LUMES
Lund University International Master's
Programme in Environmental Science

Master thesis

Sustainable Development and Energy Security in Armenia: a Step Towards Dilemma

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Lund 2003

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Abbreviations, acronyms, units

MoE	Ministry of Energy
MoNP	Ministry of Nature Protection
RA	Republic of Armenia
EC	European Commission
CCGT	closed-cycle gas turbines
ES	energy security
SD	sustainable development
HFO	heavy fuel oil
LPG	liquefied petroleum gas
NPP	nuclear power plant
TPP	thermal power plant
HPP	hydro power plant
Mill	million
CO_2	carbon dioxide
Gt	giga ton
KW	kilo watt
MW	mega watt
PJ	peta joule
Km	kilometer
KV	kilo volt
T	ton
Cub. M	cubic meter
GWh	giga watt hour
Bcm	billion cubic meter

Acknowledgements

I would like to express my deep gratitude to people whose invaluable help and support made this paper possible. My special thanks to my supervisor, Professor Dean Abrahamson, for his guidance and patience throughout my work; Armenian officials who were my interviewees and kindly provided me with up-to-date information and fresh ideas; my friends Gregor Sieboeck and Mike Ward, who supported me and gave helpful comments; my wife Sara for her endless patience and support.

I want to express my sincere gratitude to LUMES staff that provided me with the opportunity to study in Lund University, and the Swedish Institute which made my study and the present thesis possible, as well as supported my field trip to Armenia.

Summary

Armenia, one of the newly independent states that were formed after the Soviet Union dissolution in 1991 has passed onto a next stage of its development. The transition period for Armenia started with the 1988 earthquake, economic decline, conflict eruption with neighbouring Azerbaijan over Nagorno Karabakh which created refugees as well as economic and fuel blockade from the side of Azerbaijan and Turkey. The next step for Armenia is to move its development towards sustainability the main ways for which lie within restoration of its economics, improving the social conditions of its population, and preservation of its environment.

The consequence of the mentioned blockade in Armenia was the loss of energy security and the following energy crisis which resulted in re-opening the Armenian Nuclear Power Plant which was closed after the earthquake for safety reasons. The re-opening of this plant allowed softening the economic decline, improving social conditions. It also promoted the suspending of environmental degradation by drainage of the lake Sevan for hydropower and chopping of the forestry for firewood. The power plant has no long perspectives as a result of a pressure from numerous actors, both local and global, on Armenia with the demand of its decommissioning, which Armenia has already set for 2004. Even in case of its possible closure delay, which is predicted if take into consideration the absence of any other alternatives, it will nevertheless be closed after wasting its resources.

Armenia now faces the problem of organizing its energy policy, the main aim of which is creating an alternative for the power plant closure as well as preservation of its energy security. There are also attempts made to re-blockade its communications. This all presents a serious challenge for Armenia, taking into consideration its economic and natural conditions, as well as the geopolitical situation in the Transcaucasia region. At present there exist two scenarios for energy system development in Armenia. Both scenarios presuppose the restoration and development of the present sources of energy such as hydro power, and implementation of new energy generation facilities like geo thermal and wind ones. The first scenario suggests the thermal power development, and the second one recommends the implementation of a new nuclear cycle together with thermal power.

The numerous investigations done in Armenia have shown that the domestic sources of energy are limited. Accordingly the energy development will likely be based on one of the two scenarios in the very near term. The choice between the scenarios will depend on their correspondence to energy security, environmental impact and accessibility. Both scenarios have positive as well as negative sides that are analysed in details in the paper, including all the factors mentioned above.

1. Introduction

Energy plays an important role in all dimensions of sustainable development, such as social, economic and environmental. The energy services like electricity for households and industry, heating, cooling and light, provided by energy are essential for supporting the key aspects of development. These energy services require secure energy supply, i.e. elaboration of electric power and heat, and secure provision of energy carriers which then will be transformed by means of electricity and heat. All the actions that provide secure energy are called 'energy security', and the breach of it can lead to energy crisis which can be described as violations of key factors of state livelihood that are dependent on energy provision. It can play a negative role in the development and peace preservation.

Armenia passed through an energy crisis in 1991-1995 in the result of its energy security loss what was the consequence of a conflict with neighbouring Azerbaijan and following economic and fuel embargo by Azerbaijan and Turkey, as well as low self-sufficiency by Armenia's own energy resources. This has caused an economic decline, environmental disruptions, and decrease of live quality which resulted in emigration of 20% of the population. In order to overcome the created situation, the re-opening of the Armenian Nuclear Power Plant, which was decommissioned after the 1988 earthquake, was necessary. Nowadays this plant provides about 40-45% of required energy in Armenia. However, the re-opening of the plant has evoked a negative reaction among both the neighbouring countries such as Azerbaijan, Turkey and Georgia, and the EU and the USA. The protest was mainly based on the assumption that the plant was located in the seismically active zone, as well as on the presence of numerous conflicts in the region, which could be the cause of sabotage, and Armenia's inability to maintain safety measures of the plant. The outcome of the protests resulted in Armenia having to enter negotiations with the EU and set the closure of the plant for 2004 in case of an alternative source of energy. The suggestion supported by the EU was the replacement of the nuclear power plant by new thermal and hydro facilities and construction of a pipeline from Iran to Armenia which will decrease Armenian dependence from Russian gas. This will, however, increase Armenian dependence from imported gas for 90%. The present geopolitical situation with numerous unresolved conflicts and a growing tension among countries of the region which are being divided into different blocks can lead to another energy crisis in case of re-emergence of any of the conflicts. Anyway, Armenia considers two scenarios for development of its energy sector. Both of them consist of development of its domestic renewable sources of energy, and, in the first case – of the development of thermal power, and in the second one – of the development of the nuclear cycle, what is not supported by the EU.

This paper aims to analyze both of the scenarios in order to find which of them is more appropriate for Armenia, taking into consideration its geopolitical environment, soundness with sustainable development and availability.

The goal of the investigation is not a quantitative analysis but a qualitative evaluation of both scenarios based on bibliographical review of possibly updated information from books, reports, articles, newspaper articles, as well as interviews with Armenian officials. The first part of the investigation presents the concept of sustainable development, energy in relation to sustainable development and the issue of energy security with possible consequences of the loss of energy security in Armenian context. The investigation proceeds with general information about Armenia and its energy sector, as well as analyzes obstacles and risk factors including geopolitical environment and its effect on energy security of Armenia, which can hinder its development. The investigation's main focus is directed on the two scenarios, i.e. gas and nuclear section, and their ability to satisfy the energy security goals.

2. Country background

Armenia is a small, landlocked, mountainous country, situated in the southern part of the Caucasus region, which is on the north-eastern part of the so called Armenian Plateau and borders with Georgia, Azerbaijan, Turkey and Iran (see Fig.1). The smallest republic of the former USSR, Armenia covers an area of 29,800 km² and has a population of 3.7 million, over 96 percent of which is ethnic Armenian.

Figure 1. Armenia, Transcaucasian Region
Source: Environmental Research and Management Centre, American University in Armenia

After the collapse of the USSR it became an independent democratic state with presidential governance and market economy. Under the old Soviet central planning system, Armenia had developed a modern industrial sector, intensive agriculture and extended social infrastructure[1]. According to the GDP production per capita Armenia was in the number of countries like Greece, Portugal, and Former Socialistic countries in Eastern Europe[2].

The transition towards market economy is marked with deep economic decline in Armenia as well as in other post-Soviet countries. The situation in Armenia is worsened by a number of factors connected with the specificity of its economic structure with a low provision of its primary resources (18%) such as energy carriers, raw materials; high integration of Armenia into national economic complex of the Soviet Union and a weak

[1] World Fact Book, *Armenia - Country Profile*, 2002, http://www.cia.gov/cia/publications/factbook/geos/am.html, accessed on 15-Nov-2002

[2] UNDP/Ministry of Natural Protection of RA, GEF Project Implemented By UNDP, *First National Communication of The Republic of Armenia Under the United Nations Framework Convention on Climate Change,* October 1998, Yerevan, Armenia, chapter 2, pp. 3-12

local market. The economic decline was also influenced by the 1988 earthquake with 25.000 deaths and 14 bill.$ of damage[3]; the conflict with Azerbaijan over Nagorno Karabakh, an Armenian dominated enclave within Azerbaijan; the presence of 900,000 refugees from the disaster zone and as the consequence of the conflict; an economic and fuel embargo from Azerbaijan and Turkey, as well as the following energy crisis, which, together with the closure of the Armenian Nuclear Power Plant (ANPP) worsened both the social-economic and ecological state of the republic.

The economic recovery started in 1994, after the government introduced a tighter fiscal policy, which had become possible since the cease-fire, and started an IMF stabilisation programme, after which Armenia achieved one of the highest GDP growth rates among CIS countries, which in 2001 amounted to 9.6%[4], and in 2002 – 12.5%[5]. The restarting of ANPP in 1995 also allowed overcoming the energy crisis in Armenia. Table 1 presents some common natural and socio-economic characteristics of Armenia.

Table 1. Natural and Socio-Economic Characteristics of Armenia

Natural Characteristics*	Total area *thousand ha,* including:						2974.3	
	Agricultural lands / Water surface / Land occupied by buildings, roads and purlin / Other lands						1391.4/164.0/ 85.0 / 979.2	
	Total area of eroded lands and lands exposed to erosion						1225.0	
	Average height of territory / highest / lowest m.						1830 / 4090 / 350	
	Climate - semiarid continental, including:							
	Average high temperature / absolute maximum +°C						10-26 / 45	
	Average low temperature / absolute maximum - °C						1-13 / 40	
Socio – Economic Characteristics	Population (excluding 750000 emigrants) million						3.8	
	Age structure % (2002 est.)							
	0-14 years / 15-64 years / 65 years and over						22.2 / 67.7 / 10.1	
	Rate of natural increase %						0.1	
	Annual rate of growth %						-0.3	
	Life Expectancy (2000)						73.2	
	Infant mortality *(per 1,000 live births)*						15	
	Population density per km²						127 people	
	Urban Population % (1999)						70	
	Access to safe water %						93	
	Access to sanitation %						67	
	Poverty *(% of population below national poverty line)*						51	
	Adult Literacy Rate %						99	
	Human Development Index (HDI) Rank (1999) **						72	
	Official unemployment % (2000) ***						11.7	
	Labour force %						-1.9	
	Real GDP growth rate % (2000)						6.0	
	Years	1990	1994	1995	1997	1998	1999	2000
	GDP *million US$*	8770	651.4	1250	1637	1892	1844	2000

[3] WHO, Press Release *Experts Meet in Kobe to Discuss Earthquakes and Health,* 24 January, 1997, available online http://www.who.int/archives/inf-pr-1997/en/pr97-08.html, accessed on 25-Oct-2002

[4] The World Bank Group Data, http://lnweb18.worldbank.org/eca/armenia.nsf, accessed on 14-Oct-2002

[5] AZG Armenian Daily, Interview with Minister of Finance and Economy of RA, # 015, 28/01/2003, http://www.azg.am/_RU/20030128/2003012813.shtml, accessed on 28-Jan-2003

	The structure of GDP %							
	Industry	44	29.1	24.3	22.5	20.4	21.0	21.5
	Agriculture	13	45.3	38.7	29.4	29.8	26.2	22
	Construction	18	6.7	8.5	8.1	8.5	9.0	
	Services	25	17.6	24.8	32	32.1	35,2	56.5
	Net indirect taxes		3.1	3.7	8	9.2	8.6	
	GNP per capita *US$*	2370	174	348	432	500	485	503.3
	Inflation %		5000		14.0	8.7	0.7	- 0.8
	External debt stock : *million US$*		130.3					840.4

* The data of 1995; ** In 1991 the same indicator was 48; *** Number of unemployed registered officially in the Labour and Employment Service in % over economically active population. Together with shadow unemployment amounted to 28%

Sources: Armenian Statistic Service; World Development Report 2000/2001; Human Development Report 2001,World Fact Book 2002, Transition Report 2000 (EBRD); IMF World Economic Outlook (May 2001); World Bank Report website, Interim Poverty Reduction Strategy Paper (2001); U.S. Bureau of the Census, Summary Demographic Data for Armenia, (2002).

Armenia, as any other transit economy, strives towards Sustainable Development (SD), at the same time having a task of solving problems connected with Energy Security (ES), geopolitical stability in the frames of national security, sustainable economic growth and environmental security.

3. Sustainable Development and Energy

Sustainable Development was broadly defined by John Holdren in the "Meaning of Sustainability: Biophysical Aspects" as "maintaining or improving the integrity of the life support system of Earth. Sustaining the biosphere with adequate provisions for maximizing future options includes enabling current and future generations to achieve economic and social improvement within a framework of cultural diversity while maintaining (a) biological diversity and (b) the biogeochemical integrity of the biosphere by means of conservation and proper use of air, water, and land resources." [6]

The second definition mentioned here was formulated in 2002 by the Nongovernmental Sector of National Council of Sustainable Development of the Republic of Armenia, which was found in 2001 on the base of Association "For Sustainable Human Development", with Geographic and Botanic Societies of Armenia, Republican Women Council and other NGOs, representatives from Scientific-Research Institutes and Universities, mass-media and business sector. According to this definition "Sustainable Development is a development, which guarantees adequate, possibly equal starting conditions for the representatives of the present and future generations for displaying their abilities and satisfying living needs. SD is based on economics, which is combined with the principles of environmental security and social justice in democratic society with respect of human rights". Thus the concepts like 'starting conditions', 'environmental

[6] Holdren, J.P.;Daily, G.C.;Ehrlich, P.R., The Meaning of Sustainability: Biogeophysical Aspects, 1995, Edited by Munasinghe, M. and Shearer, W., Distributed for the United Nations University by The World Bank Washington, D.C.

security', and 'human rights' presuppose the principles of preservation of both biological, landscape and ethno-cultural diversity[7].

