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THERMOELECTRICITY IN TURKEY

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The present paper provides information about Turkey. The high potential of Turkey in the field of solar, geothermal and wind energy and industrial waste heat is shown. The issues of incentives for investments in industry, power engineering, development works, the science of Turkey and new home productions are discussed. A survey of the current state of thermoelectric science and industry in Turkey is made, the prospects of development and all kinds of international cooperation for the progress of these technologies in Turkey are considered.
Key words: Turkey, investments, thermoelectricity, cooperation.

Introduction

Turkey, officially called the Republic of Turkey, mainly in Anatolia, with a smaller portion in Europe, has a territory of total area 783.562 square kilometers. Turkey's location at the crossroads of Europe and Asia makes it a country of significant geostrategic importance.After defeating the occupying countries in the war for independence (1919 – 1922) in 1923, Mustafa Kemal Atatürk proclaimed the Republic of Turkey. Turkey is a democratic, multicultural, secular, unitary, constitutional republic. The majority of population professes Islam. Turkey as a member of the Council of Europe, NATO, the Organization for Economic Cooperation and Development (OECD), the Organization for Security and Cooperation in Europe (OSCE) and the G-20 group has been integrated into the western world. Since 1963 Turkey has been an associate member of European Economic Community, in 1995 joined the EU Customs Union, and in 2005 the European Union started negotiations with Turkey towards full membership in the EU. The country is also a member of the Turkish Council, the International Organization of Turkic Culture, the Organization of Islamic Cooperation and the Organization for Economic Cooperation. Today Turkey with its 80-million population, growing economy and active diplomatic initiatives is a recognized powerful regional state. With the gross domestic product 718,221 billion US dollars (2015), purchasing power parity 1.543 trillion US dollars (2015) and annual growth of gross domestic product 4 %, Turkey is the world's 16th powerful economy. Turkey is the largest Moslem economy in the world followed by Indonesia and Saudi Arabia [1].

The energy potential of Turkey for hydroenergy is 216 billlion kW-h, geothermal energy - 31 500 MW, solar energy -500 Mtoe/year (million tons of oil equivalent), wind energy - 400 billion kW·h, respectively. In other words, according to the value of renewable energy sources, Turkey is in one of the most favourable regions of the world. At present, hydropower with its share of 41 % in total electricity production of Turkey is one of the most widely used renewable energy sources. By 2020 about 90 % of hydropower potential of Turkey is expected to be exploited. On the other hand, today from the geothermal resources in Turkey 20 MW of electric energy is generated. It is planned that in

2020 this value will increase to 1000 MW. In other words, in 2020 1 mln 250 thousand buildings will be heated by geothermal energy. On the other hand, as per the end of 2002 1.8 GW of electricity was produced from wind energy. It is planned that by 2025 7% of demand for electric energy will be covered at the cost of wind energy.

Although Turkey has a big potential in terms of using renewable energy sources, the share of renewable energy sources in total volume of energy production is very low. Nevertheless, biomass energy of renewable energy sources is of great importance due to very high proportion in total volume of energy production. In fact, total energy demand of the country making 77 044 Mtoe/year and annual energy demand in 2010 175 054 Mtoe prove to be lower than the potential of renewable energy sources.

The infrastructures of renewable energy sources in Turkey received the official status in 2005, when the Renewable Energy Law was issued, and for harmonization of actions with the EU there was adopted the National Renewable Energy Action Plan (LEAP) for the period of 2011 – 2020 [2]. According to this plan, by 2023 22 % of electric energy will be produced by hydroelectric power stations of Turkey (but the amount will be much greater due to greater total amount), and 16 % will be produced from other renewable energy sources. According to LEAP, in trasport sector 10 % of energy will be produced from renewable energy sources. According to plan, the energy of wind will increase from 3 GW to 20 GW, and solar energy will increase to 5 GW. In 2013 Turkey exceeded the average world level in energy production from the renewable energy sources. While the average world level was as low as 22 %, in Turkey this figure reached 29 % [3]. By the end of 2015 32.5 % of electric energy in Turkey had been produced from renewable energy sources. In the same year 25.8 % of energy was produced by hydro power plants, 4.4 % from wind energy, 1.3 % from geothermal energy, 0.6 % from biogas and other sources, 0.4 % from solar energy [4].

