plants. Our calculations have shown that by long-term investment of 11 000 GEL, consumer can save about 3000 GEL, and greenhouse emissions into environment are reduced by 1,6 t.
2. Development of those non-traditional energy sources, whose resource and quality is hogher.
3. The use of helio-installations equipped with vacuum tubes for hot water supply of public, household, industrial, agricultural and administrative utilities, would be efficient in Georgia. The experiment showed that by

spending 1900 GEL for purchasing a water heater with vacuum tubes, when using the collector, the family saves 11000 GEL from the family budget, and the environment is protected from about 8 tons of greenhouse emissions.

4. To date, wind power plant is much more competitive in comparison with hydro power plant. For installing 1 KW capacity, they need almost the same amount of the investment (WPP - $1690, and HPP - $1616).
5. Calculations have shown that the use of thermal energy of geothermal waters from Zugdidi-Tsaishi wells allows for providing more than 5000 residential houses in Zugdidi with heat and hot water in winter. In the warm period of the year, we will be able to provide more than 26000 families with hot water. The use of thermal energy of geothermal waters in the household sector will allow the population for saving up to 30 mln GEL annually. Also, it will be possible to protect the atmosphere from 1 mln ton of gas emissions every year.
6. In the Imereti region,the use of the thermal pumps for heating glass greenhouses with the area of 400 m^2 and the height of 5 m with electricity, during 3 months in winter, allows for saving more than 10000 GEL, 23000 GEL more than in case of using natural gas for heating, but we protect environment from up to 17 t of greenhouse emissions annually. Taking into account moderate climate of Georgia, the existing large reserves of ground waters and abundance of surface waters, we can safely say that if the purposeful and sound activities are to be carried out in this regard, it will be possible to obtain large amount of cheap, clean energy from the thermal pumps.

Publications made by the author related to dissertation topic:

1. Georgia's power industry in 2005-2012; The Journal of the Akaki Tsereteli State University, No 1, Kutaisi, 2016.
2. The role of heat pump unit in conservation of thermal-energy resources. The Journal of the Akaki Tsereteli State University, No 1 (5), Kutaisi, 2015.
3. Hydrogen – energy resource of the future; Energy: Regional Problems and development Opportunities. Third International Scientific Conference. Kutaisi, 2015.
4. The effectiveness of the use of heat pump unit; energy resource of the future: Energy: Regional Problems and development Opportunities. Second International Scientific Conference. Kutaisi, 2014.