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РОЛЬ ВОЗОБНОВЛЯЕМЫХ ИСТОЧНИКОВ ЭНЕРГИИ В ОБЕСПЕЧЕНИИ ЭНЕРГЕТИЧЕСКОЙ БЕЗОПАСНОСТИ РЕСПУБЛИКИ АРМЕНИЯ

Аннотация. Цель: *определить роль возобновляемых источников энергии в обеспечении энергетической безопасности в Армении и представить некоторые варианты строительства энергоаккумулирующих мощностей. Методология: проанализировав литературу и Отчет о долгосрочных (до 2036 года) направлениях развития энергетического сектора Армении, а также статистические данные представлены варианты строительства объектов хранения энергии.* ***Результаты:*** *Наблюдается определенный дисбаланс в энергетическом секторе Армении, в частности, объекты атомной энергетики, хотя составляют всего 10% от всех генерирующих мощностей, обеспечили 35,7% генерируемой электроэнергии. Положительный баланс экспорта и импорта электроэнергии свидетельствует об избытке производственных мощностей, однако долгосрочная стабильность работы энергетической системы находится под угрозой из-за устаревших объектов и других факторов. Хотя возобновляемым источникам энергии в рамках национальной стратегии развития энергетического сектора отводится небольшая роль, представленные угрозы энергетической безопасности вынуждают по новому обсуждать возможности расширения роли этих источников энергии в энергетической структуре республики. Армения обладает широким диапазоном и объемами экономически обоснованных возобновляемых ресурсов, эквивалентных установленным мощностям и годовому объему производимой электроэнергии существующих электростанций. Возможности развития гидроаккумулирующих мощностей имеют большой потенциал, особенно учитывая наличие каскадов гидроэлектростанций.* ***Заключение:*** *императивом энергетической безопасности Армении является строительство энергоаккумулирующих мощностей, а не искусственное законодательное ограничение развития солнечной и ветровой энергетики, которое рекомендуется долгосрочной программой развития энергетики. Повышение уровня энергетической самообеспеченности не только обеспечит устойчивость и доступность энергии в будущем, но и значительно укрепит региональные позиции Армении.* ***Практическое значение:*** *Результаты исследования могут быть использованы Министерством энергетических инфраструктур и природных ресурсов при разработке концепции энергетической безопасности и других стратегических документов.*

Ключевые слова: *энергетическая безопасность, самодостаточность, энергетическая зависимость, возобновляемые источники энергии, диверсификация энергии, хранение энергии.*

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THE ROLE OF RENEWABLE ENERGY IN ENSURING ENERGY SECURITY OF THE REPUBLIC OF ARMENIA

Abstract. Purpose: *to identify the role of renewable energy in ensuring energy security in Armenia and provide several options for building energy storage facilities.* ***Methodology:*** *By reviewing*

the literature and the Report on the long-term (up to 2036) development pathways for the Armenian energy sector, and analyzing statistical data options for building energy storage facilities are identified. ***Results:*** *Definite imbalance is observed, in particular, nuclear power generating facilities, although comprise only 10% of the whole generating facilities, have provided 35.7%t of the generated energy. The energy export and import positive highlights the evidence of excess production, meanwhile the arrangement a long-term stable operation of the energy system is at risk owing to obsolete facilities and etc. Although a small role is given to the renewable energy within the scope of the energy sector development national strategy, the presented security threats force to discuss the importance of this source of energy from a new angle. Armenia possesses a wide range and volume of economically feasible resources equivalent to the installed capacity and annual volume of the produced energy of the power plants. The possibilities of development of hydro accumulation facilities have great potential, especially considering the existence of hydro power plants cascades.* ***Conclusion:*** *The imperative of Armenia's energy security is the construction of energy storage facilities rather than artificial legislative restriction of solar and wind energy development, which is recommended by the long-term energy development program. The increase of level of energy self-sufficiency will not only ensure affordable and sustainable energy availability in the future, but will also significantly strengthen Armenia's position in the region.* ***Practical Implication:*** *The findings of the article could be used by the Ministry of Energy Infrastructures and Natural Resources in drafting the energy security concept note, and other strategic papers.*

Keywords: *Energy security, self-sufficiency, energy dependence, renewable energy, energy diversification, energy storage.*

Introduction. Having studied the logic of use of different types of energy over thousands of years, it could be stated that energy, like capital and labor, is as an important factor of progress of production and society (Jefferson, 2015) [5]. Although studies aimed at identifying the relationship between energy consumption and economic growth have yielded different results (Tiba and Omri, 2016) [13], it is obvious that the energy shortage is a limiting variable of economic growth, the supply shocks of which have a negative impact on the size of economic growth. Consequently, energy security and uninterrupted energy supply are essential components of the economic policy of every country.