According to Turkish Wind Atlas (REPA), at the height of 50 meters the Aegean Sea, Marmara Sea and eastern mediterranean regions are regarded as the places with high wind energy potential. For wind velocities over 7 m/s the wind energy potential in Turkey is set at the level of 47.849 MW. Wind electric energy production and its connection to Turkish power grid started in 1998. Since 2005, especially after the adoption of Renewable Energy Law, electric energy production constantly increases and by now global growth rate has been achieved. In Turkey, by the end of 2015 the volume of wind energy production made 11.552 GWh. By the end of 2015 the installed capacity of wind power plants for operation was 4.503 MW [5].

According to Atlas of Solar Energy Potential (GEPA) prepared by Turkish Ministry of Energy, the annual time of sunlight is 2.737 hours (on the average 7.5 hours daily), the annual amount of solar energy is 1.527 kWh/m² (on the average 4.2 kWh/m² daily). In was determined that in 2012 the total installed area of solar collectors was about 18.640.000 square meters. The annual production of flat-plate solar collectors was 1.164.000 m², vacuum tube collectors - 57.600 square meters. 50 % of produced flat-plate collectors and 100 % of vacuum tube collectors were realized in the domestic market of Turkey. In 2012 by means of solar collectors there was produced about 768.000 toe of thermal energy. In the same year from this thermal energy 500.000 toe were used for heating of dwellings, and 268.000 toe – for industrial application. With creation of unlicensed solar power stations, by the end of 2015 electric energy production reached the capacity of 248.8 MW. According to Turkish Ministry of Energy, in 2023 the licensed solar power stations will reach the capacity about 3000 MW. Today for the potential and direct usage of geothermal energy Turkey ranks second in Europe and fifth in the world. By the results of 2005 the potential of geothermal energy production in Turkey, with the annual use 24.839.9TJ/year or power factor 0.5 for 6900.5 GWh/year, was 1495 MW [6].

Investments in Turkey

In the volume and scope of investments, primarily in scientific-technological and innovative implementations, as well as investments in industry, agriculture, defence, science and culture Turkey is one of the leading countries of the world. To attract international and domestic investors to Turkey, the state and government of the country have prepared the legal infrastructure and brought to readiness the government and private sectors of the country. The investment strategy of Turkey is to provide full technological, economic and political independence due to development of local production and creation of new industries. Investments in Turkey are supported by various means. Among them, creation of Free Economic Zones has top priority. According to the latest data of the Ministry of Economy of the Republic of Turkey, in 21 zones about 50.000 companies from hundreds of different countries manufacture various goods and services for the domestic and world market. These companied are provided with the following privileges:

1. Privileged position in the domestic market of Turkey for major manufacturers.
2. Low cost for plots of land and labour force in free trade zone.
3. Free transfer of international revenue and profit.
4. Exemption from tax on profit government tax.
5. Exemption from VAT for tax on profit.
6. Absence of legal restrictions on the foreign trade.
7. The use of any converted currency.
8. Duty-free imported goods.
9. Easy access to Turkish ports.
10. Exemption from taxes on bank operations.
11. No restrictions on the quality of products and prices of goods.
12. Unlimited participation of foreign capital in investments.
13. Provision of ready, modern workplaces with a good infrastructure for production and business.
14. A ban on the strike and lockout.
15. Removal of restrictions on the terms of stay of any product in free trade zone.
16. Granting of privileges to all companies irrespective of their affiliation [7].

At the top of measures by the Ministry of Science, Industry and Technology of Turkey to support investments and local mass production is Teknoyatirim grant for domestic companies. According to the Ministry, in the framework of Teknoyatirim grant the program of investments in high-technology products is funded. This program supports the investments from natural and legal persons of Turkey engaged in research activity, as well as in the introduction of the results of these works in the form of a patent or novel high-technology products. Within the program of investments in high-technology products today the Ministry in 26 provinces has concluded 204 contracts on the projects. 35 projects of them have been successfully completed, and the companies have obtained from the state free of charge 15.256.138.98 TL for the purchase of machines and equipment.