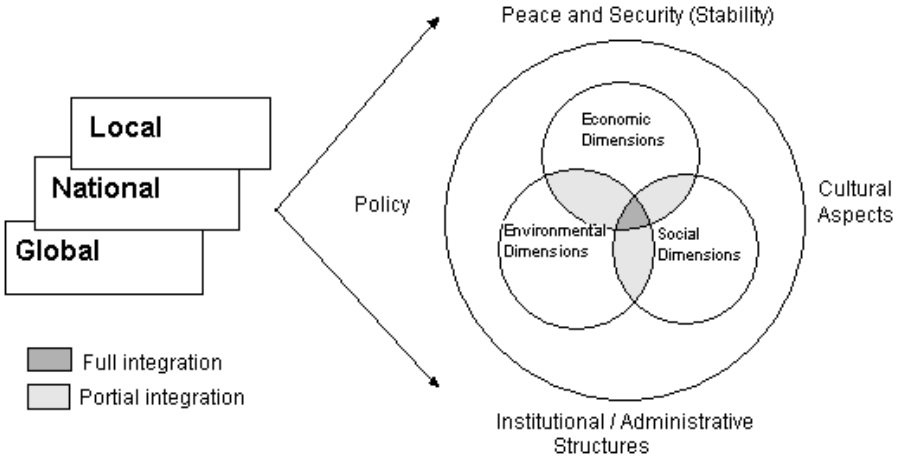

Figure 2. The system of Sustainable Development

Source: "Concept of Sustainable Development of the Republic of Armenia" by Association "For sustainable Human Development"/National Comity of UNEP RA / Nongovernmental Sector of National Council of Sustainable Development of the Republic of Armenia

Summing up the above mentioned, SD is defined with respects to three aspects: *natural sustainability, social sustainability and economic sustainability*[8]. Figure 2 shows the combinations of these constituents.

A 2001 report of the OECD's project on sustainable development describes these three dimensions as follows: [9]

1. Economic sustainability encompasses the requirements for strong and *durable economic growth,* such as preserving financial stability and a low and stable inflationary environment.
2. Environmental sustainability focuses on the stability of biological and physical systems and on preserving access to a healthy environment.
3. Social sustainability emphasizes the importance of well functioning labour markets and high employment, of adaptability to major demographic changes, of stability in social and cultural systems, of equity and of democratic participation in decision making.

SD leads to integrations of dimensions where it is possible and compromises between the dimensions where integration is impossible[10].

Finally, it is well known that only in the presence of such integral conditions like *peace*[11] *and existence of energy*, SD can be achievable.

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[7] Association "For sustainable Human Development"/National Comity of UNEP RA/ Nongovernmental Sector of National Council of Sustainable Development of the Republic of Armenia, *Concept of Sustainable Development of the Republic of Armenia*, 2002, Yerevan, Armenia

[8] Sverdrup, H.; Svensson, M., *Defining the Concept of Sustainability*, January 21, 2001, Lund, Sweden, p.3

[9] OECD, *Analytic Report on Sustainable Development*, 2001 Chapter 2, Key Features and Principles, p. 4.

[10] Association "For sustainable Human Development", 2002

[11] The Principle 25 of Rio Declaration on Environment and Development (*The United Nations Conference on Environment and Development, Rio de Janeiro, 1992*) read as follows "Peace, development and

Energy has deep and broad relations with each of the three pillars of SD: the economy, the environment and social welfare. SD requires a supply of energy resources that, in long term, are ready and sustainable, available at reasonable cost and can be utilized for all required tasks without causing negative social impacts.[12] Another implication is that energy resources must be used as efficiently as possible[13].

Energy, in itself, is of little interest but the energy services are a fundamental ingredient for socio-economic development and economic growth. It remains as a strategic commodity: it is a source of power, heat and mobility which is indispensable for normal functioning of any modern society as well as it is a critical production factor in virtually all actors of industry.[14] The provision of adequate and affordable energy services, in a secure and environmentally benign manner, and in conformity with social and economic developmental needs, is an essential element of SD. [15]

Globally, the demand for energy is increasing in consonance with socio-economic development. At the same time, the production and use of energy can cause environmental degradation - local, regional and global. Thus, in spite of fact, that economic growth requires a secure and reliable energy supply, it is sustainable only if it does not threaten the environment or social welfare. Environmental quality is more readily protected if basic economic needs are also met, for example maintaining and improving environmental quality along with economic growth involves improving energy efficiency and switching to environmentally less harmful fuels, such as renewable energies, and on another hand social development needs both economic growth and a healthy environment. [16]

3.1 Energy Security – security for Sustainable Development

A key element in any sustainable energy system must be that it is robust and can continue to provide the power regardless of changed circumstances. Clearly, whatever the energy system, it is important to have a secure energy supply[17].
Concerns over ES have probably reached their peak during the 1970s when the world economy struggled to overcome the damaging effects of the oil crises of 1973-74 and

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environmental protection are interdependent and indivisible", which was the base for the *Statement on Peace and Sustainable Development for the Johannesburg World Summit in 2002,* where mentioned that "Peace is a prerequisite and component of sustainable development, and for a sustainable society that solves fundamental global social and ecological problems and strives for worldwide justice."

[12] Rosen, M.A.; Dincer, I., *A worldwide perspective on energy, environment and sustainable development,* International Journal of Energy Research [Int. J. Energy Res.], vol. 22, no. 15, pp. 1305-1321, Dec 1998

[13] MacRae, K.M., *Realizing the Benefits of Community Integrated Energy Systems,* 1992, Canadian Energy Research Institute, Calgary, Alberta.

[14] Bielecki, J., *Energy security: is the wolf at the door*?, The Quarterly Review of Economics and Finance 42 (2002) pp. 235–250

[15] UN, Economic and Social Council, Committee on Sustainable Energy, *Indicators for Sustainable Energy Development: A Collaborative Project,* Eleventh session, 21-22 November 2001, pp. 2,3

[16] International Energy Agency, *Highlights Toward a Sustainable Energy Future, Statement on Sustainable Development*, 2001, OECD/IEA, Paris, pp. 72-76

[17] Elliot, D., *Energy, Society and Environment,* 1997, London and New York: Routledge pp. 119-127

1979-80. These were triggered by inflation, which ultimately led to economic recessions involving substantial losses of Gross Domestic Product (GDP) and high unemployment.

ES is a broad concept embracing all energy sources. Bielecki, J defines the concept of ES as "reliable and adequate supply of energy at reasonable prices." The meaning of reliable and adequate supply is rather basic: it simply means uninterrupted supply that fully meets the needs of the economy. Furthermore, the concept may have many different dimensions, ranging from political and military to technical and economic. [18]
In the 2002 report of the UN's "Re-evaluation of the Energy security Problems in the Light of Recent Changes" the concept of ES includes three following aspects: [19]

- physical disruptions of supplies in the result of infrastructure fails, natural disasters, social instabilities, political actions and terrorist acts;
- negative impact of energy deficit on economic activity and social status;
- direct and indirect damage, caused by acts of terrorism, leading to human victims and considerable harmful consequences for health and environment.

Interruptions of energy supply - even if brief - can cause serious financial economic and social losses [20] and large-scale risk in the energy sector can lead to irreversible effects that would constrain the economic, social and environmental options of future generations.[21]
According to 2001 *National Energy Security Act* of The Congress of USA "Increasing dependence on foreign sources of energy row materials causes systemic harm to all sectors of the State [United States] economy, threatens national security, undermines the ability of federal, state, and local units of government to provide essential services, and jeopardizes the peace, security, and welfare of the people in country."[22] Morse and Jaffe summarizing that loosing of energy security would dramatically affect the state national security and foreign policy.[23]

From the above-mentioned it is clear, that the absolute security of energy supply therefore is crucial. It is also important to note that establishment of international relations and economic cooperation can promote ES as well peace preservation. Thus, for summarizing, the IEA's statement of sustainable development will be mentioned that "*there can be no sustainable development without a secure energy supply to underpin essential economic activity and provide services to society*"[24]

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[18] Bielecki, J., *Energy security: is the wolf at the door*?, The Quarterly Review of Economics and Finance 42 (2002) pp. 235–250
[19] UN, Economic and Social Council, Committee on Sustainable Energy, Re-evaluation of the Energy security Problems in the Light of Recent Changes, Session 12, November 20-21, 2002, pp. 2-6
[20] UNDP, World Energy Assessment, *Energy and the Challenge of Sustainability*, 2000, pp. 113-130
[21] IEA, *Highlights Toward a Sustainable Energy Future, Statement on Sustainable Development*, 2001, OECD/IEA, Paris, pp. 11-14
[22] Congress of USA, *National Energy Security Act of 2001, http://www.senate.gov/~murkowski/pdfs/NatEnergySecurityAct.pdf,* accessed on 25-Sep-2002
[23] Morse,E. L.,Jaffe, A.M., *Strategic Energy Policy Challenges for the 21st Century,*2001 Report of an Independent Task Force, James A. Baker III Institute for Public Policy of Rice University and the Council on Foreign Relations
[24] International Energy Agency , *Towards Solutions, Sustainable Development in the Energy Sector,* 2002, OSCD/IEA Paris, France

A many scientific works are dedicated to the concept of energy security and majority of authors mention the following roots to enhance it in the short- and long-term prospectus:[25]

- the ability to draw on foreign energy resources and products that can be freely imported through ports or other transport channels and through cross-boundary energy grids (pipelines and electricity network)
- the mix of energy that should be selected, targeted or encouraged, to meet the country's long-term concerns regarding energy supply and consumption
- the level of fuel stocks, particularly strategic petroleum reserves, that should be maintained to respond optimally to possible supply disruptions
- the new energy technologies that should be pursued, supported or promoted, to ensure efficient, sound and safe energy supply
- improvement of energy efficiency
- interregional cooperation and joint actions
- adequate attention to environment, health and safety
- promotion of the local (national) supplies establishment

The data mentioned above could be applied for national energy policy for any country. In the next chapter the concepts of SD and ES with regard to Armenia will be discussed.

3.2 Energy Security of Armenia: an obstacle or an opportunity for Sustainable Development?

In 1991-1995 Armenia went through a deep energy crisis and tested in practice the results of loss of its ES with all consequences, affecting social, economical and environmental spheres of the country, which will be discussed later in the paper. The crises had an influence on the psychology of Armenian people and its leaders and pushed their efforts to preserve Armenia from another energy crisis[26]. The deputy energy minister Areg Galstyan admits, "Armenia is one of the few countries in the world to know what it means to lose its energy security"[27].

The crisis showed how vulnerable Armenia is with its ES.The government of Armenia considers country's energy sector as a driving force in rapidly restoring the whole national economy, that is why the development of energy sector as well as ES issues are one of the priorities in the state policy.
As defined by Dr. Levon Yegiazaryan, the general director of the Institute of Energy in Armenia, the "Energy Security, or an ability for the reliable energy supplying of all requirements of a person, society and country under stable development as well as

[25] For example see Hossein, R., Economic*, Security and Environmental Aspects of Energy Supply: A Conceptual Framework for Strategic Analysis of Fossil Fuels*, 1997, World Bank; UNDP, *World Energy Assessment, Energy and the Challenge of Sustainability*, 2000; International Energy Agency , *Towards Solutions, Sustainable Development in the Energy Sector*, 2002, OSCD/IEA Paris, France

[26] Anex, R.P., *The Armenian Energy Sector: Power and Politics,* To appear in a report of the United States National Academy of Sciences: "Energy Issues in Armenia", 1999, http://www.ou.edu/spp/people/armeniapower.pdf , available on line accessed on 08-Des-2002

[27] A citation of Areg Galstyan used by Fred Pearce in the *Power Vacuum,*2001, Leadership for Environment and Development (LEAD) International, Annual Review 2001

extreme conditions, give the specific role for the fuel-energy complex in insuring the ES which deemed as principle of sufficiency of material resources for survival and development of the society. In its turn economical security in line with social, political, defence, ecological and other types of safety coming as a basis for National Security".[28] According to him, Armenia today can satisfy its own needs of energy, however after the closure of the ANPP a problem of energy deficit will arise together with the risk of ES in Armenia. So he defines the following dimensions, insuring the ES for Armenia:

1. Three-level energy diversification policy:
   - Generation side – hydro, thermal, nuclear, wind etc. power plants
   - Fuel supply side - natural gas, oil, nuclear fuel
   - Fuel transportation side - gas pipelines, oil product delivery
2. priority development of domestic energy resources, including fuel resource exploration, energy conservation and renewable energy utilization,
3. regional co-operation.

On the other hand, Ruben Muradyan, the director of Energy Strategy Centre, sees some specific factors which can be obstacles and must be considered for the development of energy strategy policy:[29]

- Armenia does not possess its own domestic fuel resources
- High level of deterioration of equipment in the energy sector as well as of the consumers cannot ensure the realization of wide-scale energy saving programs without large capital investments
- The gas supply of Armenia via the only operating gas pipeline is deemed as a factor of political, technical and economical risk
- As an emergency measure during the crisis a decision on utilization of water resources of Lake Sevan for energy purposes has been taken. The problem of protection of Lake Sevan is not only within the interests of the Republic of Armenia but also acquired the status of a problem of global changes of climate
- The issues of development of own energy resources, including exploration of domestic industrial reserves of fuel and utilization of renewable energy sources are in the initial stage and require large-scale investments

Summing up Chapter 3, it can be concluded, that energy has an essential role for development in Armenia, however there can be found obstacles, the main of which is the vulnerability of energy security. The next chapters will thoroughly analyze the Armenian energy system and its development, as well as risk factors, which can prevent it.