The literature addressing energy security is quite rich, and the scope of the issues under review is quite wide. Ang and other authors have shown that out of 83 definitions of the energy security, "energy availability" is encountered in 82 (99%), "infrastructure" in 60 (72%), "prices" in 59 (71%), "environment" in 28 (34%), "social impact" in 31 (37%), "management system" in 21 (25%) and "energy efficiency" in 18 definitions (22%) (Ang et al., 2015) [1]. It is obvious that in the public perceptions of the energy security phenomenon energy availability acts as the first association. This is due to the fact that in principle all spheres of social life are directly based on the intensive consumption of energy, in which case the interruption in the energy supply chain can result in unpredictable, even disastrous consequences.

In the countries with insufficient energy resources like the Republic of Armenia is, the energy availability depends on the stability of energy carriers imports chain. Moreover, if in such countries the unavailability of energy is often treated as a possible scenario or theoretical risk, in the early 1990s Armenia faced the tough challenges of that risk, when after the collapse of the Soviet Union it appeared in energy blockade. As a result, in 1992-1996 in the conditions of energy shortage, the population was supplied with electricity for 2 hours per day in average, which caused emigration, large-scale deforestation for heating purposes, and massive residential and industrial property was simply destroyed or demolished due to disruption of operation and maintenance regimes (Sargsyan et al., 2006) [11]. In addition, all the factors that led to the energy and economic blockade of Armenia, including the Nagorno-Karabakh war, still ongoing blockade of Armenia on the part of Azerbaijan and Turkey, existence of internal ethnic problems in Georgia, Russian-Georgian unstable and unpredictable economic and political relations, sanctions imposed against the Islamic Republic of Iran, have not lost their relevance and can be manifested in a new manner at any time.

Due to its geographical position and conflict situation in the region, despite the existence of huge

renewable energy resources, up to now Armenia has had to accept its energy dependency as an unavoidable reality. At the same time, in small economies the solution of energy security and availability issue is inadvertently connected with the national security, political decisions and additional restrictions, in case of which economic expediency is not determined by financial indicators. Any change in the energy sector is able to penetrate into such social and economic dimensions, which are immaterial or insignificant in practice for large economies.

However, in recent years, conditioned by scientific and technological achievements in the area of renewable energy and constant decline in prices of photovoltaic panels and guided by the economic feasibility considerations the increase of energy security level supported by the renewable energy has gained new incentives (Steiner, 2016) [12]. In the conditions of smart technologies the obstacles to the development of renewable energy are mainly removable, although can require significant additional investments.

Findings/Analysis. The main energy generating facilities of the Republic of Armenia include nuclear, hydro and thermal energy generating plants, the total size of which in terms of the country's territory and population is quite impressive. However, in fact there are problems that not only hinder the further development of the system, but also restrict the overall flexibility of the energy system.

2.1 Energy heritage of the Republic of Armenia

After the collapse of the Soviet Union, the Republic of Armenia obtained significant energy generating facilities. Occupying the territory of about 30 thousand square kilometers (the 138th country per classification based on the occupied area) (World Bank, 2016a) [15] and having the population of about 3 million (the 136th country per classification based on population) (World Bank, 2016b) [16], Armenia is one of those 31 countries, which has and operates a nuclear reactor, possess about 2.4 GWh thermal power and 1.3 GWh hydro power installed capacities (Table 1). The existence of such energy generating capacity is primarily due to the concentration of powerful energy-consuming industrial enterprises in Armenia in the USSR times.

