

Armenia

Country Profile

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1. Overview of Electricity Supply

Armenia was formed in the early 1990s upon the breakup of the former Soviet Union. Armenia is bordered by Georgia to the north; Azerbaijan to the east; Turkey to the west; and Iran and Azerbaijan to the South. The economy experienced positive growth throughout the 1990's, despite setbacks associated with the formation of the independent state and the 6-year war with Azerbaijan.

Electricity is currently generated through thermal, hydroelectric, and nuclear resources, with no significant generation from non-hydro renewable energy sources.

Reform of the energy sector is now under way. The sector has required increasing levels of government support, and is suffering from severe underinvestment. Restructuring to upgrade the system, promote commercialization and increase competition is imperative. The priorities are to address system malfunctions and invest in maintenance of circuits and equipment as well as technology replacement.

In line with these reforms, Armenia adopted the "Energy Law of the Republic of Armenia." This law states that all electricity capacity generated by renewable sources including hydropower shall be purchased at 31.343 AMD/kWh (approximately 0.09 USD/kWh in January 2009) for the first 15 years after being licensed. The table below summarizes basic information regarding energy in Armenia (Renewable Energy Armenia, 2008).

Demographical Information	
Population, millions (2009)	2.97
Land area, thousand sq km (2009)	29.74
Macroeconomic Information (2008)	
GDP, billion US\$	18.9
Real GDP growth rate, percent	7.6
Foreign direct investment (net), million US\$ (2007)	658
Electricity disposition, billion kWh (2006)	
Generation	5.54
Consumption	4.54
Exports	0.32
Imports	0.40
Generation capacity, GW (2005)	
Nuclear	0.37
Thermal	1.78
Hydro	1.05
Other renewables	0.00
Total	3.20
<i>Sources: CIA World Factbook, U.S. Energy Information Administration, United Nations Conference on Trade and Development.</i>	

Armenia Country Summary Table

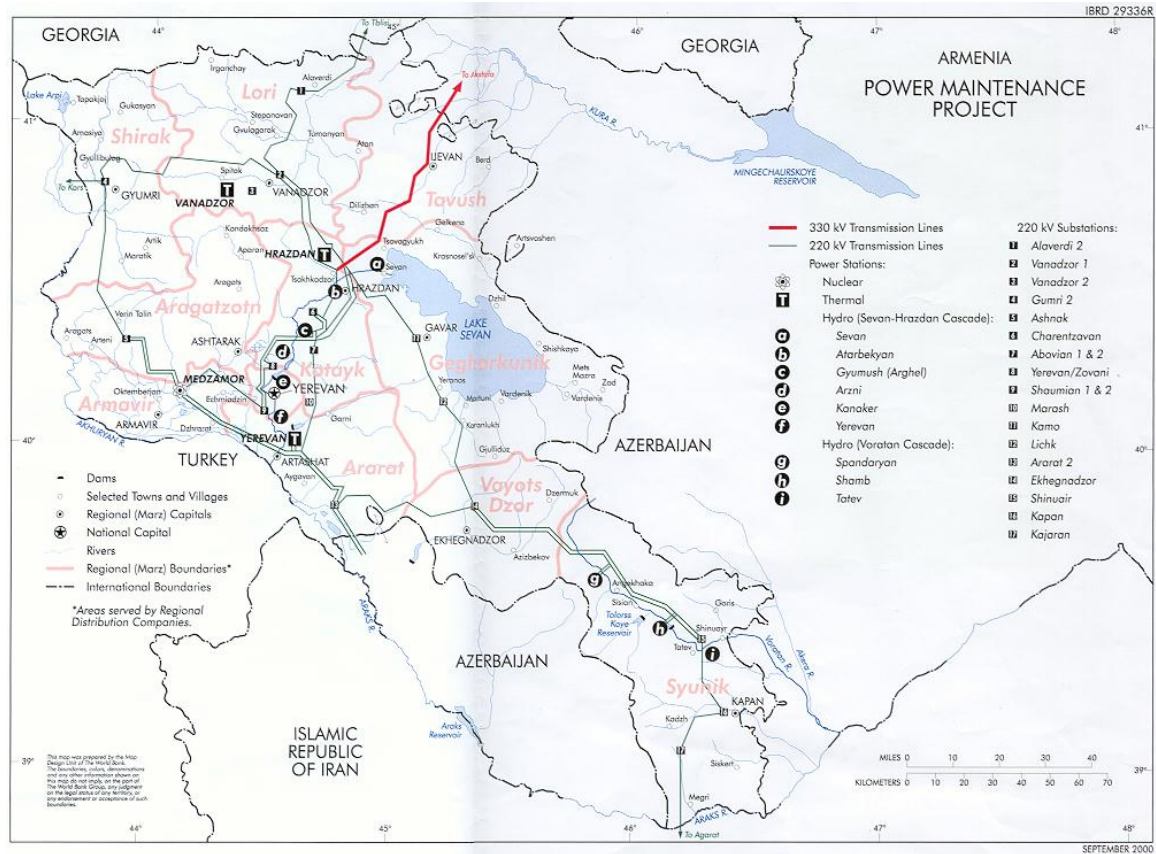
A near majority of Armenia's electrical generation is produced via the Metsamor Nuclear Plant. This plant has two units with a combined capacity of 815 MW. The plant was shut down in March of 1989 because of safety concerns, however, Unit 2 was restarted in 1995, while Unit 1 has been deemed unusable to operate and will not be restarted.