4. Armenian Energy Sector

The energy sector of the Republic of Armenia has been one of the most developed parts of the economy. Traditionally, Armenia received its energy supplies, including all its gas

[28] Interview with Dr. Levon Yegiazaryan, General Director of the Institute of Energy in Armenia, 05-Sep-2002, Yerevan, Armenia

[29] Interview with Ruben Muradyan, the director of Energy Strategy Centre, 05-Sep-2002, Yerevan, Armenia

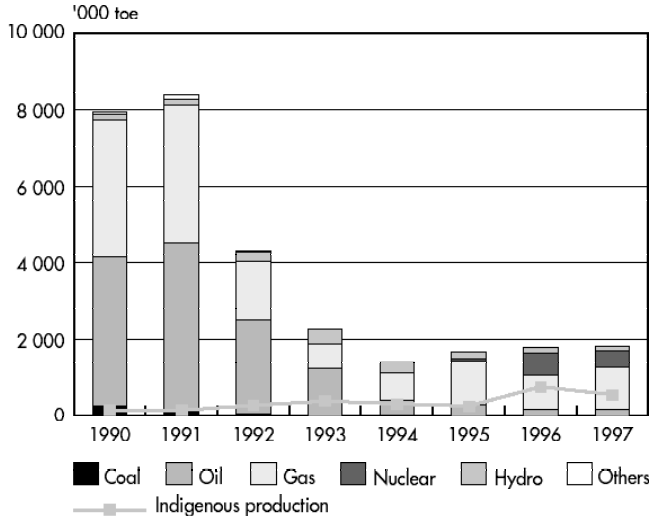

Figure 3. Total primary energy supply in Armenia,1990 – 1997
Source: IEA

and oil needs as well as nuclear fuel, from Russia and Turkmenistan (for gas). The country was well connected with its neighbors in the Soviet Union. Its electricity system was operated jointly with Georgia and Azerbaijan. Electricity exchange was frequent and provided for network stability and reliability of supply.

In the 1980s Armenia was a net exporter of electrical power to the region, but by 1991 after the closing of the ANPP, Armenia was importing nearly 14% of its electricity[30]. During the energy crisis domestic energy consumption dropped from 12-13 million tons of oil equivalent per year during the period 1985-1988, to about 3 million tons per year in the period 1993-1995 (see Fig. 3). [31]

Table 2. Armenia: Electricity Production by Fuel (GWh)

	1990	1991	1992	1993	1994	1995	1996	1997
Oil	8807	5300	3900	546	636	425	127	127
Natural Gas	0	2670	2060	1456	1508	2913	2191	2905
Hydro	1550	1546	3044	4293	3514	1919	1572	1600
Nuclear	0	0	0	0	0	304	2324	1389
Total	10362	9516	9004	6295	5658	5561	6214	6021

Source: Ministry of Nature Protection

The situation improved as from 1995, when the ANPP was reopened, and the cease-fire with Azerbaijan improved fuel imports. It is important to recognize that much of the Armenian energy system infrastructure is more than 20 years old and is in a very poor condition[32].

The main components of Armenian energy system are the hydropower plants (HPPs), thermal power plants (TPPs), the Armenian nuclear power plant, electrical power transmission and distribution networks, and the natural gas transmission system (see Fig.4). There are also theoretical resources of wind, solar and geothermal power, which are not elaborated yet.

[30] World Bank, *Armenia Energy Sector Review,* 1993, *Report* based on a joint World Bank/International Atomic Energy Agency (IAEA) mission that visited Armenia in May/June 1992.
[31] USAID, *Armenian Energy Sector Investment Conference: Energy Sector Overview,* 1998, Sponsored by the U.S. Agency for International Development and U.S. Energy Association.
[32] Ministry of Energy, *The Armenian Energy Sector: Development Tasks and Key Issues,* 1998, Republic of Armenia, Ministry of Energy, Yerevan, 1998.

4.1 Fossil fuel supply

4.1.1 Oil

Armenia has no oil production, known reserves, or refineries, making the country completely dependent on imports of refined oil products. There are no oil pipelines into Armenia, all of the country's petroleum products are mainly imported by rail. There are three main rail lines – one from Georgia and other two from Azerbaijan (see Fig. 5). In the past, most Armenian imports of petroleum products were from refineries in Baku (Azerbaijan) and Grozny (Chechnya, Russia). Till the end of subsidized oil supplies before the collapse of the Soviet Union, Armenia's oil consumption was 48,400 barrels per day (bbl/d) in 1992[33].In the early 1990's, about one-third of total oil consumption was mazut (black oil)for thermal power stations. The rest was used primarily in the transport sector[34].

Figure 4. Power generation system in Armenia
Source: IEA

Figure 5.Armenian communications
Source: IEA

As from 1992, oil imports were massively impaired due to the Azeri blockade, as consequence of conflict over Nagorno-Karabakh. The trade embargo with Azerbaijan and the war in Chechnya closed supplies from both refineries. As a consequence the oil consumption in Armenia decreased to just 4,000 bbl/d in 2001, most of which comes from the Batumi refinery in western Georgia[35] (see Fig. 5).The current transport route through Georgia makes the use of oil in power generation economically unattractive if compared to natural gas. Mazut accounts for only 5% of fuel consumption in the power sector, but it remains important as a back-up fuel.

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[33] US Energy Information Agency, Countries Analysis Briefs, *Caucasus Region,* March 2002, available online http://www.eia.doe.gov/emeu/cabs/caucasus.html accessed on 22-Nov-2002
[34] International Energy Agency, *Black Sea Energy Survey,* 2000, OSCD/IEA, Paris, France, pp. 67-93
[35] US EIA, *Caucasus region,* 2002

4.1.2 Gas

Armenia has no gas production of its own and imports gas from the United Gas Supplying System of the former Soviet Union through the territories of the Northern Caucasus, Georgia and Azerbaijan. Under the Soviet Union, Armenia was one of the most intensively gasified republics. In the residential sector, the market penetration was the highest of all former Soviet Union republics, with more than 83% of all residents receiving either natural gas or liquefied petroleum gas (LPG). Natural gas was supplied to over 2,200 industrial and institutional users and to 485,000 residential consumers (61.5% of households). In addition 200,000 consumers were supplied with LPG (21.8% of households) [36].

While the territory of the Republic is relatively small, the length of the main gas pipelines is about 2,000 km, and the length of the gas supply network is 11,000 km. The volume of underground gas storage intended to control seasonal gas consumption peaks is 240 million cubic metres[37].

Three trunklines enter Armenia, one from Georgia, and two from Azerbaijan (see Fig. 5). The two trunklines entering via Azerbaijan are currently inoperable due to the blockade. The trunkline from Georgia is near the Azeri border and was frequently disrupted due sabotage between 1992 and 1994 as well as because of the Georgian and Abkhaz conflict[38].

Before the crisis the gas consumption peaked at 6.3 billion cubic meters in 1989. Armenian gas consumption is presented in the table 4. Armenia's three thermal power stations consumed nearly one third of total gas supplies. Gas consumption then decreased 87% between 1989 and 1994, making 421 million cubic meters in 2001. Since 1993, thermal power plants have been the major consumer of natural gas, accounting for about 80% of total gas demand.

Table 3. Natural gas supply in Armenia 1986- 1997

	1986	1989	1991	1992	1993	1994	1995	1996	1997
bcm	4.93	6.33	4.15	1.88	0.8	0.87	1.46	1.11	1.44

Source: IEA

During the crisis the population was completely cut off from gas supply. It had a negative impact on industry as well, which in that period used 15-20% of its capacity. Rehabilitation of the low-pressure distribution network started. Around 82,000 households and 260 industrial consumers have been re-connected.

[36] IEA, *Black Sea Energy Survey,* 2000
[37] Adonz, R., *The Oil And Gas Vertical,* analytical magazine "The Caspian Oil And Gas", No 1, 1999
[38] Anex, R.P., *The Armenian Energy Sector: Power and Politics,* 1999

4.1.3 Coal

Coal resources in Armenia are very small, and were never seriously exploited. Total proven reserves of low quality lignite are some three to five mega tons. Industrial mining is uneconomic because of the geographic spread and geological conditions of the reserves. In the mid-1980's Armenia imported 300-550,000 of coal per year from the Donbass basin in Ukraine, used primarily for domestic heating. Since then coal imports have fallen to less than 5,000 t/year (see Fig.3). With the disruption of the main communications the price for the transportation increased, what made the export less profitable.[39]

Furthermore, Armenia's power plants have no coal-burning unit that is why it is not probable that coal will be widely used in Armenia.

4.2 Power generation industry

4.2.1 Thermal power plants

In Armenia there are three thermal power plants located at Yerevan, Hrazdan, and Vanadzor. All thermal power plants up to a capacity of 150 MW are designed as combined heat and power plants, with steam extractions for industrial and/or district heat supply. The thermal power plants are designed to run on natural gas or heavy fuel oil (HFO). HFO is used only when gas supplies are interrupted. The installed capacity of existing thermal power plants in Armenia amounts to 1,754 MW, accordingly Hrazdan TPP – 1100, Yerevan TPP – 550, Vanadzor TPP – 94. The construction of a fifth unit at Hrazdan (300 MW) has been suspended due to the lack of funds and mismanagement. In 2002 Hrazdan TPP was given by the Armenian government to Russia as a cover of its external debt.
Before the crisis about 63% of population was provided with a centralized heat supply. During the crisis the steam and heat production sharply decreased mainly because of the fuel shortages and collapse of industrial production. District heating broke down and the population switched to other fuels – mainly fire wood, kerosene and electricity.
The work of TTPs is limited not only by insufficiency of fuel, but also natural conditions of Armenia, e.g. because of high temperature in summer the work of TPPs has to be suspended for almost 50%, therefore covering the electricity needs by HPPs and ANPP[40].

4.2.2 Nuclear power plant

The Armenian nuclear Power Plant at Metsamor was built in 1960 for meeting the growing needs of the copper and aluminum production industry[41]. Its consists of two VVER 440/V270 model light water reactors, each rated at about 440 MWt, that went on

[39] IEA, *Black Sea Energy Revue,* 2000
[40] Anex, R.P., *The Armenian Energy Sector: Power and Politics,* 1999
[41] Tatevosyan, A., *Living Dangerously with Nuclear Power in Armenia*, Transition,3 May 1996, pp. 23-25, 63.

line in 1976 and in 1980 and with a designed lifetime of 30 years. Unit two was designed to withstand an earthquake registering up to nine on the Richter scale[42].

Both units of the ANPP were shut down in March of 1989 following the 1988 earthquake. In response to the energy crisis, Armenia decided to resume operation at the 440-MW second unit. From 1993 to 1995 a list of upgrades was done at ANPP with assistance of Russia and International Atomic Energy Agency (IAEA) and with financial help from the Armenian budget, a Russian loan, the US DOE, TACIS and France[43], what, according to different sources, made 75-150 millions of US dollars. In November 1995 it was restarted and supplies between 40% and 45% of the country's electricity[44].

Radioactive wastes were transferred to Russia during Soviet period. After independence the wastes were stored in Armenia on the territory of ANPP. In 1998 French Framatome has installed a dry storage facility for FF40 m**.**

Although the plant did not suffer any damage during the earthquake, the plants location in a high seismicity region had raised serious concern since the beginning of its construction and operation[45]. The safety issues become a matter of anxiety and debates both before and after re-commissioning of the ANPP. There were strong objections both from the UN and the USA, as well as neighbouring countries. Among the arguments against the reopening of the plant, except the seismic instability of the region, are the age and design of the VVER 440, particularly the lack of a containment vessel for the reactor to prevent the accidental release of radiation, weak nuclear regulatory authority and regional conflicts. Azerbaijan, Georgia, and Turkey protested against the reopening of the plant, largely on political grounds[46].

According to Dr. Richard Wilson, after testing Unit 2 reactor's vessel in which the reactor and its coolant water are placed under pressure in the pressurized water reactors, Russian specialists suggested that it will be safe for 10 to 20 more years[47]. Therefore Armenian and Russian nuclear officials believe that the reactor could operate through 2016. The European Union, however, is pressuring Armenia to shut the plant earlier, promising Armenia 100 million euros ($91 million) to build alternative thermal and hydro power-generating facilities to replace Metsamor. The Armenian government has pledged to decommission the plant by 2004. However, Armenian Energy Minister Karen Galustian

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[42] Ministry of Energy, *National Report of the RA on the "Nuclear Safety" Convention,* September 2001, Yerevan, Armenia

[43] IEA, *Black Sea Energy Revue,* 2000

[44] US EIA, Countries Analysis Briefs, *Caucasus Region,* March 2002,

[45] International Atomic Energy Agency, report to the *Seismic Safety Review Mission: Review of the seismic Re-Evaluation and Upgrading Programme of the Armenian NPP,* Report was organized by IAEA to the Government of Armenia under TC Project (ARM/9/002), 26-31 October, 1997, Yerevan, Armenia

[46] Nuclear Threat Initiative (NTI), NIC Nuclear Profiles, *Armenia: Reopening Metsamor,* 1996, http://www.nti.org/db/nisprofs/armenia/overview.htm 03-Jan-2003

[47] Wilson, R., *Armenian Nuclear Plant Report,* July 25, 1995, Report done for Andrey Sakharov Foundation in Moscow and New York

said that the country will need up to $1 billion from foreign investors and donor countries to safeguard Armenia's energy security after closing Metsamor ANPP[48].

In February 2003 ANPP was transmitted to the trust management of Ministry of Nuclear Energy of Russia[49], at the same time remaining the property of Armenia according to the Armenian Law[50] .

Today Armenia does not possess any supplementary energy-generating facilities, which would allow its refusing the power plant, that is why the decommissioning of the ANPP by 2004 seems unrealistic. The possibility of its closure in 2008 is being discussed together with investigations concerning creating of alternative sources of energy[51], what will be related in the following chapters.

4.2.3 Hydro power plants

Hydro power is the only indigenous source of electricity in Armenia. There are six HPPs in the Sevan- Hrazdan Cascade, three HPPs in the Vorotan Cascade and a number of small HPPs generating a total of 1500 GWh/year (see fig. 4). The total capacity of the HPPs in Armenia is 1022 MW.