Table 1

The RA installed generating capacity per energy types, MW

	2000	2005	2010	2015
Total	**3231.1**	**3208.7**	**3504.5**	**4086.8**
Nuclear	*1799.4*	*1774.5*	*1931.1*	*2390.0*
Thermal	*1024.2*	*1026.7*	*1162.0*	*1286.7*
Hydroelectric power plants	*407.5*	*407.5*	*407.5*	*407.5*
Other sources	-	-	*3.9*	*2.6*

Data source: Statistical Yearbooks of Armenia (National Statistical Service of RA, 2016, 2011, 2006, 2001) [7], [8], [9], [10].

The study of statistical data of energy system of the Republic of Armenia of the last 15 years shows that it was in relatively stable condition. In 2000-2015 the RA energy generating capacity was increased by 26%, and the gross generated energy - by 31% (Table 2). At the same time, the energy export and import balance is always positive, which evidences about the excess production.

Table 2

Energy generated in Armenia, imported and exported energy per types of power plants, mln. kW/h

	2000	**2005**	**2010**	**2015**
Energy generated	5958.6	6316.9	6491.4	7798.2
Energy imported	352	337.6	246	174
Energy exported	814.8	1151.1	1061	1424

Data source: Statistical Yearbooks of Armenia (National Statistical Service of RA, 2016, 2011, 2006, 2001) [7], [8], [9], [10].

One may get the impression that the existence of such diverse energy generating enterprises and installed generating capacity should ensure long-term energy security and availability in Armenia, especially considering the fact that after the collapse of the USSR the majority of the industrial energy consuming enterprises ceased to exist due to disruption of economic relations with other USSR republics and loss of markets. Meanwhile, in the reality, physical deterioration and obsolescence of the existing energy generating facilities and transmission lines, significant losses and general insufficient efficiency, a large share of imported energy carriers, the risk of uninterrupted supply of energy carriers and limited integratedness into regional transmission grid do not allow to arrange a long-term stable operation of the system.

Disproportionate use of energy generating facilities. The data presented in Figures 1 and 2 reveals quite important features. When comparing the share of power plants of different types in the structure of the total energy generated and energy generating facilities, a definite imbalance is observed. In particular, nuclear power generating facilities, although comprise only 10 percent of the whole generating facilities, have provided 35.7 percent of the generated energy. In contrast, though thermal power plants take up 58.5 percent share of the whole generating facilities, they have produced 35.9 percent of the generated energy. Hydro and other power plants have produced the energy equal to their share in the whole generating facilities.

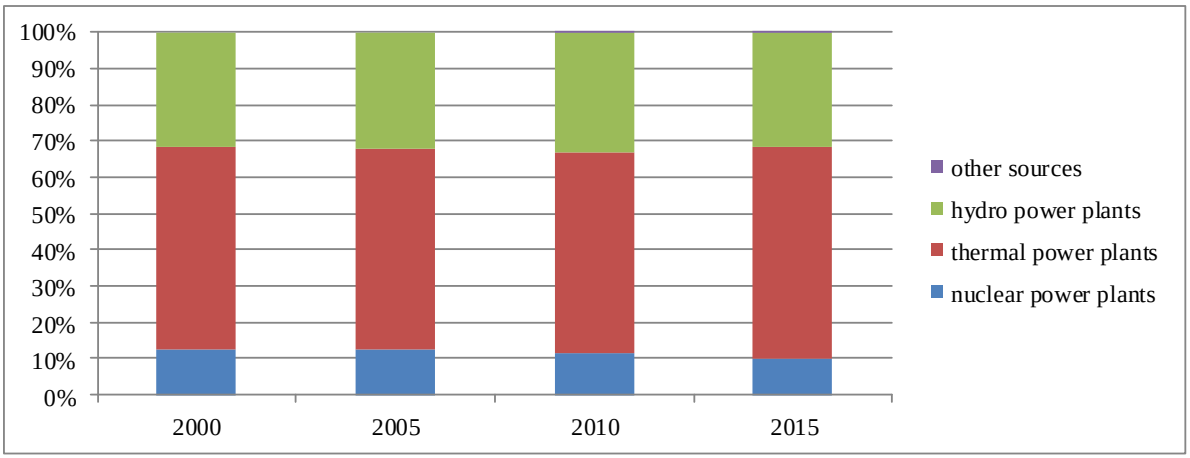

Figure 1. *The structure of the RA installed generating capacity per types of power plants, %*
Data source: Statistical Yearbooks of Armenia (National Statistical Service of RA, 2016, 2011, 2006, 2001) [7], [8], [9], [10]