In addition to the nuclear plant, Armenia has 3 thermal plants with a total capacity of 1,756 MW. These plants are operating beyond their planned lifetime, which significantly limits plant efficiency. All fossil fuels must be imported into Armenia, thus these plants are continually low on fuel and are unable to operate near capacity.

Hydroelectricity provides a significant portion of Armenia's electricity, with a capacity of 1.05 GW in 2007. The current hydroelectric capacity is concentrated on the Hrazdan River.

The electric supply is currently not available to all regions on a regular basis, thus potential demand far outpaces supply. The national transmission grid can be seen on the map below.

Electricity Transmission Grid of Albania (Source: GENI)



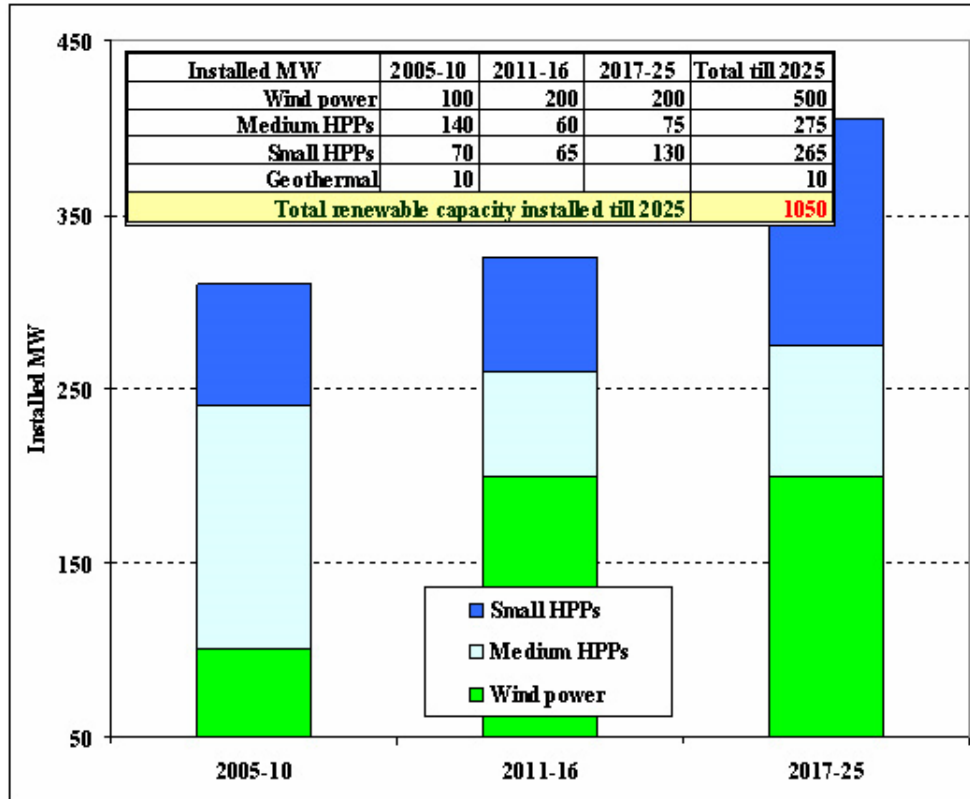
Armenia's national electricity transmission system is operated by the state-owned ArmEnergio firm. It consists of 164 km of 220 kV lines, and 3,146 km of 110 kV lines. Several transmission lines to neighboring areas are not in use due to political conflicts; however, a 220 kV line connecting Armenia to Georgia was reactivated in 1997. Also, a 220 kV line to Iran is used occasionally. In 2002 Iran and Armenia signed an electric power transmission agreement that involves Iran building a \$10 million high voltage power line and Armenia in return selling Iran \$10 million worth of electricity (GENI).