Lake Sevan which feeds the Sevan-Hrazdan Cascade is Armenia's most important strategic energy buffer resource. Between 1992 and 1994, when the country was relying solely on hydropower, the forced operation of the cascade lowered the water level of Lake Sevan to ecologically dangerous levels. Sevan-Hrazdan is now running at about half its capacity (about 490 GWh/year), to allow refillment of the lake and to build up a stock of water which can be exploited in the case of a new energy crisis[52]. In winter months its operation is lower than in summers when it needs to compensate the decreasing operation of TPPs. It is supposed that this cascade will be operating at a reduced level until 2007.[53]

4.2.4 Electrical power and transmition

The Armenian transmission system was a part of the Soviet Trans-Caucasus Interconnected System, but has been operating independently since 1991. The high-voltage transmission network of Armenia consists of 1323 km of 220 kV lines and 3169

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[48] Karen Galstyan cited in *Caucasus Region,* Countries Analysis Briefs, US EIA, March 2002

[49] Caspian News Agency, *Metsamorskaya AES Budet Peredana Pod Upravlenie Rossii, (The management of Metsamor NPP will be given to Russia),* 2003-02-06, http://www.caspian.ru , translated from Russian by author, accessed in 10-Feb-2003

[50] Ministry of Energy, *National Report of the RA on the "Nuclear Safety" Convention,* September 2001, Yerevan, Armenia, p. 6

[51] European Commission / Government of Armenia, *Strategy Paper for the Design of an Energy, Security, and Diversification Plan for the Republic of Armenia,* September 2000, This report was produced by Sogin/Decon Consortium in the framework of the TACIS Project EAR 9801

[52] European Commission - Directorate General for Energy .The SYNERGY Programme. Black Sea Regional Energy Centre *Black Sea Energy Review – Armenia. Energy Balance Data,* 1996, available online http://www.bsrec.bg/armenia/armenia.html, accessed on 10-Oct-2002

[53] IEA, *Black Sea Energy Survey,* 2000

km of 110 kV lines with 133 substancions. In the table 5 presented interconnections of Armenian high-voltage transmission network with the neighbouring countries.

Table 4. International grid connection

Destination	Power line	Status
Georgia	220 kV (200 MW)	Operational
Iran	220 kV (150 MW)	Completed in 1997, operates synchronously at 50MW.
Azerbaijan	330 kV (400 MW) + 110 kV (50 MW)	Interrupted because of Nagorno-Karabakh conflict
Nagorno-Karabakh	110 kV	Operational
Turkey	220 kV (250 MW)	Completed in 1987, only used for trials prior to Nagorno-Karabakh conflict
Azerbaijan (Nakhichevan)	220 kV (500 MW)	Out of service

Source: IEA

The medium and low-voltage distribution system comprises 35, 10, 6 and 0.4 kV lines and have a length of about 40,000 km, with about 9,000 transformers supplying over 850,000 connections (of which 740000 in the residential sector)[54].

5. Risk context – limits and possibilities

As mentioned above, it is essential for SD to preserve ES which can secure sustainable socio-economic development and preservation of peace. It is also evident that the ES issue in Armenia is a key factor not only for development, but also for national security preservation. Armenia has once passed an energy crisis which had an impact on all the spheres of the state livelihood. According to the precautionary principle, which in 1992 was defined in Australian Intergovernmental Agreement on the Environment as "…careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and an assessment of the risk weighted consequences of various options"[55], the energy crisis of 1992-1994 could become a serious example for stakeholders for further decisions concerning energy policy.

This chapter will examine possible consequences for Armenia in case of ES loss and possible difficulties which can prevent the ES preservation. All these factors must be considered in the elaboration of energy policy and definition of the priorities in the further development of energy system of Armenia. As an example, there will be analyzed the consequences of the energy crisis in 1992-1995 on the social, economic and biophysical factors in Armenia, as well as peculiarities of Armenia's geopolitical environment which can play a significant role in ES of Armenia.

[54] Ministry of Energy, *Energy Sector of Armenian*, 1998, Republic of Armenia, Ministry of Energy, Yerevan, 1998.

[55] Dovers, R.S.; Hanmer, W. J., *Ignorance, the Precautionary Principle and Sustainability,* Ambio Vol. 24, No. 2, March 1995, pp 92-97

5.1 Social factors

In the list of negative phenomena such as conflict and blockade, economic decline, hyper inflation, etc, which had their harmful impact on the population of the country, the loss of ES played not the last role. Due to energy shortages, the standard of living deteriorated dramatically.

During the crisis the distribution of natural gas to households has been completely suspended (before crisis 83% of population had a gas supply, in the resent times only 9.9 % rehabilitated). As a consequence the population switched to other fuels – mainly fire wood, bottled gas, kerosene and electricity. Fuel shortage lead to the decrease of electricity production in two times and thermal energy in 20 times[56], which limited the district heat and lead to electricity rationing with between one and three hours per day being supplied to the population. Temperatures in residences fell as low as -5 ºC in the winters.[57] Lack of electricity reduced the ability to pump water to homes and thermal power plants, which in-turn led to the freezing and breaking of water pipes, further limiting the ability to supply heat.[58]

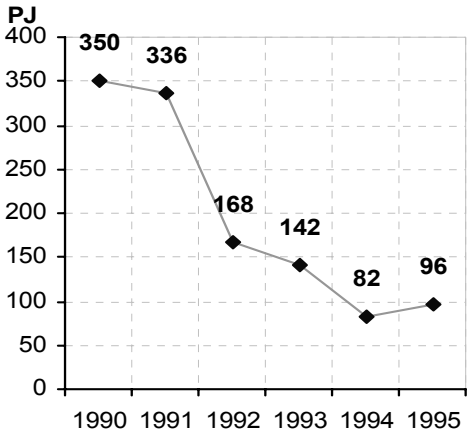

Figure 6. Change in power consumption in Armenia,1990-1995
Source: UNDP, GEF project "Armenia-Country study on Climate Change

Price increase on electricity and low availability of other type of fuel led to reduction of electricity and fuel consumption in 3,6 times. At the same time unemployment rose. All this together with the increased prices for food and transportation led to a considerable decrease of the quality of life of the population and its depression. Living conditions presuppose here provision with water and food, heat and light as well as possibilities to earn for one's living. High rate of emigration was the consequence of the created conditions.

According to the UNDP Human development Report 2001, a total of 760-780 thousand people left Armenia between 1991-1998 mostly to Russia, EU and USA. An independent assessment giving a negative migration balance of 75-80 thousand 1999, plus, 52.6 thousand who left in the year 2000 (according to the RA National Survey Service) it could be concluded that from 1991-2000 the total number of people who left Armenia totals approximately to 900 000[59]. Academic V. Khodjabekyan distinguishes between two sides of such an outflow of the population:

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[56] UNDP/Ministry of Natural Protection of RA, GEF Project Implemented By UNDP, *First National Communication of The Republic of Armenia Under the United Nations Framework Convention on Climate Change,* October 1998, Yerevan, Armenia, chapter 2, pp. 3-12

[57] IEA, *Black Sea Energy Survey,* 2000

[58] Anex, R.P., *The Armenian Energy Sector: Power and Politics,* 1999

[59] UNDP, National Human Development Report, *10 Years of Independence and Transition in Armenia,* 2001, pp. 92, 93

positive sides

1. As a result of approximately 700.000-1.000.000 emigrants (20% of the population), the problem of unemployment existing in the country radically reduced
2. The forced migrants generally find jobs in the host countries and send considerable amounts of money in the form of remittances to their families. According to UNDP report in Armenia, about 300 million US$ enter the country yearly, what has a positive impact on the economy of the country

negative sides

1. Armenia has a few natural resources like some construction materials and minerals, but the *only and main* resource is the population, and Armenia has developed its main resource by means of education, development of sciences, i.e. has developed a large number of highly qualified personnel. So the brain drain results in the loss of the vitally important resource of the country preventing the further development of the economy.
2. Aging of the population, as the main emigrants are between 17-50 years old
3. Negative growth of birth rate (-0.3)
4. Instability of demographic balance, i.e. the female population surpasses the male population, as the male emigrants are more frequent than female.[60]

5.2 Economic factors

With the collapse of the Soviet Union there was also a collapse of the links connecting the ex-soviet republics into an integrated economic space, what had a negative impact on the economies of these republics. The above-mentioned factors of Armenian economic decline brought the inflation in 1994 to 5000 %.

As a result of economic and energy crisis in Armenia in 1995 in comparison with 1990 the following has taken place:[61]

- Reduction of GDP by 70%
- Volume reduction of the industrial production by 75% and agricultural – by 30%
- Industry reduction, the share of which in GDP declined from 44% in 1990 to 24% 1995 and 21% in 2000.

In Soviet era Armenia had an advanced multi-branched industry, which included machine-tool construction, precision tools making and radio electronics, chemical industry, building materials industry, textile industry, aluminum and copper industry, etc., i.e. mainly represents a manufacturing type of industry, which is energy intensive. By 1994, the industry only operated at 15% capacity because of lack of fuel.[62] The majority

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[60] Khodjabekyan, V *Strana Stradaet iz-za Migracii* (*The Country suffers from Migration*) "Migration processes should be controlled" (translated from Russian by author) Interview with Academic of the Armenian Academy of Science V. Khodjabekyan, " Golos Armenii" independent newspaper #40, 15 April 1999г.

[61] UNDP/Ministry of Natural Protection of RA, *First National Communication of The Republic of Armenia Under the United Nations Framework Convention on Climate Change,* 1998,chap. 2 , pp. 4-7

[62] *IEA, Black Sea Energy Review, 2000*

of productions have closed because of a considerable increase in electricity prices. This, in its turn, increased unemployment, and loss of qualified labors.

5.3 Biophysical factors

The energy crisis brought to an acceleration of environmental problems which had already taken place in Armenia. Speaking about problems created by energy crisis, it is necessary to analyze their consequences in the frame of global changes, e.g. climate change to which the Armenian ecological systems in semi-arid area are especially vulnerable. It is explained by the fact, that these changes which in the long run could turn to the ecological catastrophe, will have an impact on infrastructure of Armenia, what can threaten not only Armenia's development and national security, but also the environment of the whole region.

5.3.1 Climate change

Economic and energy crisis played a twofold role in Armenia's possible participation in the global climate change. With the decline of industry, especially energy industry (as far as the share of energy and transformation industry in greenhouse gas emissions comprised 53%), greenhouse gases emissions within a period of 1990 to 1995 decreased by 75.5%, and Armenia's contribution in global greenhouse gas emissions in 1995 was 0.02%, compared to 1990 – 0.1%.[63]

On the other hand, as a result of lake Sevan drainage for hydropower the level of the lake, the biggest water body in Armenia, reduced. As the result of the increased role of firewood in fuel mix of population a considerable amount of forest-covered territories was cut. Both these ecosystems are participating in the formation of micro-climate of Armenia and both ecosystems are vulnerable to the climate change in the conditions of aridity, which is typical for Armenia. The investigation by the Ministry of Nature Protection (MoNP) under the United Nations Framework Convention of Climate Change, mentions that in the nearest 50-100 years the temperature in Armenia will rise by 1-2°C, what will lead to precipitation decrease of 10%, with increased evaporation from the lake surface by 13-14%. If it is taken into consideration that lake Sevan is mainly fed by annual precipitations, a natural decrease of the lake's level is expected, which is added to the anthropogenic decrease as the result of hydropower generation and irrigation.

On the other hand, according to the same investigation, due to a decrease of precipitations the reduction of soil humidity by 10-30% is expected and natural moisture-provision of plants for 7-13%, what will lead to the drop of plant growth by 7-14%. Vulnerability of forests will increase as well as a result of increase of mass reproduction of leaf-cutting beetles, which will cause a 15% loss in the annual wood growth. All above-mentioned

[63] UNDP/Ministry of Natural Protection of RA, *First National Communication of The Republic of Armenia Under the United Nations Framework Convention on Climate Change,* 1998, chap. 3, pp. 10-15

factors will cause in increase of aridity and desertification. It is expected that desert-semi-desert zone area will expand by 33%, and a new desert zone will form. [64]

Thus it can be concluded that the energy crisis provoked such changes in the ecosystems of Armenia, which in the long term will have a negative impact on all consequences of climate change in Armenia, as well as in climate related industries like energy, agriculture, forestry, etc.

5.3.2 Sevan Lake problem

A majority of experts consider that Lake Sevan has a strategic significance both for Armenia and the whole region. The importance of the lake consists in the fact that Sevan is a great source of fresh water which will become even more important in the future, as well as has an influence not only in the water regime of the Caucasus but the northern regions of Iran and Turkey. It is important to mention its role in the biodiversity of Armenia and the local microclimate formation. Besides, Sevan is the main source of drinkable water in the republic; an indispensable source for irrigation and an important buffer source for the power production the importance of which has increased during the crisis.

In the period of intensive drainage for hydro power and irrigation the water level of the lake decreased by approximately 20m, or 40 % of the lake volume, if one takes into account the fact that it has been exploited since 1936. Such a decrease led to a 90% drop of hypolimnion, bottom layer of water with slow water-interchange. It resulted in the rise of biogenic material from the bottom leading to significant morphological, physical, chemical, and biological changes that ultimately induced eutrophication[*] of the system. As the result the biomass of phytoplankton has grown approximately twice, the lake systematically produced blooms of blue-green algae that can lead to the swamping of the lake.[65] In case the current rate of eutrophication remains, the water of the lake soon will not be suitable for drinking, irrigation, recreation as well as for hydropower generation. The lowering of the water level can intensify the desertification processes in the lake's basin as well.

The water reduction and changes in the lake had a negative impact on the biodiversity of the republic. Drying of the littoral zone led to a subsequent decline in macrophyte and periphyton communities. Some 900,000 macrophytes perished and decomposed. The corollary to this was a decrease in the abundance of invertebrates - a major dietary component of the Sevan trout (*Salmo ischkhan*). This reduction in food items, combined with the loss of spawning sites, contributed to the disappearance of this species. Of 167 endemic and migratory birds formerly inhabiting the peripheral marshlands of Lake

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[64] UNDP/Ministry of Natural Protection of RA, *First National Communication of The Republic of Armenia Under the United Nations Framework Convention on Climate Change,* 1998, chapter 5, pp. 35-55

[*] Eutrophication – increase of productivity of water objects in the result of biogenic elements accumulated in water under the impact of anthropogenic or natural factors. Definition taken from Reimers, N.F., *Nature Management,* Glossary, 1990, Moscow: Mysl

[65] Hovhanissian, R.; Gabrielyan, B., *Ecological problems associated with the biological resource use of Lake Sevan, Armenia*, Ecological Engineering , 16 (2000) pp.175-180

Sevan, only 18 species remain following the loss of nearly 10 000 ha of swamp; a decline in mammalian fauna was also observed.[66]

5.3.3 Deforestation

The second problem occurred beginning from 1991 in connection with the energy and economical crisis, due to which significant part of forest-covered territories has been destroyed, because the forests were the first to suffer as the cheapest and most available energy sources, which was used by population. The destruction in its turn has brought to disturbance of ecological balance of the environment[67].