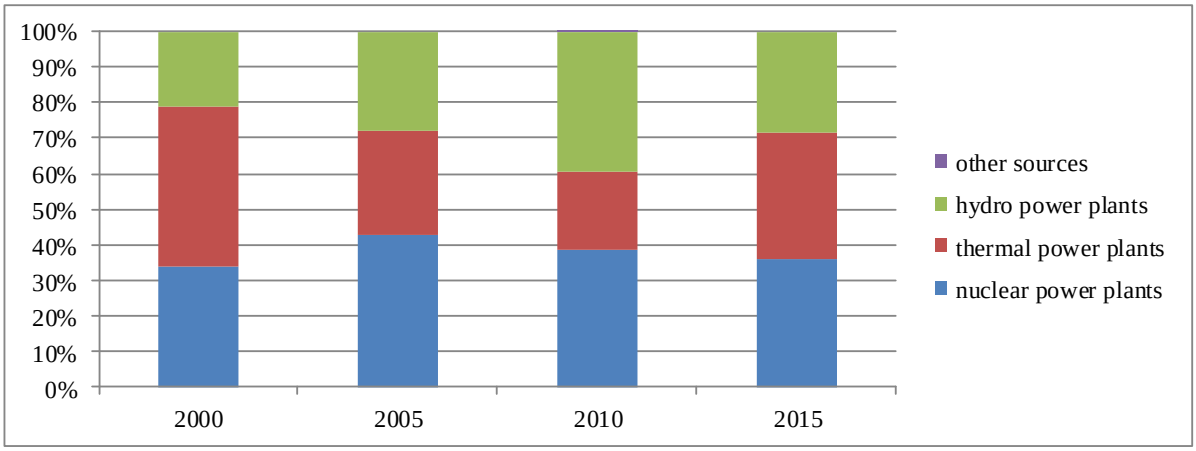

Figure 2. *The structure of the energy generated in Armenia per types of power plants, %*
Data source: Statistical Yearbooks of Armenia (National Statistical Service of RA, 2016, 2011, 2006, 2001) [7], [8], [9], [10]

This observation shows that Armenia does not use the installed capacity of its thermal power plants. Despite the full satisfaction of domestic demand and positive value of net export, it should be stated that in principle there is a potential market for export of energy to Iran, which is not used. Common sense suggests that failure to use this potential should be probably based on objective factors.

Obsolete energy infrastructures and seeming security. The energy system of Armenia is characterized by physical deterioration and obsolescence of logistical base. In spite of a number of large investment projects of recent years, the majority of production facilities are exploited for over 30 years, and in the national energy generation system even 80 year-old facilities exist (Table 3). Similarly, transmission and distribution networks were built in 1960-1980 and despite the modernization undertaken in recent years and carried out on an ongoing basis, they are characterized by a high risk of failure and high indicator of losses.

Table 3

Large energy generating plants of Armenia and exploitation dates

Name	Installed capacity, MW	Year of being put into operation
Armenian Nuclear Power Plant (ANPP)	440	1980 (1989-1995 suspension) 1995
Yerevan Combined-Cycle Thermal Power Plant	272	2010
Hrazdan, units 1-4	810	1972-1974
Hrazdan-5	480	2011
Sevan-Hrazdan Hydro Power Plant Cascade	559	1936-1962
Vorotan Hydro Power Plant Cascade	404	1970-1989

Data source: Long-term (up to 2036) development pathways for the Armenian energy sector (Government of the Republic of Armenia, 2015).[3]

The data presented in Table 3 indicates that units 1-4 of Hrazdan thermal power plant were put into operation in the early 70s of the 20th century. Besides physical deterioration and obsolescence, these units are characterized by low efficiency coefficient and high not competitive cost of the generated energy. Sevan-Hrazdan HPP Cascade is characterized by a greater obsolescence. In addition, its use is limited since its operation is dependent on the amount of water supply from the Lake Sevan, the water abstraction from which is restricted by the law. Comparison of other plants shows that more than a half of Armenia's energy generating facilities (2.2 GW) are obsolete for 30 years and more and are subject to modernization or replacement. The maintenance of current energy generating facilities of Armenia requires major investments, otherwise the energy security will be seriously endangered.