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2. Energy Policy, Barriers and Incentives

The Diversification Strategy Document sets a national target for alternative energy resources in Armenia. The following chart shows the goals for small and medium hydropower and wind power capacities.

Diversification Strategy Projection



The "Energy Law," adopted in April 2001, ensures the obligatory purchasing of renewable energy with higher than average electricity tariffs during the 15 years after the commissioning of the plants. As of January 2009, the announced feed in tariff is approximately 0.09 USD/kWh (31.343 AMD/KWh) without value added tax. Some of the basic principles of the policy are as follows

- Enhancement of competition and efficient operation in the energy sector.
- Regulation on energy sector operations.
- Protection and balance of interests between consumers and economic entities.
- Efficient use of domestic and alternative sources of energy, and the creation of economic and legal mechanisms to serve that purpose.
- Encouragement of investments, safety and environmental protection in the energy sector.
- Separation of the generation, transmission, and distribution system operator.

On November 9, 2004 legislation was passed on the Law of the Republic of Armenia on Energy Saving and Renewable Energy. The purposes of the present Law shall be defining the

principles of the state policy on development of the energy saving and renewable energy and the mechanisms of the enforcement of those aimed at:

- Strengthening the economic and energy independence of the Republic of Armenia;
- Increasing the economic and energy security; and energy systems safety level of the Republic of Armenia;
- Establishing and developing new industry infrastructure and organization of services promoting energy saving and renewable energy;
- Reducing adverse techno-born impacts on the environment and human health.

The principles of state policy in the area of energy saving and renewable energy are:

- Increasing level of supply of indigenous renewable energy carriers to satisfy the energy demand of the economy;
- Implementing energy saving, as well as development and enforcement of legal and economic mechanisms for the promotion of renewable energy;
- Ensuring high priority of efficient use of energy given the increasing volumes of imported and extracted energy resources;
- Ensuring increase of renewable energy resources usage as well as application and development of renewable energy new technologies aimed promoting that;
- Ensuring competitiveness of renewable energy resources and protection/enforcement of rights of businesses engaged in the area of renewable energy;
- Ensuring high priority of issues of environmental protection and efficient (economic) usage of natural resources while implementing measures/activities aimed at the development of the energy saving and renewable energy;
- Promotion of energy efficient production of electric and/or heat energy, including for autonomous energy producers;
- Promotion of integrated activities between the autonomous energy producers, using renewable energy resources, and the energy system aimed at the exchange of electric energy;
- Promotion of consumer choices and use of different energy carriers and energy efficiency technologies;
- Implementation of energy saving and renewable energy state (national) targeted programs.