Within the period between the 1992-1995 around 30 thousand ha. of forests have been cut down. Seven thousand ha. out of them have been cut completely. Deep structural changes have happened in the result of uncontrolled use of forests, over-pasture and hay-mowing in the forests and other reasons: stands have lost their natural ability to restoration, their productivity has reduced, erosive processes have activated, the hydrological regime of forests has been disturbed. On deforested slopes of mountains possibility of mudflows and landslides has increased due to erosion. Within the last 1000 forest-covered territories of Armenia reduced 3-4 times, which intensified erosive processes of the soil, has led to desertification of territories and increase of climate aridity.[68]

5.3.4 Soil degradation

The problem of desertification and the organization of measures to combat it are extremely urgent in Armenia, which is located in an semi-arid area.[69] One half of the territory of the Republic is subject to mudslides, which intensify the processes of desertification. The energy crisis of the 1991-1995 has aggravated the situation, provoking intensive unregulated clearance of forests which served to protect the soil and other functions, since Armenia's forests are concentrated mainly on steep slopes.[70]

5.4 Geopolitical factors

Speaking about the risk factors, it is necessary to mention the geopolitical environment of Transcaucasia, to which the Armenian ES is sensitive. The dependence of energy supply is obvious – thus the Armenian energy system is influenced by the political situation and

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[66] Hovhanissian, R.; Gabrielyan, B., *Ecological problems associated with the biological resource use of Lake Sevan, Armenia*

[67] Republic of Armenia *National Report on "Rion+10" Assessment Process,*2001 Confirmed by the final national conference on "Rio+10"assessment process, National Academy of Science, Yerevan, Armenia

[68] UNDP/Ministry of Natural Protection of RA, *First National Communication of The Republic of Armenia Under the United Nations Framework Convention on Climate Change,* 1998, chapter 5, pp. 35-55

[69] Republic of Armenia *National Report on "Rion+10" Assessment Process,*2001

[70] United Nation's, Sustainable development *Natural Resource Aspects of Sustainable Development in Armenia*, 2001, United Nations Division for Sustainable Development, available online http://www.un.org/esa/agenda21/natlinfo/countr/armenia/natur.htm#desert

conflicts in the region, since most of the energy carriers are imported, therefore the supply is vulnerable to disruptions.

Armenia is situated both in Black Sea and Caspian regions. Both regions are characterized by active geopolitical and economic changes; however this chapter will be mainly focused on the second one. Political situation in the Caspian region is influenced not only by its energy potential[71] but also by geopolitical and geoeconomic factors, such as: the strategic geographical location of the region in the heartland of the Eurasian continent and on the traditional trade routes connecting Europe and Asia; the strategic significance of the region in contemporary international political and economic relations ; the highly complex inter-confessional relationship existing in the region between its Muslim and Christian populations, but also inside the Muslim community itself, numerous inter-ethnic tensions existing both in the Caucasus and in Central Asia[72].

During Soviet time a big part of this region was represented by Soviet Socialistic Republics, while the main power in the region was Soviet Union. After USSR dissolution all this centrally ruled states turned into independent ones with their own interests. Soviet era borders arbitrarily divided ethnic groups into one or more states with dissatisfied minorities within, which later became flash point of ethnic conflicts inside the states or interstates confrontations. Most of these conflicts are in the Trans-Caucasus part of the Caspian region - the conflicts in Nagorno-Karabakh, Georgia, and the Chechen republic of southern Russia.[73]

The end of Soviet Union created a strategic power vacuum in the region that becomes a source of rivalry or commercial interests among neighbours and distant powers, such as Russia, Turkey, Iran, and China; nearby Pakistan and India; and the United States, Europe, Japan, Saudi Arabia, and even Israel.[74] The mentioned factor creates multipolarity in the region which led to creation of economic as well as military blocks within local and foreign states.[75] This competition, which becomes even more vigorous after implementation of such factors as oil, gas, their transit roots and control over them, and labeled by many observers the new 'great game', has the potential to fuel instability and conflict.[76] Moreover, the mentioned ethnic conflicts turn out to be an instrument for these powers in their competition.

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[71] Caspian Basin contain 3-5% of world oil reserves and 10% of gas reserves. Sokolsky, R.; Charlick-Paley, T., *NATO and Caspian Security: A Mission Too Far?,* 1999, New York: Rand Corporation; ISBN for Project ART FORCE, chap. 9, pp. 71, 72

[72] Chufrin, G., *The security of the Caspian Sea Region,* 2001, Stockholm International Peace Research Institute (SIPRI): Oxford University Press, chap.19, pp. 325-341

[73] Energy information Agency, *Caspian Sea Region: Regional Conflicts,* July 2002, http://www.eia.doe.gov/, accessed on 22-Jan-2003

[74] Baker Institute Study Number 6, April 1998, *Unlocking the Assets: Energy and the Future of Central Asia and the Caucasus*, http://www.rice.edu/projects/baker/Pubs/Studies.htm, accessed on 15-Dec-2002

[75] Coppieters, B., *Contested Borders in the Caucasus*, 1996, Brussels: VUB Press,

[76] Sokolsky, R.; Charlick-Paley, T., *NATO and Caspian Security: A Mission Too Far?,* 1999, chapter 6, pp. 69-80

The development of the situation in Caspian region is differently interpreted and maintained by diverse powers, and here more important actors, whose dealings have directly or indirectly influenced Armenian energy security, will be taken into consideration. For the EU and the USA independence of Transcaucasian and Central Asian states, particularly the oil-producing ones, denotes a possibility to exploit the oil and gas from Caspian basin, which contain about 3-5% of world oil, and diversify their energy supply. By supporting these states, the USA is obtaining the objective to insure the absence of monopoly over the oil and gas production and over the regional pipelines and to maintain a favorable regional balance of power.[77]

The focus of attention is also directed towards numerous conflicts, which are blazed up in the Caspian region area, as they can jeopardize the development process of the countries in the region and the desired oil and gas projects, as well as can spread out from the region, as it is bordering the NATO boundaries. For instance the Armenian-Azerbaijani conflict over Nagorno-Karabakh receives more attention from the international community[78], and one of the reasons for the attention this conflict received, is a concern that Russia and Turkey, the latter a North Atlantic Treaty Organization (NATO) member, could be drawn into the conflict.[79]

For Russia, the region represents an area of traditional Russian dominance where in the recent times it is raising its presence to prevent other powers from asserting themselves, which is vital for its security interests.[80] With the connection of this the growing Russian opposition to U.S./Western inroads, heightened Russian fears of Chinese economic penetration is obvious.[81] Russian resistance becomes clear if bear in mind the fact that after the access of multinational oil companies in the region's oil and gas as well as emergence of plans to direct oil and gas roots from oil-producing states - Azerbaijan, Kazakhstan and Turkmenistan to the external markets bypassing Russia, the latter will have declined ability to control energy production and exports in the region and lose a significant amount of cash.[82] As well as this oil- and gas-connecting projects and the support from western countries, especially USA, are making mentioned oil-producing as

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[77] Sokolsky, R.; Charlick-Paley, T., *NATO and Caspian Security: A Mission Too Far?,* 1999, chapter 4, pp. 23-49, chapter 6, pp. 69-80

[78] Carley, P., *Nagorno-Karabakh Searching for a Solution,* part 3, Obstacles and Opportunities for a Settlement Comparisons with Other Conflicts, 1998 United States Institute of Peace, Peaceworks No. 25, http://www.usip.org/pubs/pworks/pwks25/pwks25.html , accessed on 24-Sep-2002

[79] As mentioned B. Coppiters in the *Contested Borders in the Caucasus*, 1996, "to prevent any potential Turkish opportunism at the time of the Soviet Union's disintegration, Marshal Shaposhnikov, the Commander-in-Chief of the Joint Armed Forces of the CIS, warned of a "Third World War" if Turkey were to interfere militarily in the Armenian-Azerbaijani conflict".For more information see a "Groong" Armenian News Network's interview with political scientist I. Muradyan, 1July 2001, http://groong.usc.edu; Demoyan, H., *Kharabakhyan Hakamartutyune ev Tyurcik Gortsone, (The Karabakh Conflict and Turkic Factor),* 2002, in Armenian, the English summary, Caucasus Centre For Iranian Studies, Volume 17, Yerevan 2002

[80] Cutler, R.M., *Cooperative Energy Security in the Caspian Region: A New Paradigm for Sustainable Development?,* 1999, Global Governance, # 2, April–June, pp. 251–271.

[81] Sokolsky, R.; Charlick-Paley, T., *NATO and Caspian Security: A Mission Too Far?,* 1999, chapter 4, pp. 23-49

[82] Adams, J.S., *The U.S.-Russian face-off in the Caspian Basin* Problems of Post-Communism, the magazine, 1-2, January-February 2000

well as transit states less dependant from Russian influence, when the weight of the West there becomes more evident. [83] This in the other hand leads to a growing tension between Russia and these states.

It is important to mention the Russian attitude towards growing Turkish efforts to bond ties with five Turkic states in Caucasus and Central Asia, Azerbaijan, Turkmenistan, Kazakhstan, Uzbekistan, and Kyrgyzstan, with its desire of expansion of Pan-Turkism ideology, based on historic, religious, cultural and linguistic links between these nations, and unification of the whole world of 185 millions Turkic speakers in the region, including the Turkish-Tatar populations in the Russian Federation and Uigur population in China under its leadership.[84] For obvious geographical reasons, Azerbaijan forms the principal link between Turkey and Central Asia, so the strategic goals of Turkey and Azerbaijan are joined at the point of desiring to shrink Russia's sphere of influence and eliminate the 'narrow Armenian wedge' between them.[85] In light of this Russia increases its efforts to prevent and secure Armenian sovereignty and energy security[86], as Armenia, being a military ally for Russia and together with Iran forms a barrier for spreading Pan-Turkism ideology onto region.[87]

Recently developed Iranian cooperation with Armenia is confined by political and economic relations; however, according to the opinion of the political scientist I. Muradyan, with the tendency of growing Turkish policies in the region, these relations can be turned into Iran-Armenian or Iran-Armenian-Greek military cooperation.[88] On the other hand, by supporting economic and political sovereignty of newly independent states in the region Iran maintains a buffer zone between its own territory and Russia[89].

For Armenia the emerged situation together with historically formed relationship with its neighbors played a significant role in its foreign policy and formation of bonds with the above-mentioned powers, while the national security and particularly the energy security *was and are* major objectives[90], since the major problem for Armenia, as is mentioned by Armen Aivazian, a Fulbright fellow from Armenia at Stanford University, is "to survive as a state and as a nation".[91]

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[83] Sokolsky, R.; Charlick-Paley, T., *NATO and Caspian Security: A Mission Too Far?,* 1999, chapter 4, pp. 23-49

[84] Coppieters, B., *Contested Borders in the Caucasus*, 1996

[85] Carley, P., *Nagorno-Karabakh Searching for a Solution,* 1998

[86] Sokolsky, R.; Charlick-Paley, T., *NATO and Caspian Security: A Mission Too Far?,* 1999, chapter 4, pp. 23-49

[87] Gradirovskiy, S. *Strana, kotoraya sushestvuet po sebe ,* the weekly newspaper "Sodrujestvo" (The Community), # 06 (39) 27 June 2001, in Russian, available online http://cis.ng.ru/strategy/2000-05-31/4_selfcountry.html accessed on 10-Oct-2002

[88] Muradyan, I., *Sovremennie Gruzinsko-Armyanskie Otnosheniya, (Modern Georgian-Armenian Relations),* 2001, translated from Russian by author

[89] Coppieters, B., *Contested Borders in the Caucasus*, 1996

[90] "Groong" Armenian News Network, Interview with political scientist Igor Muradyan (Armenia), 1July 2001, http://groong.usc.edu , accessed on 10-Jan-2003

[91] Armen Ayvazyan cited by Carley, P., in *Nagorno-Karabakh: Searching for a Solution,* part 3, Obstacles and Opportunities for a Settlement Comparisons with Other Conflicts, 1998 United States Institute of

According to political scientist Aleksandr Iskandaryan from Media Caucasus Institute, the primary origin of Armenian energy crisis can be considered the Nagorno-Karabakh conflict and following blockade of main gas and rail communications from Azerbaijan and Turkey, and the secondary reasons are Russian-Georgian confrontation, Chechen war, Georgian-Abkhazian and Georgian-south-Ossetian conflicts, as well as Armenian low self-sufficiency of own energy resources, principally in the period of 1991-1995, which was accompanied with ANPP inaction while the only source available for Armenia was its hydro power[92]. Preceding from all mentioned factors it is feasible to estimate the possible adjustments of geopolitical factors and their effects in Armenian energy security in the context of interruption of energy carriers' supply, by analyzing each of its neighbors.

As mentioned above Armenia was in a war with its Eastern neighbour Azerbaijan over Nagorno-Karabakh from 1990-1994. Nagorno-Karabakh is an Armenian populated territory which in the beginning of Soviet Union formation was signed by communist regime to Azerbaijan. The Azerbaijani strategy of pressuring Karabakh indirectly was the isolation of Armenia politically and economically. This blockade was supported by Turkey. After 1994 cease-fire until now this conflict found no solution and international efforts have essentially failed to cope with the dispute[93] as well as the fuel and trade embargo against Armenia hitherto has not been lifted. In the event that no compromise is reached, the conflict has the potential to escalate[94].