The necessity to modernize the energy generating facilities is beyond of a doubt, however, the selection among nuclear power, thermal power and renewable energy or determination of allocation proportion of the whole facilities has become a subject of serious discussions. Although a small role is given to the renewable energy within the scope of the energy sector development national strategy, the presented security threats force to discuss the importance of this source of energy from a new angle.

Renewable energy potential in Armenia. Almost all countries in the world have quite large resources of renewable energy, the exploitation of which, however, is not always economically feasible. As a result of technologies development and scientific and technological achievements historically economically infeasible source of renewable energy can be turned into beneficial, which is observed in recent years in many directions (International Renewable Energy Agency (IRENA), 2014) [4].

In the context of current prices of fuel and energy resources, Armenia possesses a wide range and volume of economically feasible resources. Data presented in Table 5 shows that depending on different estimates, renewable energy resources with potential capacity of 3800-4300 MW and an annual output capacity of 7.4-8.7 billion kWh are available in Armenia, which is equivalent to the installed capacity and annual volume of the produced energy of the power plants currently operating in Armenia.

Table 4

Potential of renewable energy resources in Armenia by technology types

Technology type	Capacity (MW)	Generation (GWh/year)
Wind	300	650
Industrial solar PV	830-1200	1700-2100
Concentrated solar power	1200	2400
Decentralized solar PV	1300	1800
Geothermal power plant	25-150	200-1100
Landfill gas	2	20
Small HPP	100	340
Biogas	5	30
Biomass	30	230
Total	3800-4300	7400-8700

Data source: Scaling Up Renewable Energy Program (ARREEF, 2014) [2]

Underestimation of renewable energy in the energy sector development national strategy. On 15 December 2015 the RA Ministry of Energy and Natural Resources presented to public the report on the long-term (up to 2036) development pathways for the Armenian energy sector, which was focused on upgrading the physically deteriorated and obsolete infrastructures of the RA energy system at the least cost (Government of the Republic of Armenia, 2015) [3]. Though in the report in general the importance is attached to the development of renewable energy, it should be stated that the policy adopted by the RA government, by giving top priority to the least cost policy, ignores a lot of energy security issues. The report explicitly states that it is necessary to limit the capacity of solar photovoltaic power plants to 70 MW and the capacity of wind power plants to 200 MW, with the expectation that studies of geothermal potential will give positive results and will justify the construction of another geothermal power plant with 30 MW capacity during the period up to 2036.

Such an approach is substantiated by the fact that on the platforms of the studied wind power plants quite great wind instability is observed, which is case of a large capacity can cause regulatory problems in the system. At the same time, the use of solar power network stations requires the availability of equivalent facilities in the system, which are intended to be used in very cloudy weather and at night, especially because of the short duration of the solar day in winter season. Therefore, the integration of large-scale network energy facilities into the energy system will significantly change the structure of the energy generation and will strictly require the availability of equivalent reserve capacity in the traditional resource-generating plants, in which case additional investments are required.

However, the least cost policy is developed based on several controversial provisions, the failure of execution of which will lead to the system collapse. In the stated document, in the discussions of energy sector development the energy export is emphasized. The objective is set to further develop the existing capacities and at least double the generated energy to 15 billion kW/h annually, the 30% of which should be exported by targeting Iran Islamic Republic as a potential market, which currently has an electricity deficit (export of energy to other neighboring countries in foreseeable future can be disregarded: Georgia is already self-sufficient with much cheaper hydro resources, and the relations with other neighboring countries are frozen). Both construction of new energy generating plants and their service will be included in the tariff. However, here is overlooked the question of what would happen if such generating facilities are built, but the export potential is remained unused. The answer is quite simple: fixed costs will be reallocated to the amount of the energy consumed, resulting in the tariff increase. Moreover, in the conditions of further development of energy-saving technologies, the issue of preservation or growth of current trends in increase of energy consumption rates in the domestic market is questionable. Tariff growth in the second stage of influence will lead to the reduction in consumption and decline in the product competitiveness, which will again give rise to the need to revise the tariff. Therefore, the scenario of development of export-oriented energy generating facilities in the absence of long-term contracts and purchase guarantees is not only a dan-

gerous trap, but also a threat to the economic security of the country.