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3. Wind

Armenia's energy strategy documents set wind power as high priority for energy sector development. The Diversification Strategy Documents set the national target for wind power at 500 MW of installed capacity by 2025. Armenian law provides that purchasing of all the electrical energy from renewable energy sources is mandatory during the first 15 years after commissioning. As of January 2009, the announced feed in tariff is approximately 0.09 USD/kWh (31.343 AMD/KWh) without value added tax. Wind power in Armenia also benefits from having support from the public and local authorities.

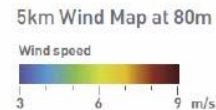
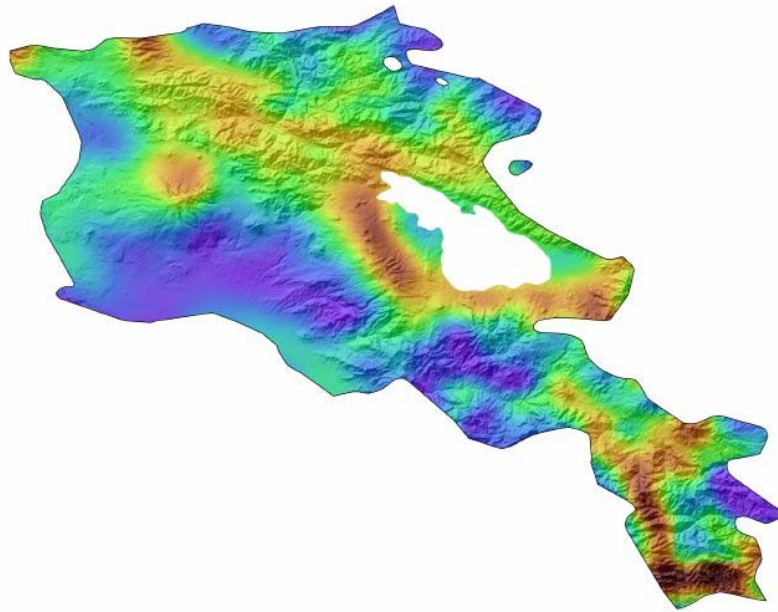
Armenia's best wind resource areas are generally located on top of the higher ridges and mountains or in wind corridors such as mountain passes. Armenia is located beneath the mid-latitude westerly jet stream, a high-speed ribbon of air several kilometers above sea level that circles the globe and also affects the wind resource in North America and Asia. The interaction of the jet stream and the major topographic features of Armenia is one of the factors that have a significant influence on the distribution of the wind resource. The jet stream also controls the progress of weather systems across Armenia and the Trans-Caucasus region. The pressure gradient between weather systems can have a major effect on the wind resource in areas subject to acceleration because of local terrain. The jet stream influence is greatest from October through March. In the warmer part of the year (April through September), the

jet stream is considerably weaker, and differential heating caused by the elevation changes within Armenia and between locations to the north and east of the country controls the distribution of the wind resource. The differential heating among the plateaus, ridge tops, and low elevation areas produce regional and local temperature and pressure gradients that cause the wind to blow.

As a result of the regional and local winds, the wind resource distribution in Armenia during the warm season is quite disparate. Some locations have little wind resource and other locations, especially in some passes, have high wind resource. Overall, the combination of jet stream and regional heating influences produce a complex wind resource pattern in Armenia and it is highly recommended that measurements be made before any wind energy project is established. The wind resource map of Armenia is displayed below.

Armenia Wind Resource Map (Source: 3Tier)

Armenia Wind Map at 80m



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In recent years, Armenia has erected many wind monitoring devices in different areas throughout the country with funding from several wind development projects. It was confirmed by monitoring that the sites listed in the table below have potential for the estimated wind farms.

Site or Land Area	Installed Capacity (MW)	Annual Average Production (GWh)
Pushkin Pass	19.5	48.9
Karakhach Pass (Eastern Gates)	125	320
Zod Pass	50	120
<i>Total</i>	<i>195</i>	<i>490</i>

Wind monitoring for the following areas is not complete; however, from initial monitoring measurements, the following wind sites have been estimated.