Armenian Northern neighbor Georgia, since its independence in 1991, has been struggling with numerous territorial conflicts in Abkhazia, South Ossetia. Possible flash-points can be Ajaria, and the Javakheti predominantly Armenian populated region[95]. Another tension is the discrepancy between Georgia and Russia and possible penetration of Russian-Chechen conflict onto Georgia. During these conflicts the only pipeline connecting Russia with Armenia was several times the target for saboteurs. The vulnerability of this route is still very actual which is obvious in the light of recent disruptions followed by increased tension between Russia and Georgia which left Georgia as well as Armenia without gas[96]. Anxiety can be raised as well between Armenia and Georgia, mainly connected with Georgian demand of getting rid of the Russian military basis from Javakheti region and their replacement by Turkish ones. If one takes into account this plausible scenario, and the construction of pipelines running

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Peace, Peaceworks No. 25, http://www.usip.org/pubs/pworks/pwks25/pwks25.html accessed on 24-Sep-2002

[92] Interview with political scientist Aleksandr Iskandaryan, Caucasus Media Institute, Head of Research Unit, 25-Aug-2002, Yerevan , Armenia

[93] Carley. P., *Nagorno-Karabakh Searching for a Solution,* 2002

[94] Sokolsky, R.; Charlick-Paley, T., *NATO and Caspian Security: A Mission Too Far?,* 1999, chapter 3, pp. 11-21

[95] Baker Institute Study Number 6, April 1998, *Unlocking the Assets: Energy and the Future of Central Asia and the Caucasus*, http://www.rice.edu/projects/baker/Pubs/Studies.htm, accessed on 15-Dec-2002

[96] AZG Armenian Daili , *Desyat' dney bez Russkogo Golubogo Topliva, (Ten Days without Russian Sky Blue Fuel)*, translated from Russian by author , "Azg" Armenian Daili, 2003/01/24, http://www.azg.am/index_ru.shtml, accessed 24-Jan-2003

Azerbaijani oil and gas throw Georgia, which will make it independent from Russian gas, Georgia will get a tool to affect Russian policy by pressuring energy security of Russian ally, Armenia, as well as to control Armenians in Javakheti[97].

Iran, the southern neighbour of Armenia, is a fundamental Islamic state, recently established economic ties with Christian Armenia. In the present moment this relations can be considered strained. Formal trade has been discouraged by the Iranian government, although underground trade has continued, and formal talks have brought about agreements on providing Armenia with natural gas.[98] In the other hand, Iranian lands, bordering with Armenia, or the southern Azerbaijan, populated with 19 million population of ethnic Turks, which is 40% of Iranian population, and the second large ethnic group in Iran. The attention of Azeri in Iran to the Armenian-Azerbaijani confrontation was carefully guarded, what precipitated in Iranian efforts to settle the conflict.[99] In the case of reestablishment of Armenian-Azeri tensions, the development of gas-related project could be insecure.

Armenia's relationship with its last remaining neighbour has been infamous, dating back to the early years of last century when the Turkish Ottoman Empire carried out mass killings of one and half million Armenian civilians (the Armenian Genocide of 1915)[100]. The mentioned event spread out significant part of ethnic Armenian population all over the world that has formed Armenian Diaspora which has tendency to grow and nowadays it is more than twice as large the population in Armenia.[101] While the Diaspora plays an important role in the Armenian economy, it is organized and is not controlled by any government. It has developed a strong anti-Turkic lobby in such key countries like Russia, USA, and France with the main aim of the recognition of genocide. During the war between Armenia and Azerbaijan, Turkey has supported Azerbaijan and coincidentally sealed its border with Armenia.[102]

All the mentioned factors made Armenian-Turkey relations complicated, especially when it comes to Turkish influence in Azerbaijan, and recently in Georgia, which can have direct effect on the Armenian energy security.

Summing up, it is reasonable to quote Robert Annex, a research fellow from University of Oklahoma, who mentioned that "the strategic importance of energy in Armenia elevates management of the energy system to a level where nearly every decision has a

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[97] Muradyan, I., *Sovremennie Gruzinsko-Armyanskie Otnosheniya, (Modern Georgian-Armenian Relations),* 2001, translated from Russian by author

[98] Trade and Environmental Database (TED) Case Studies, *Armenia and Nuclear*, Case Number: 360, American University, Washington D.C., Trade and Environmental Database , www.american.edu/TED/ARMENIA.HTM, accessed 12-Jan-2003

[99] Nasibzade, N., *The Azeri Question in Iran: A Crucial Issue for Iran's Future,*2000, University of Southern California, http://www-scf.usc.edu/~baguirov/azeri/nasibzade2.html , accessed on 25-Dec-2002

[100] Bell-Fialkoff, A., *Ethnic Cleansing,* 1999, New York: St. Martin's Griffin, chap. 7, pp.150, 151

[101] Comparing with about tree million Armenians leaving in Armenia, according different estimates Armenian Diaspora consists of about five to seven millions of Armenians

[102] Trade and Environmental Database (TED) Case Studies, *Armenia and Nuclear*, Case Number: 360

political dimension… and requires that the planning process [of energy system] include as objectives system flexibility and adaptability to changing political demands[103]."

6. Possible development of the Energy sector in Armenia

Speaking about possible scenarios of energy industry development in Armenia, it is important to take into consideration all the factors, as well as the necessity of sustainable development, keeping in mind the energy crisis of 1991-1995. Taking into consideration the geopolitical, natural conditions, absence of any considerable energy resources, as well as the development level of Armenia, there will be examined all the possible alternative ways of energy sector development, especially the involvement of ANPP.

6.1 Renewable source of energy

Renewable energy increases diversity of energy supplies and can replace diminishing fossil-fuel resources over the long run. Most renewable energies use indigenous resources enhancing a country's independence from external supplies of primary fuels. Their use in place of fossil fuels can substantially reduce greenhouse gases and other pollutants.[104]

For Armenia it is necessary to develop its renewable source of energy, and there are enough stimuli for this:

- Absence of proved reserves of fossil fuels in significant amount to cower the power demand for both industrial and residential sectors
- Difficulties in the fuel supply to Armenia because of political problems in the region and fuel embargo from Azerbaijan and Turkey
- Provision of diversity in the sphere of elaboration of electric power for more energy security

6.1.1 Wind power

The Ministry of Energy of RA, in collaboration with a group of foreign firms, organized a project on the possibility of wind power usage in Armenia. The assessment of wind energy potential of Armenia is based on data of meteorological stations and the results of currently implemented monitoring. According to those results, utilization of wind energy resources in several regions of the Republic is economically reasonable (see Fig. 8).[105]

The Danish government is exploring the economic feasibility of installing 10MW of wind power in Pushkin Pass. They have funded a 2-year program for detailed wind resource assessment, through a newly established office in Yerevan, ArmNedWind. According to ArmNedWind, the long term potential for electric power generation from wind, in Armenia is 100-200 MW[106].

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[103] Anex, R.P., *The Armenian Energy Sector: Power and Politics,*1999

[104] International Energy Agency , *Towards Solutions, Sustainable Development in the Energy Sector,* 2002, OSCD/IEA Paris, France pp.8

[105] Touryan, K.J. *Perspectives in Renewable Energy and Sustainable Development,* AIAA Journal of Propulsion and Power, March-April 1999

[106] The Organization for the Promotion of Energy Technologies, E-bulletin on Renewable Energy No 2 – 2001, pp. 19, 20

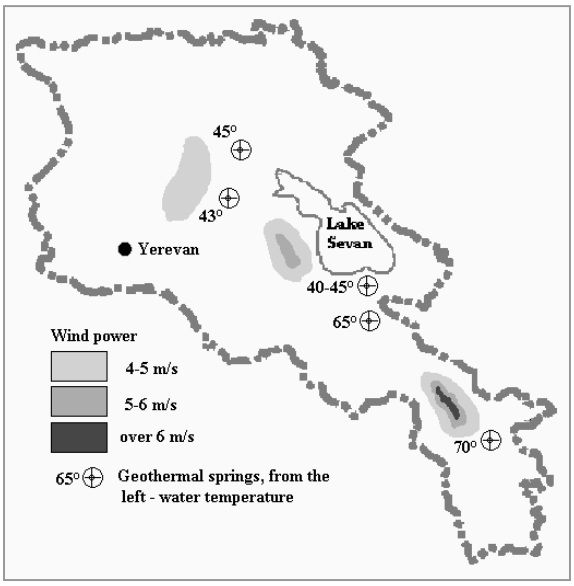

Figure 7. Map of the winds and geothermal springs in Armenia
Source: European Bank for Reconstruction and Development, Black & Veatch

Touryan K.J., widely recognized as the foremost expert on renewable energy in Armenia mentioned that specific costs for the wind converters are decreasing due to standardization, higher production numbers and improved designs. Besides, the Armenian law provides mandatory purchasing of mentioned electrical energy from renewable energy sources until the year 2016[107].

According to SolarEn, LLC, a private manufacturing, development, and consulting company focusing on clean energy, which since 1999 has been conducting wind resource assessment in Eastern regions of Armenia, when successfully implemented, this project will prevent the release of about 40,000 tons of CO_2 gas to the atmosphere contributing to the reduction in carbon dioxide emission.[108]

The development of Wind power in Armenia can lead to the decrease of Armenia's dependence on the energy export. Despite the small potential of wind, anyway attention is paid to its development which together with hydro power will enlarge Armenian domestic sources of energy.

There is some obstacles which could be taken into account such as the closeness of one of the areas with high wind velocity to National Park Lake Sevan. A considerable obstacle is also a lack of investments and high cost of projects.

6.1.2 Solar heating and power generation

According to the assessments carried out in the framework of EU programme (2000) about 10 km² is available in Armenia for solar energy exploration, including the possible usage of un-cultivated land and the exploitation of buildings.[109] The organization for the Promotion of Energy Technologies in Armenia mentions that there are a number of positive factors contributing to the development of solar energy in Armenia:

[107] SolarEn International Corporation of Minnesota, Wind Project Development, Wind Resource Assessment and Consulting *Zod-1 Project ,* 2002 SolarEn LLC, http://www.solaren.am/windproject.htm# , accessed on 13-Oct-2002
[108] Ibid
[109] OPET-Caucasus, Caucasus Energy News, *Prospects for the utilization of non-traditional and renewable sources of energy in Armenia,* 2001 Regional Newsletter #2 , pp. 6,7

- Significant solar power potential. Annually about 2500-2600 sunny day hours/year with average-annual irradiation of 3.0 – 3.5 kWh/m2/day (worst month); up to 4.9 kWh/m2/day (year average)
- Presence of developed machine-building industry and qualified technical personnel to insure the implementation of the energy technologies
- Favorable public opinion

According to the calculations of this organization, if energy efficiency is about 10 percent theoretical annual generation will be approximately 14000 MWh/year while the largest reported figure of the consumed power in the country is of about 9300 GWh in 1988[110].

The main barrier for using solar energy is an economic one. The unsatisfactory state of economy in the country has as a sequence the absence of investments. There is not any large project using solar energy, except some small projects on solar hot water heating. Over 4000 square meters of solar water heaters have been manufactured and installed in Armenia in the frames of the project ArmNedSun, held by a Danish Company Econosto and Armenian Technocom Co. This is very little, compared to two million square meters installed in Greece, located on the same level as Armenia (but three times more populated). The cost at present is 2000 US $ per KW installed, and 10 cents per KW/hr specific generation costs, what is too high for Armenia and makes an obstacle for a broader distribution of the such kind of energy elaboration, despite the fact, that the technology for designing, manufacturing and installing both parabolic trough and parabolic dish concentrators for generating electric power exist in Armenia.

There is also a possibility of producing solar Cells in Armenia, which employ the photovoltaic principle to convert sunlight (not solar heat) directly to electricity[111], however the input of that technology is prevented by the very high prices for Armenia – at present 1 KW system will cost 6000-10000 US$ installed[112].

6.1.3 Geothermal power

The specialists of OPET- Armenia consider that in Armenia geothermal energy has prospects for development due to relatively juvenal volcanic activity observed on its territory. However, the investigations of Black & Veatch Corporation, held for the European Bank for Reconstruction and Development in the framework of the program *Strategic Assessment of the Potential for Renewable Energy* exposed, that despite the fact Armenia is located in a zone of high tectonic activity and recent volcanism, its geothermal resources are not so rich and presented by low-to-medium temperature thermal water. The discovered underground reservoirs located in depth of 1.2-3.6 km

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[110] Ibid

[111] Fahrenbach, A.L. and Bube, R.H. *Fundamentals of Solar Cells,* 1983, New York, Academic Press, pp. 9-16

[112] Touryan, K.J. *Exploiting the Solar/Wind/ Geothermal Resources in Armenia,* 2000 , National Research Council and National Academy of Science, Young Investigator Program of Energy Issues in Armenia, Trip Report, pp.2,3

containing the thermal water with temperature 45-140 ºC and geothermal gradient 50ºC/km (see Fig. 7). [113]

Currently thermal water is used only for swimming pools and in balneology. According to the data of Black & Veatch Corporation, the only definite opportunity for geothermal development in Armenia lies in creation of state-of-art heat supply systems with heat pumps. Any electricity production projects need high cost investigations with additional exploration drilling[114].

6.1.4 Hydro power

Potential hydro resources of Armenia are rather scarce, but by concentration of hydro resources on the territory the potential is significant. Hydroelectricity accounted for almost 25% of Armenia's electric power generation in 2000. Armenia has traditionally used hydro power as one of its basic sources of energy. There exist two main cascades: Sevan-Hrazdan cascade with capacity of 550 MW and Vorotan cascade with the capacity of 400 MW, as well as several small hydro power stations with the common capacity of 56 MW. In the result of the decreased level of lake Sevan and all the attempts to avoid the aggravation of that process, the power used from the Sevan-Hrazdan cascade has been reduced for its half. According to R. Manukyan, the main specialist in the Scientific Investigation Institute "ArmGidroPoekt" there will also appear reduction of Vorotan cascade as a result of a tunnel between Lake Sevan and river Vorotan, which is being built for the increase of lake's water and the construction of which will soon be finished[115].

The Hrazdan River, Lake Sevan, the Vorotan, Debed, Araqs Rivers have the largest potential, which is nearly fully developed. The Government of Armenia is taking efforts in rehabilitation of power sector; there was developed the investment program of power development up to the year of 2010. Further hydro development is connected with using potential of medium-size and small rivers.