To scientists and postgraduates working on the dissertations including industrial introductions and to companies introducing these new inventions and technologies to local industry, the Ministry lends very big financial support. This grant is called SANTEZ and its budget volume is 500.000TL - 1.000.000TL. Moreover, the Ministry for young businessmen with condition of creation of a new private company for the purpose of realization of a new project according to Teknogirişim program immediately and without compensation grants to a businessman 100.000 TL. Similar programs also exist in the other ministries of Turkey. There is a peculiar competition between different ministries [8].

In Turkey, the greatest support to research activities, the acquisition and implementation of

patents is offered by TÜBITAK. TÜBITAK grants are grouped into six programs. These include grants for scientists or grants for companies that are grouped into two programs: ACADEMIC, including national programs, international programs, programs for guest researchers and other programs, and INDUSTRIAL, including national programs, international partner programs and other programs. Academic national programs are grouped into 11 grants. The terms of these grants vary from 12 to 36 months, and the budget – from 30.000TL to 2.500.000TL. Academic international programs include three grants. Academic programs for guest researchers include two grants. Under these grants, foreign guest researchers receive full medical and other insurances and are paid high salaries. Industrial national programs are grouped into 13 grants. The terms of these grants vary from 12 to 36 months, and the budget - from 500.000TL to 5.000.000TL. Industrial international partner programs are grouped into 2 grants. Moreover, companies engaged in research activities are offered very big tax and other discounts [9].

Thermoelectric research in Turkey

It is fair to say that the basic research in the field of heat pipes and thermoelectricity in Turkey dates back to 1992, when the family of a Turkish scientist Ahiska working on these issues returned to its historical homeland. The first peak of thermoelectric activities in Turkey was election of the first and so far the only Turkish scientist a corresponding member of the International Thermoelectric Academy during the XIII Forum held in 2009 in Kyiv. The first thermoelectric investigations represented as thermoelectric projects in the annual interlyceum project competitions organized by TÜBITAK were a great success in Turkey. The thermoelectric projects of 1992 – 2007 without exception always won the first or second places, and these projects represented Turkey at Science Festivals in the USA or other countries. In 1993, for the first time in Turkey, an international patent was received on medical device for thermoelectric cooling of human brain. Flexible technology of thermoelectric module patented in this medical device is an important event not only for Turkey, but for the whole world. Founded in 1999 at Gazi University, Ankara, the first and only in Turkey research Thermoelectrıc & Heat Pipe Laboratory raised the quality of scientific and technical research in the field of thermoelectricity and heat pipes to the university level. In this laboratory, by 2013 dozens of dissertations had been prepared, hundreds of papers had been published, dozens of projects and patents had been done [10 – 48]. Since 2013 this work continues at Department of Physics of Gazi University. Here, for the first time in Turkey, such lectures as Physics of Thermoelectricity 1 and 2, Physics of Heat-Exchange Systems 1 and 2, Patent Preparation Rules were organized for students, and for post-graduates - such lectures as Theory of Thermoelectric Module and Devices and Bulk and Nano Thermoelectric Materials. Here again was created Thermoelectrıc & Heat Pipe Laboratory. At the cost of state Teknogirişim grant the first and only thermoelectric company TES Ltd was founded in 2010 in Turkey. Thus, the foundations for new industrial branches of thermoelectricity and heat pipes were laid in Turkey. Unfortunately, such extensive and comprehensive studies as performed by Gazi University and company TES Ltd., are very few in Turkey. However, with the onset of state investments in semiconductor and thermoelectric technologies, with every passing day the number of scientists involved in these fields in Turkey increases considerably, as well as the number of projects, published papers and obtained patents. The research geography also expands. Today, besides Gazi University, thermoelectric studies are pursued at Tokat University, Hitit University of Çorum, Istanbul Technical University, Sakarya University, Erdogan University in Rize, Pamukkale University in Denizli and other universities of the country. A number of university and research projects financially

supported by TÜBITAK are implemented and carried out there.