Site or Land Area	Installed Capacity (MW)	Annual Average Production (GWh)
Sissian Pass	155	420-430
Karakhach Pass (Western Gates)	125	300-320
Charentsavan Region	20	45
<i>Total</i>	<i>300</i>	<i>765</i>

The monitoring information about Pushkin Pass was the start of the first Armenian wind farm, named Lori 1, which was put into operation at Pushkin Pass in December 2005. The total installed capacity of the wind farm is 2.64 MW, which is made up of four 660 kW turbines. Other potential wind farms are currently being discussed including an extension of Lori 1. A map showing the location of Lori 1 is displayed below (Renewable Energy of Armenia, 2008).

Lori 1 Location within Armenia



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4. Biomass

Biomass energy in Armenia has the potential to provide significant power, if utilized. Armenia has reasonable areas of land covered by forests and lands for agricultural industry, including

farming of plants and animals. These areas can potentially produce residues which could be used as fuel for biomass combustion or gasification, as well as biogas production through anaerobic digestion. Forest residues (slash from forest thinnings or waste wood from sawmills) can provide a concentrated resource to be used as fuel for energy production. Agricultural residues can provide a range of residues, including crop residues (corn stover, nutshells, fruit tree branches, etc.) and animal wastes.

Biogas is not currently utilized as a modern energy resource in Armenia. However, an attempt has been made to attract foreign investment for the construction of a large biogas plant. If funding were available, it could be possible to construct a biogas plant within 12 to 15 years with a daily methane production of up to 100,000 m³.

In 1994 The Armenian Ministry of energy articulated a strategy to "Develop and demonstrate a set of improved farm scale biogas concepts". Under this program, The Armenian State Engineering University, the Armenian Agricultural Academy, and the Biological Institute assisted in the technical design and construction of a few digesters. However, given the reorganization at the farms and lack of technical and organizational support, these systems became non-operational over a short time. No meaningful data was therefore generated, however the interest to anaerobic digesters is strengthening by the privatization of agriculture and farm in Armenia. Family farms are increasingly incorporating strong commercial elements. One result is livestock concentration, a situation offering potentially larger quantities of available animal manures in a more localized region.

The table below shows the overall biomass resource data for Armenia.

Armenia Biomass Resource Data

Biomass resource type	Total production	Production density
Total land area covered by	(avg. 2006–2007, km ²)	(avg. 2006–2007, %)
Arable Land	4,040	14
Permanent Crops	525	2
Permanent Meadows and Pastures	11,550	39
Forest Area	2,764	9
Other Land	9,321	31
Inland Water	1,540	5
Primary crop production	(avg. 2006–2007, tonne)	(tonne / 100 km ²)
Total primary crops (rank among COO)	2,062,857 (7)	6,936.3 (18)
Top 10 primary crops		
Potatoes	539,738	1,815
Tomatoes	264,000	888
Grapes	200,686	675
Vegetables fresh nes	169,000	568
Wheat	149,850	504
Watermelons	132,468	445
Cabbages and other brassicas	112,500	378
Apples	76,000	256
Cucumbers and gherkins	75,500	254
Barley	72,750	245
Animal units, number	(avg. 2006–2007, number)	(number / 100 km ²)
Cattle	606,134	2,038
Poultry	4,527,500	15,224
Pigs	145,154	488
Equivalent animal units	709,470	2,386
Annual roundwood production	(2006–2007, m ³)	(m ³ / 100 km ²)
Total	61,145	206
Fuel	51,000	171
Industrial	5,000	16.8
Wood-based panels	8,085	27.1
	(2006–2007, tonne)	(tonne / 100 km ²)
Paper and paperboard	19,073	64.1
Recovered paper	0	0

Source: Food and Agriculture Organization of the United Nations

Approximately, 2.26 million m³ of solid municipal waste is annually generated in Armenia including industrial, municipal, construction and other wastes. Armenia has 58 landfills, and 57 of those landfills are managed by local governing bodies. The other landfill is owned by the Yerevan municipality, and currently, a Japanese company is implementing a landfill gas extraction at their site.