Armenia is planning to build 325mini HPPs and the three bigger HPPs with common power of 296 MW. The cost of this program will be $300 million, part of which will be financed by the World Bank and the European Bank for Reconstruction and Development. Programs of small hydropower development in Armenia include adding small HPPs to water management projects with already existing water retaining structures with the aim of utilizing waste releases, and construction of new small HPPs for power supply of users in the outlying districts of the power system. [116]

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[113] European Bank for Reconstruction and Development, Black & Veatch Corporation, *Strategic Assessment of the Potential for Renewable Energy, Renewable Energy Country Profiles,* Page last updated October 16, 2002, available online http://projects.bv.com/ebrd/renew_profile.htm , accessed on 15-Okt-2002

[114] Ibid

[115] Interview with Manukyan, R. The main Specialist at the Research Institute "ArmHydroProject", , 23-Aug-2002, Yerevan, Armenia

[116] Sarkisyan, A.M.; Kanaeva, A.B.; Grigoryan, P.N. *Skhema Razvitiya Maloy Gidroenergetiki Armenii,* tom 3, 807-T-3 *Skhema ispol'zovaniya Gidroenergeticheskikh Resursov,* 1991, Ministerstvo Energetiki

Table 5. Potential Medium-Size and Small Hydro Power Projects

Projects. New construction	Installed capacity, MW	Average over year power output, Million kWh
Megri HPP	78.9	469
Shnokh HPP	75	300
Loriberda 1and 2 HPPs	59	200
Small HPPs	257	770

Source: European Bank for Reconstruction and Development, Black & Veatch Corporation

The development of hydropower in Armenia for present is one of the most actual and perspective options, compared with other kinds of electricity elaboration. It is promoted by a well-developed infrastructure with knowledge and experience in that sphere, as well as necessary technical possibilities for development. As a simple stimulus can be considered the factor that the development of the sphere is not connected with the fuel export, be it carbohydrate or nuclear one.

There also exist possible difficulties of the development and a negative impact of the mentioned sphere. The main problem is the lack of finance. Hydropower generation in Armenia depends largely on the seasons, although it has a double meaning. For example, as Levon Vardanyan, the head of the Main Department of Technical Policy at the Ministry of Energy in Republic of Armenia, mentions, in 2001, as the result of considerable precipitates on the territory of Armenia, the possibility of hydropower elaboration increased, what gave the republic an opportunity to cut the export of gas and fuel oil for the TPPs, and the main elaboration of energy was provided at the expense of HPPs and ANPP. From the other hand, the productivity of HPPs can decrease in dry seasons[117].

There exist also political difficulties. When it comes to the elaboration of border rivers, Araqs that border Iran, and whose part of the water supply is divided with Nakhichevan, Azerbaijan Autonomous Oblast. Armenia and Iran have set up a joint company to construct the Megri HPP, however, Azerbaijan has objected to the proposed plant, arguing that its Nakhichevan exclave will have its water supplies severely decreased if the Megri hydroelectric power station is constructed.

6.1.5 Biomass

The biomass usage as an energy is on a low level in Armenia, compared, for example, with the UK. The elaboration of the necessary quantity of electricity, using hydro, thermo and nuclear power, has pushed the development of that branch in Armenia. It was also promoted by the fact that despite the developed intensive agriculture, as well as stock-breeding, on the Armenian scale could not provide the material for the serious elaboration of biogas.

SSSR, Gosudarstvennoe Injenerno-Porektnoe Ob'edinenie "EnergoProekt", Vsesoyuznoe Ob'edinenie "GidroProekt", Research Institute "ArmHydoProject", Yerevan, Armenia

[117] Interview with Levon Vardanyan, Head of the Main Department of the Technical Policy. Ministry of Energy of the Republic of Armenia, 05-Sep-2002

Another option is the growing of energy crops or trees in Armenia. Armenia needs to develop a domestic fuel for electricity generation. Reforestation is also an urgent issue. A follow-up evaluation was conducted in July of 1995. At that time the Ministry of Nature Protection, Ministry of Energy and Fuels, and the National Academy of Sciences all expressed interest in cooperating in greenhouse gas reduction efforts related to potential biomass-to-electricity projects and concomitant tree planting.

The proposed actions are to prepare for the installation of three biomass-to-electricity projects in Armenia including sustainable biomass supply development and retrofit of existing conversion facilities to use biomass. Total energy production will be 85-100 MW and carbon reduction benefits should be in excess of 500,000 tons. A main thrust of the biomass supply is the evaluation of potential short-rotation woody crop production systems (and other possible energy crops) and their near-to-mid term improvement for energy generation in Armenia, these fast growing poplars may be used for biomass for energy, reforestation, and erosion control projects[118]. The Lincy Foundation has been one of the major contributors to this project[119].

6.2 Non-renewable source of energy

Non-renewable sources of energy are considered the main traditionally used fuels in Armenia, particularly thermal and nuclear power generation. Today the main focus in the energy development of Armenia is put on one or two of these industries. The development of these industries in Armenia depends on many factors, including the secure supply of fuel for these industries and provision of security for ANPP. The geopolitical factor is very actual here. The development of the whole republic depends on the development of this sphere, as the main share of power supply to industry and residential sector falls on these parts of the energy industry.

6.2.1 Thermal Power

As mentioned above, the thermal power section of energy industry in Armenia was presented by three Combined Heat thermal power plants with pooled installed capacity of 1,754 MW, which was 54.4% of electric power generation in Armenia in 1987, and correspondingly 82% in 1990, 60.9% in 1995, and 37.7% in 2000. [120] The issue of gas and oil communications was already stated. As was pointed out, the most part of both generating capacities and pipe-lines infrastructure was more than 20 years and need to be changed or rehabilitated.

The development of this section of energy industry is viewed as the most proper variant for the EU, what presupposes the readiness of the EU to assist in the financing. The

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[118] Armenian Engineers and Scientists of America *Wood Energy Crops and Other Biomass to Electricity in Armenia,* 1995, available on http://www.aesa.org/fast_tree.htm accessed in 14/10/2002

[119] Ibid

[120] UNDP/MoNP RA, *First National Communication of The Republic of Armenia Under the United Nations Framework Convention on Climate Change*, 1998

development presupposes rehabilitation, increase of technical resource and modernization of existing structures, including the start of new energy block (Razdan-5, 300 MW).

In the ten-year program of Ministry of Energy, presented in 1997, there are two mentioned scenarios of developments. A partial conservation and liquidation of the old aggregates on TPPs is expected, together with the new facilities' introduction: in scenario A – two closed-cycle gas turbines (CCGT) with combined power of 337 MW till 2005, and conservation of nuclear power plant; in scenario B – introduction of either third CCGT with power of 167 MW (A), or new NPP with the power of 500 MW by 2010, with remaining one previously introduced CCGT power of 167 MW (scenario B).[121]

In 1999 there was developed a project which was established by the Government of Armenia and the European Commission (EC) within the framework of the Joint EC-Armenia Working Group on Metsamor NPP with a view to define an EC-Armenia Energy Substitution Action Plan. This plan is mainly focused on the elaboration of energy development program in Armenia corresponding to the projected closure of ANPP in 2004. The development of thermal power instead nuclear was anticipated. According to the mentioned project the new Combined Heat Plant with capacity of 100 MW will be introduced in 2003, two CCGT 340 MW each - accordingly in 2007, 2008, and a Fluidized bed Coal Plant with capacity 80MW, which will be running by the locally produced coal.[122]

Both mentioned plans are implying the construction of Iran-Armenia gas pipe-line. The issue of Iranian Gas export to Armenia and the relevant gas pipeline has been considered since 1992-1993.The proposed gas pipeline's length will be around 141 Km and the total cost of the project has been estimated 120 to150 million dollars.[123] The European Union has declared its readiness to assist in financing the pipe-line's construction; however implementation of the project has been delayed for years due to disagreements between the two sides over natural gas prices (from $84 to $90 per 1,000 cubic meters) and the location of the pipeline. Despite the fact that no agreement on the gas prices was reached yet, in December 2001, Armenia and Iran signed a transit agreement to allow Armenia to import Turkmen natural gas via Iran[124], and the remaining thing is the construction of the pipeline.

The development of the present scenario will put Armenia into dependence from gas deliveries, as well as from gas supplying and transit states, what, taking into consideration the geopolitical situation, can have a destabilizing effect on the economics and security in both Armenia and the whole region.

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[121] Ministry of Energy, *Perspective Program of Energy Sector Development in Armenia(1997-2000-2010),* 1997, Yerevan, Armenia

[122] European Commission / Government of Armenia, Strategy Paper for the Design of an Energy, Security, and Diversification Plan for the Republic of Armenia, 2000, pp. 3-7

[123] Shahabi, S., *Iranian-Armenian Gas Pipeline*, 6 April 2001, International Institute for Caspian Studies, http://www.caspianstudies.com/article/Shahabi.htm , accessed on 10-Oct-2002

[124] Energy Information Administration, Official Energy Statistics from the U.S. Government *Caucasus Region Country Analysis Brief,* March 2002, available online http://eie.doe.org , accessed in 16/10/2002

6.2.2 Nuclear power

While the development of the thermal power is obvious, it is hard to speak about the development of nuclear energy in Armenia due to highly politicized nature of this issue. Today there are negotiations between Armenia and the European Commission led about the closure of the only present reactor of Metsamor ANPP and establishment of a corresponding program. TACIS and other donors are providing substantial assistance for the improvement of safety at the Metsamor NPP. This aims to support the commitment of the Government of Armenia to close the plant by the year 2004, provided that there are sufficient, secure, diversified, alternative sources of energy. This assistance takes place pursuant to a letter issued on the occasion of the signature of the Partnership and Co-operation Agreement in April 1996 (but outside the Agreement itself), which limits TACIS and other donors' assistance at Metsamor to safety issues *only and in the context* of its eventual closure[125].

As was mentioned above, the construction of the new ANPP was examined as a possible alternative in the mix of electricity generation capacities in Armenia, particularly the Armenian Ministry of Energy has interest in obtaining replacement nuclear capacity, such as a 640 MW Russian reactor.[126] Russian specialists suggested the re-establishment of the first block of ANPP. However, according the president of Armenia Robert Kocharyan, Armenia has an excess of generating powers and the wastes for re-establishment of one more block will not be approved.[127]

Today it is hard to believe, despite the negotiations with the EC, that the Metsamor ANPP will be decommissioned in the nearest future. In case of closure of ANPP, Armenia, having no developed new powers and being in a politically unstable situation, can find itself in an energy crisis similar to 1992-1995 and would be forced to deplete its other natural resources as well as its industries would also have a major effect.

6.3 Regional cooperation

The concept of regional co-operation considers the creation of energy community based on co-ordination of capital markets, new technologies and energy resources. The practical realization of this concept has significant importance for the South Caucasus region, as well as for the global environment. The main point here is the fact that the conditional border between the Eastern countries possessing fossil fuel resources (Russia, Middle Asia, Iran, Azerbaijan, etc.) and the Western countries with the most important consumers (Europe, Turkey) passes through the South Caucasus region.

Due to its location Armenia is a potential transit zone for a number of such projects, however the presence of unresolved conflict over Nagorno-Karabakh leaves Armenia

[125] European Commission / Government of Armenia, Strategy Paper for the Design of an Energy, Security, and Diversification Plan for the Republic of Armenia, 2000, pp. 3-7
[126] Anex, R.P., The Armenian Energy Sector: Power and Politics,1999
[127] National News Agency, referring Daily-Commercial, Interview with President of Armenia Robert Kocharyan by O. Maksimenko, 21.09.2001, http://www.nns.ru/interv/int5417.html

beyond all the projects in the region. For instance a project Baku-Ceyhan, a route from Azerbaijan to Turkey; or Eastern route – the route through Caucasian passage, etc. In the first case, the pipeline through Armenia would decrease the price of the construction by 500 mill. US$ from 2.3 bill. US$, however Azerbaijan refuses any cooperation with Armenia; in the second case, despite the fact, that technical and economical indicators of the transit of Russian gas through the territory of Armenia are more preferable, Turkey demands from Russia to execute the gas supply out of the territory of Armenia in case of the realization of the project. Another possible option can be Iran-Armenian gas-duct. The project would help Armenia with needed reliable energy sources, and reduce its dependency to Russia. In the long-run Armenia may also become an important transit point for exportation of gas to Europe. [128] However this project is still under negotiation.

The realization of these projects might promote multi-profitable cooperation among the countries of the region and the conflict solutions and security rise in the whole region. In the current situation Armenia is disconnected from the system of gas pipelines Russia-Azerbaijan-Armenia and Iran-Azerbaijan-Armenia, and, for the moment, only one Trunk Gas Pipeline – the so-called North direction (coming from Georgia) – is under operation. This is one of the reasons for the decrease of Energy Security level of Armenia. That means, Armenia has great interest for de-blockade and development of new electrical links and Trunk Gas and Oil Pipelines in the region.

8. Discussion

The energy system of Armenia and Armenian natural conditions provide possibility to diversify energy producing facilities introducing geothermal, wind and solar power. More visible among them are new small and medium hydro plants and wind farms, which can produce a considerable amount of electricity necessary both for industry and households. Geothermal power plants and solar hot water heating systems can provide heat needed for space heating in households, whereas the biomass option which is not yet taken seriously could have very important advantages such a reforestation, rehabilitation of saline and alkaline degraded soils, bringing in agro forestry with new job places, as well as produce energy. Introducing all this variety of domestic source of clean energy will diversify the generation facilities and together with actions to increase the energy efficiency will promote the ES, decreasing Armenian dependence on foreign source of energy. However the development of all mentioned energy sources except hydropower is just in preliminary stage, and have one common obstacle which is the high cost for research, development and installation. It can also be a hard task to increase energy efficiency. While the already privatized transmission and distribution systems in Armenia have a chance to be rehabilitated and their energy efficiency can be significantly increased, it is hard to say the same about the buildings. According to Ruben Muradyan, the director of Energy Strategy Centre, the majority of buildings in Armenia, constructed during Soviet period, were designed for subtropical climate, without considering the cold Armenian winters, and with an abandoned access to energy supply the energy efficiency criteria was ignored.[129] Thus in order to meet this task, a lot of inputs will have to be made.

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[128] Shahabi, S., *Iranian-Armenian Gas Pipeline*, 6 April 2001
[129] Interview with Ruben Muradyan, 2002

Another significant drawback is the low rate of all domestic sources in the general requirements of energy in Armenia, so the export of the necessary rest is still actual. The proposed development of Armenian energy industry balked to the chose between thermal and the thermal mix with nuclear cycle which need to cover main part of energy required for running industries in Armenia and household needs.