It should be stated that as a matter of fact in the document are not discussed the risks of disruptions of operation of currently used energy resources supply chain, changes in market conjuncture and appearance of new market players. Moreover, considering regional developments, imposition of new economic sanctions on Russia and Iran and extension of the effective ones, it is wrong to focus only on these countries, having disregarded the national energy security issues. Without underestimating the economic component, we should agree that more attention should be given to the removal of barriers to a wider use of renewable sources.

The necessity to develop energy storage facilities. Barriers to large-scale use of renewable energy are inherent in almost all countries. Disproportionate load of wind power plants, daily and seasonal capacity variations of solar power plants are inseparable attributes of these sources of energy, which does not prevent their successful development in many countries (Verbruggen et al., 2010) [14]. However, if in large economies, especially in those covering several time zones, the use of unified network of renewable energy greatly contributes to mitigation of fluctuations in the generated energy, the use of such method in small economies is associated with additional difficulties.

The next option of solution is a close integration of national networks into regional networks, which makes it possible to reduce energy generation variations by counter supply. In case of Armenia, the application of this instrument has some prospects if we consider the projects launched for the construction of new transmission lines with neighboring countries.

In terms of security of Armenia energy system the availability of energy storage facilities is of importance, which, as such, do not exist at present. The most advanced methods of energy storage have been discussed in many studies. Among them are hydro accumulation, thermal energy storage, chemical method, etc. (Kousksou et al., 2014) [6].

In Armenia, given the mountain terrain, possibilities of development of hydro accumulation facilities have great potential, especially considering the existence of hydro power plants cascades. Unfortunately, in the long-term strategy for energy sector development in Armenia no room is allocated for discussion of energy storage possibilities. The energy storage facilities of appropriate size will provide new possibilities for development of renewable energy by applying all the instruments of the state policy of the sector development.

Conclusion. In parallel to the growth of energy consumption volumes and increase of dependence of different areas of public life on energy, the energy availability and security issues are becoming more vital throughout the world. Energy self-sufficiency is an ultimate goal of the energy security for every country, and integratedness of regional energy hubs is a guarantee of energy policy flexibility.

The Republic of Armenia, in contrast to being rich in metal and non-metal raw materials, does not possess economically significant approved fuel and energy resources. Certain uranium reserves have been discovered on the territory of the Republic of Armenia, which, however, have no economic significance. Eventually, Armenia has to meet the whole energy demand at the expense of imports.

Calculations show that 68.5% of the existing energy generating facilities operate, and 71.6% of the generated energy has been produced by the imported natural gas and nuclear fuel. At the same time, if natural gas is imported from two sources, i.e. Russia and Iran, nuclear fuel can be imported only from Russia. Iran-Armenia gas pipeline is small in diameter, and natural gas imported by it is supplied under “energy in exchange for gas” non-commercial scheme, thus it can be concluded that Armenia is in strong energy dependence on Russia. Moreover, since Armenia has no immediate border with Russia, this dependence is also accompanied by a risk of worsening relations with a third country (Georgia). Availability of energy generating facilities in Armenia, in case of disruption in the supply of imported energy carriers loses its potential, which is a serious threat to the energy security.

The imperative of Armenia’s energy security is the construction of energy storage facilities rather than artificial legislative restriction of solar and wind energy development, which is recommended by the long-term energy development program. The increase of level of energy self-sufficiency will not only ensure affordable and sustainable energy availability in the future, but will also significantly strengthen Armenia’s position in the negotiations with those countries or regional unions on which Armenia is energy dependent.

Practical Implication. The findings of the article could be used by the Ministry of Energy Infrastructures and Natural Resources in drafting the energy security concept note, and etc.

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