To utilize biomass as an energy resource in Armenia would require significant analysis of the available residues. Given the amount of forestland, agriculture, and livestock, biomass fuels could prove to be valuable sources of energy.

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5. Solar

Armenia is rich in solar energy resources, the utilization of which will reduce the need for imports of other energy sources. The average annual solar radiation is approximately 1,720 kWh/m² compared to the average annual European solar radiation of 1,000 kWh/m². Over a quarter of the territory of the country has solar resources with an intensity of 1,850 kWh/m². The time duration of sunshine statistics for Armenia can be found in the table below.

Meteorological Station	Duration of Sunshine				Avg. Daily Duration of Sunshine	Cloudy Days
	Measurements		Theoretical Maximum			
	hours/year	% of year	hours/year	% of year	hours/day	days/year
Martuni	2689	30.7	4137	47	7.7	16
Sevan Lake	2629	30	4045	46	7.5	16
Yerevan	2599	29.7	4061	46	7.9	37
Kocbek	2515	28.7	4192	48	7.6	36
Gumri	2499	28.5	4165	48	7.5	35
Megri	2377	27.1	3496	40	7	26
Dilijan	2031	23.2	3627	41	6.3	42
Tashir	2016	23	4114	47	6.3	43
Average	2419.375	27.6125	3979.625	45.375	7.225	31.375
Maximum	2689	30.7	4192	48	7.9	43
Minimum	2016	23	3496	40	6	16

Solar Data for Several Meteorological Stations throughout Armenia

The table shows that the Martuni meteorological station has the largest measured amount of sunshine per year, while the Yerevan station has the greatest amount of sunshine per day.

In spite of very favorable climatic conditions and absence of traditional energy resources, there is little use of solar energy in Armenia. The solar energy resource potential is characterized by the data presented in the tables below for three areas, Yerevan (a capital), Sevan, Kochbek. Kochbek is located at Southwest of Republic at the height 2387 m over sea level.

	Yerevan	Sevan	Kochbek
Jan	200	281	311
Feb	267	357	392
Mar	417	518	537
Apr	540	545	573
May	720	666	654
Jun	821	768	764
Jul	858	825	817
Aug	754	743	743
Sep	594	580	589
Oct	428	435	445
Nov	251	285	299
Dec	171	234	272
Yearly	6021	6237	6396

Monthly and annual total solar radiation incident on horizontal surface, MJ/m²

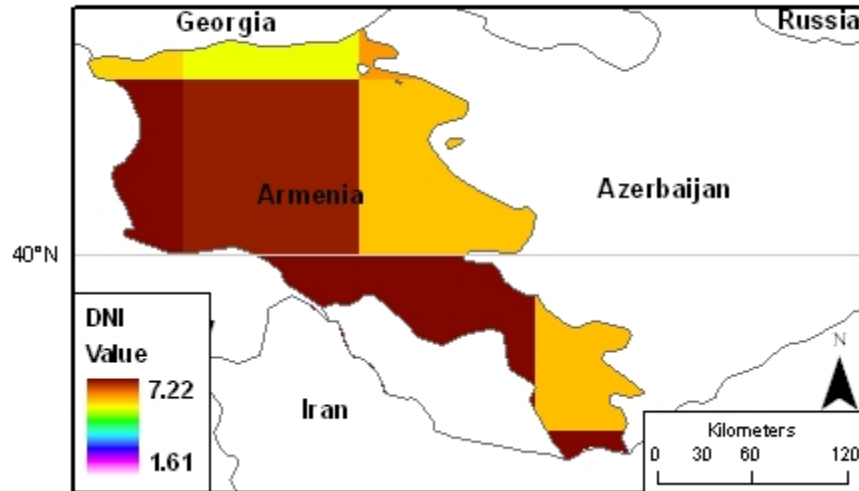
	Yerevan	Sevan	Kochbek
Jan	178	387	391
Feb	243	386	384
Mar	364	441	408
Apr	450	442	409
May	667	565	534
Jun	826	734	749
Jul	861	774	848
Aug	810	775	804
Sep	740	704	743
Oct	534	587	616
Nov	312	440	461
Dec	175	373	373
Yearly	6160	6599	6720