The first project in the field of thermoelectricity that obtained a grant from the Turkish state was TTGV138 project for thermoelectric material preparation and use for creation of medical device Thermohypotherm for cooling of human brain. The project duration was 1993-1995 and its budget - 600.000 $. Although the grant was won, no funding was allocated. Despite this, the Thermohypotherm device was fabricated and received a European patent.

Fig. 1. The first project and patent in the field of thermoelectricity that obtained a grant from the Turkish state. Medical device Thermohypotherm for cooling of human brain.

The first international project of Gazi and Ivano-Frankivsk Universities "New Semiconductor Materials On The Base Of Lead Telluride For Thermoelectric Energy Transformers, 01.05.2010 – 01.05.2012" won a grant from TÜBITAK. The second international Turkish-Ukrainian project was NATO project with a budget of 239.000 EUR "Thermoelectric Materials and Devices for Increasing of Energy Saving and Security", SPS964536, 12.02.2013 – 30.06.2016.

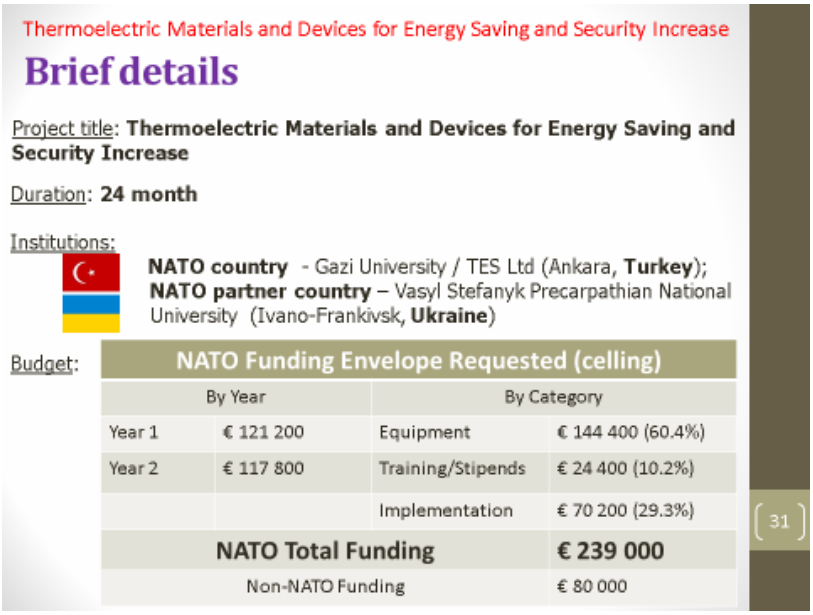

Fig. 2. Turkish-Ukrainian project NATO/SPS964536.

The second big grant from the Turkish Republic allotted for the development of high thermoelectric technologies and heat pipe technologies and products is Teknogirişim grant from the Ministry of Industry for the project "Thermoelectric solar panel" for the amount of 75.000 TL. Thus, in 2010 in Turkey the first and only thermoleectric company TES Ltd. was founded and started to work.

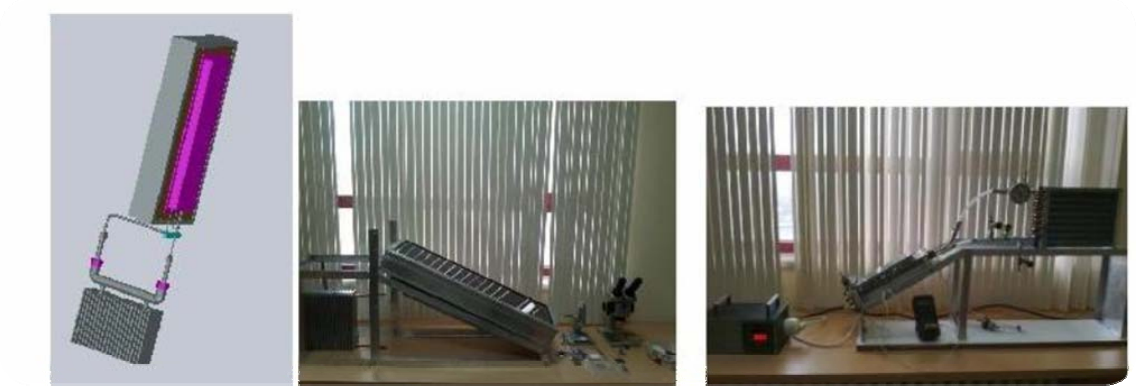

Fig. 3. Thermoelectric solar panel of company TES Ltd created in 2010 with the support of a grant from the Republic of Turkey.