Many studies have been carried out about Armenian energy security, which mainly concentrated on the possible replacement of Armenian nuclear power plant, however none of them examines the geopolitical factor which plays the main role in the ES of Armenia.

As it was mentioned above, the interstate conflicts were mainly the source of energy crisis in Armenia, in the result of which the transportation of energy carriers through transit countries was broken. Those conflicts are frozen, but there is a chance for their re-emergence, and another break of fuel transportation. As a consequence it should be mentioned, that from all the enumerated sources of energy the most actual for Armenia are those that do not require transportation (i.e. domestic sources) or their transportation is safe. Choosing between nuclear or thermal power, it is necessary to take into consideration all costs and effects, all positive and negative sides (especially environmental impact), availability and safety.

In the climate change investigation done by the Ministry of Nature Protection there were examined two scenarios on the energy development in Armenia, in the first case with the development of thermal power (scenario A), and in the second – with the nuclear cycle (scenario B). Computer modeling of the energy system with the minimum costs, energy efficiency and pollutants emission was performed for both scenarios. The comparative evaluation of the scenarios is shown in table 6.[130]

Table 6. Comparative evaluation of the scenarios of energy system development in Armenia

	2000		2005		2010	
	A	B	A	B	A	B
The use of fuel, * *kt. Toe*	1486	1486	2126	1250	1675	1145
Including:						
Mazut	146	146	152	110	93	95
Natural gas	1340	1340	1974	1150	1582	1050
CO_2 emissions *Gt*	2512	2512	3568	2127	2798	1929
Costs, *mill. US$*	302	474	635	1047	507	390

Source: Ministry of Nature Protection

The performed calculations of the CO_2 emission show that the development of the energy system according to the scenario B will allow to restrict CO_2 emissions for 1184 Gt/year from 2005-2010, and 896 Gt/year after 2010.

The scenario A has the following positive sides:

[130] UNDP/MoNP RA, First National Communication of The Republic of Armenia Under the United Nations Framework Convention on Climate Change, 1998, pp. 24-31

- Acceptability – as this scenario is more accepted by the EU and other donor supporting the energy development in Armenia
- Accessibility – both neighbouring Iran and Russia possess large resources of gas, and Turkmenistan, with whom Armenia has an agreement about gas supplies.
- The pipeline construction will allow diversification of ways to receive fuel, and create lower dependence from Russian gas and transit through Georgia.
- The pipeline construction can make Armenia a transit zone to Turkey and Europe for Iranian and Turkmen gas

The negative sides are the following:

- Increase of CO_2 emission and promotion of climate change
- Considerable increase of dependence from other countries. In elaborating of the energy industry on thermal power Armenia's dependence from import will increase on 90%[131] (see Fig.8) what can have a negative impact on ES in case of re-emergence of any conflicts
- Difficulties connected with gas industry development in Iran and USA's sanctions[132]
- The pipeline construction can become a sabotage target depending either on Iranian-Azeri or Iranian-Turkish, or Armenian-Azeri or Armenian-Turkish relations

The scenario B presupposes the introduction of thermal power together with nuclear reactor. This paper does not aim at analyzing positive and negative sides of nuclear power, as numerous studies have been done about this issue. For instance, in the summary presented in the 2001 OECD's report "Trends in the Nuclear Fuel Cycle: Economic, Environmental and Social Factors" the following general positive and negative viewpoints concerning nuclear fuel cycle[133] were adduced which will be mentioned here with connection of Armenian situation, including several specific for Armenia factors:

Positive sides

- Nuclear power can be as a source of long-term supply of economic energy in the large quantities, which is an important factor to reduce dependence of Armenia from foreign gas. As was pointed out by Levon Vardanyan, head of the department of the Technical Policies in Ministry of Energy, for Armenia nuclear power plant can be assumed as domestic source of energy, as having been fuelled once it can produce energy over a

[131] European Commission / Government of Armenia, *Strategy Paper for the Design of an Energy, Security, and Diversification Plan for the Republic of Armenia,* 2000, pp. 12

[132] Any significant investment in Iranian energy projects may be subject to the Iran and Libya Sanctions Act, the notwithstanding comprehensive unilateral sanctions against Iran and Libya (which date to 1986). The legislation was designed essentially to force foreign companies into choosing to do business with Iran and Libya or the United States which the U.S. Congress renewed in August 2001. The new law imposes sanctions on foreign companies that invest $40 million or more in these two countries' energy sectors.These sanctions can be toughed with the connection of Iran's program development on nuclear power with Russia's support. (Global Policy Forum, Security Council, *Iran and Libya Sanctions Act of 1996,* Public Law 104-172,104th Congress, http://www.globalpolicy.org/security/sanction/indxiran.htm , accessed in 05-Feb-2003

[133] OECD, Nuclear Energy Agency, *Trends in the Nuclear Fuel Cycle: Economic, Environmental and Social Aspects,* 2001, Organization for Economic Co-operation and Development, Paris, France, pp. 137-141

comparatively long period of time, which in case of Armenia with existence of hydro power can insure for certain period the interruption of natural gas[134]

- Diversification of power production, which will make Armenia less dependent from gas supply
- Greenhouse gases free from emissions
- Large and widespread natural resource base, which is important for Armenia in case of diversification of sources, as to Russia, Armenia's traditional provider with nuclear fuel, can be added Iran, which recently started exploration and processing its uranium resources[135]. There are a lot of countries that re-process nuclear fuel which can be transported to Armenia by plane.

Negative sides

- Highly politicized issue. Negative attitude of neighbouring countries, as well as donor countries towards possible development of nuclear power in Armenia, and consequently absence of funds
- High costs of new nuclear cycle implementation
- Risks of nuclear accidents. This issue was and is the main issue against nuclear power in Armenia. First of all the source of anxiety is the location of Armenia in the high seismic zone. However, the investigations done with the aim of clarification of the seismicity of the zone by the nuclear station point out, that during more than 2000 years the largest seismic event appeared there with the intensity of eight point by Richter scale.[136] For instance, the reactor of ANPP was designed to withstand against 9 points what allowed the both reactors[137] to remain undamaged after the 1988 earthquake, which affected 40% of Armenian territory, with the epicenter close to the ANPP.[138]
- Another concern is the presence of conflicts and possibility of sabotage. For example, the Western reactors are equipped with containment vessel, protecting the main parts of the reactor. ANPP does not possess it, however, according to Dr. Richard Wilson from Harvard University, "an attack is more likely to come from a neighbour than from a distant country, and although the neighbour would be far less affected by any radioactivity release than Armenia itself, the possibility of adverse effects is likely to deter such action"[139]. At the same time he mentions the danger of probability of a direct hit by a falling aircraft, if take into account that the ANPP is located not far from the

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[134] Interview with Levon Vardanyan, 2002

[135] Caspian News Agency, *Iran Nachal Dobyvat' Uran dlya Proizvodstva Atomnoy Energii, (Iran starts Uranium Mining for Nuclear Power),*2003-02-11,http://www.caspian.ru/cgi/lenta.cgi#12817 , accessed on 11-Feb-2003

[136] Ministry of Energy of RA, Armenian Nuclear Power Plant, Obosnovanie Vibora Ploshadki pod Stroitel'stvo Khranilishya "Sistemy Sukhogo Khranenia Otrabotannogo Topliva",(An approval of Constructing an Area for Storage "System of Spent Fuel Dry Preservation "), the Report, 1998, pp 22-23; see also International Atomic Agency, Seismic Safety Review Mission: Review of the Seismic Re-Evaluation and Upgrading Programme of the Armenian NPP, Report to the Government of Armenia, 1997, Yerevan, Armenia (report partially was provided by official from Armenian Nuclear Regulatory Authority)

[137]These pressurized water reactors are very different from the RBMK reactors of which one exploded at Chernobyl and more similar to western reactors.

[138]Wilson, R., *Armenian Nuclear Plant Report,* July 25, 1995, Report done for Andrey Sakharov Foundation in Moscow and New York, Archive, http://asf.wdn.com/, accessed 25-Sep-2002

[139] Ibid

airport. What concerns the threat connected with the condition and age of the ANPP, according to Dr. Ashot Mnatsakanyan, Head of the Armenian Nuclear Regulatory Authority, since the exploitation of the ANPP and after its re-commissioning there happened two accidents of a middle range which had no impact on the environment or working personnel. [140]

- Problem with the long-term management of spent nuclear fuel and highly radioactive wastes. During the ANPP exploitation there took place no changes in the radioactive background in the republic both before its closure[141] in 1988, and after its recommissioning[142] in 1995. As it was mentioned above, the radioactive wastes are kept on the territory of Armenia for dry preservation by FramAtom, what can lead to creation of radioactive waste stocks.
- Threat of nuclear weapon proliferation. As mentioned by Sokolsky and Charlick-Paley in the "NATO and Caspian Security: A Mission Too Far?", Armenia has neither possibilities nor desire to develop weapons of mass destructions. Moreover Armenia has joined the Non-Proliferation Act.

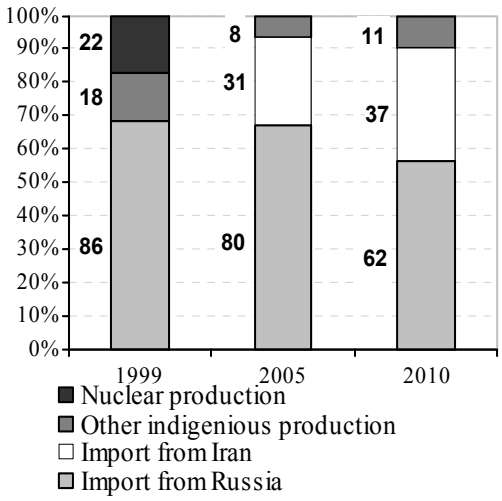

Figure 8. Armenian energy requirements broken by supplier
Source: Ministry of Energy

Thus, it can be summed up that the development of thermal power seems more possible and acceptable from World Community and will get more support for realization. However, it will bring Armenia into the main dependence from the gas imports.

For Armenia, which is situated in the region with numerous frozen conflicts, where a distribution of states is taking place, both inside and outside the region, into competing blocks, what can create obstacles in peace building and conflict regulation, the energy dependence from other countries can become a sword of Damocles both for its national security and for peace preservation in the region.

The nuclear option, being the desire of some officials in Armenia, is infamous with donor countries which could support the realization of this project. So the main purpose for Armenia is to de-blockade its communications and establish an active promotion of conflicts solution in the region. A supporting point for it can be a quotation from the Trade and Environment Database: "The energy crisis led Armenia to a sense of urgency

[140] Interview with Ashot Mnatsakanyan, Head of the Armenian Nuclear Regulatory Autority,22-Aug-2002, Yerevan, Armenia

[141] Ananyan, V.L.; Stepanyan, Z.K., *An Influence of the Armenian AES on the on the Radioactive Pollution of Surroundings,* 1993, News of National Academy of Science, Magazine "Science about Earth", 1993, XLVI, Number 1, pp.32-38

[142] National Programme in the Sphere of Environmental Hygiene, Report No1, under decision No 1204-N of the Government of Armenia, August 1, 2002, Yerevan, Armenia

to accept the risks that go along with running their dilapidated reactor. But the risk of nuclear contamination has not been felt deep enough to lead them with the same sense of urgency in its pursuit of peace, and through it increased trade. Neither has it persuaded its neighbours enough to provide alternatives."[143]

9. Conclusion

Both from the point of SD and ES, the development of renewable sources of energy and maximal increase of the share of renewables in general energy requirements might be the most accessible for Armenia. Special attention should be also paid to the increase of energy efficiency in Armenia. For the realization of this Armenia will need a considerable support from international organizations such as the EU, World Bank, etc., what might reduce the prices for the development of the renewables in Armenia. The above-mentioned scenarios with thermal and nuclear power can assist in covering the shortage, although many investigations need to be conducted to reveal the correspondence of these scenarios to SD and ES.

Armenian Nuclear Power Plant provides a significant part of Armenian energy and has no alternative for its replacement at least until new facilities will be introduced. The type of the facilities that are expected to be introduced will play an important role in the foreign policy of Armenia, its participation in peace building and its further development. Europe presents the first option of thermal power, which, as the above mentioned analysis show, will lead to a major dependence from neighbouring countries that are or can be hostile towards Armenia and this dependence can become a threat to Armenia's existence both as a state and as a nation. This dependence can be used as a blackmail for Armenia and its nation, threatening the peace in the region and beyond it, so, if take into consideration the concept of sustainable development which was introduced in chapter 3, implying the preservation of natural and cultural heritage for both the present and future generations, then the development which Armenia will undergo with the proposed scenario, cannot be described as sustainable.
The second option with nuclear cycle, which was described above, might radically decrease Armenia's dependence from fuel supply disruptions and preserve the country from another energy crisis, as well as promote Armenia's more flexibility in conflict resolution and peace keeping in the region. However, the fact of the nuclear cycle is still arguable in the concept of its sustainability. What about Armenia, it is difficult to imagine that it will receive any support to develop its nuclear power leaving the first option, i.e. the gas, more available. In order to make the first option more accessible, the de-blockading of Armenian communications and active negotiations of all the conflicts in the region are necessary, which is a real challenge both for Armenia and global powers. The supporting point for this solution could become Armenia's more active involvement into the regional cooperation and different projects which can bring Armenia to a dialogue with the conflicting states and promote the lift of the geopolitical factor in the region.

[143] Trade and Environmental Database (TED) Case Studies, *Armenia and Nuclear*, Case Number 360

As is stated in *Principle 25* of Agenda 21 on Declaration of the United Nations Conference on Environment and Development, which was presented in Rio de Janeiro 1992, "Peace, development and environmental protection are interdependent and indivisible".[144]This Principle might serve as a good basis for resolving energy security problems in Armenia, what can insure its steps towards Sustainable Development.

[144] Nelisen, N.;Van Der Straaten, J.;Klinkers, L., *Classics in Environmental Studies. An overview of Classic Texts in Environmental Studies,* 1997, the Hague: International Books, pp. 384

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