Creation of company TES Ltd marked a new stage in the development of high thermoelectric technologies and heat pipe technologies. Since the beginning of the company activities all the projects have been funded by the state and TES Ltd.

Fig. 4. Company TES Ltd created in 2010 by the grant from the Republic of Turkey.

The first project funded by Ministry of Industry and company TES Ltd. was SANTEZ project "Production and Introduction of Computer-Controlled Thermoelectric Generator, 94.160TL, 2011 – 2012". After its successful completion, the project continues, now in the framework of Teknoyatirim grant, 1.000.000TL, (2015 – 2018).

Fig. 5. SANTEZ and Teknoyatirim Projects funded by the Ministry of Industry (Turkey) and company TES Ltd.

The first project funded by TÜBITAK and company TES Ltd. was "Development of thermoelectric solar panel, thermoelectric material and modules", 880.000TL, 2013 – 2015.

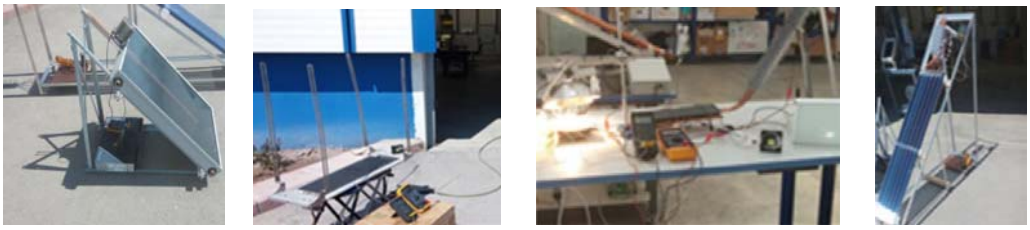

Fig. 6. Joint project of TÜBITAK and company TES Ltd "Development of thermoelectric solar panel, thermoelectric material and modules".

The second project funded by TÜBITAK and company TES Ltd was "Thermoelectric minibar with a heat pipe", 236.000 TL 2015 – 2016.

Fig. 7. Joint project of TÜBITAK and company TES Ltd "Thermoelectric minibar with a heat pipe".

The second project funded by the Ministry of Industry (KOSGEB – Small and Medium Enterprises Development Organization) and company TES Ltd. was "Desktop thermoelectric ice generator, 150.000 TL, 2014 – 2015". According to the results of the project, a patent for ice generator was obtained in 2017, the costs of which were paid by TÜBITAK under the patent grant.

Fig. 8. Joint project of the Ministry of Industry (KOSGEB – Small and Medium Enterprises Development Organization) and company TES Ltd "Desktop thermoelectric ice generator".

Besides the above projects, Gazi University and company TES Ltd continue investigations and works on many projects, such as thermoelectric boiler, thermoelectric solar pump, thermoelectric utilizer of waste heat, transport thermoelectric liquid cooler, thermoelectric CPU cooler with a heat pipe, TEPAS instrument for testing of cooling modules and TEGPAS instrument for testing of generator modules.

Concluding remarks

Turkey, with its millennial statehood, booming economy, young and dynamic population, investiments in all spheres of activity, especially in science, industry and new technologies, location at the crossroads of Europe and Asia giving the country an important geo-strategic advantage is a

powerful country. All state institutions and organizations lend material and moral support to development of science, culture, industry, local production, bilateral and multilateral cooperation that provided the figures bringing Turkey to one of the first places in the world. Such sutuation is observed in all the spheres, as well as in thermoelectric and heat pipes technology. This position is confirmed with growing support in these fields in recent years. Taking into account these realities, for scientists and companies investments in new technologies, such as thermoelectric and heat piles technologies, participation in various joint scientific grants will be a correct and cost-effective decision. Election of a Turkish scientist to the International Thermoelectric Academy and the existence of thermoelctric company are a big benefit for cooperation between the Academy members and Turkey.

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