Monthly and annual direct solar radiation incident on surface normal to sunlight beams, MJ/m²

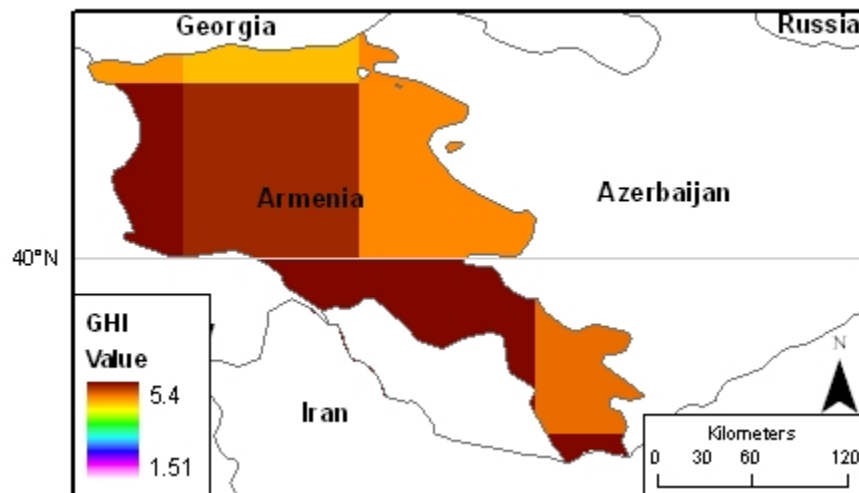
Armenia is very small and the climate is practically uniform throughout the country. The solar energy resource potential depends not on what part of the country the project is located, but more upon the height above sea level. It is evident from the tables that the solar energy resource potential increases at higher altitudes.

The solar resource maps below illustrate the direct normal and global horizontal irradiation throughout Armenia.

Direct Normal Irradiation for Armenia



Global Horizontal Irradiation for Armenia



Several private companies in Armenia produce, install and maintain solar thermal heaters. The most active companies are Solaren LLC and Technokom Ltd. Photovoltaic (PV) panels have been installed on some residential and commercial roofs throughout Armenia for the production of hot water. After current installations, there will be at least 50 kW of PV capacity.

Armenian law provides that purchasing of all the electrical energy from renewable energy sources is mandatory during the first 15 years after commissioning. As of January 2009, the announced feed in tariff is approximately 0.09 USD/kWh (31.343 AMD/KWh) without value added tax.

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6. Geothermal

Armenia is located in a zone with high tectonic activity and recent volcanic activity; however, the geothermal resources are not so rich and characterized by low-to-medium temperature thermal water. Currently thermal water is used only for swimming pools and in therapeutic baths. At this point only the most basic technologies are in use: spouting (free flow) well operation, direct use of geothermal water. Total installed heat capacity is less than 1 MWt. There is no national program promoting use of geothermal energy.

Armenia needs to carry out a careful analysis of available geological and geothermal data including the results of hydrodynamic investigations and testing of geothermal reservoirs in existing wells to reveal prospective areas in order to advance geothermal development. From reviewing published data, it appears technically possible to use the low-temperature thermal water with heat pumps in Martuni and Sisian.

The underground reservoirs containing the thermal water were formed both in the porous alluvial sedimentary rocks of intermountain basins and in fissured crystalline rocks. A narrow zone in the central part of Armenia (Sisian – Martuni – Sevan) is considered to have the best potential. The geothermal gradient here reaches 500 °C/km. The temperatures range from approximately 40-63 °C at depths varying from less than 200 m to around 1,150 m. The maximum temperature of 90 ° at 900 m depth was recorded at the Jermaghbyr site. The costs to develop a 25 MW plant at Jermaghbyr were estimated at 39.1 million USD.

Geothermal reservoirs in porous rocks containing high-temperature thermal water were investigated in some places:

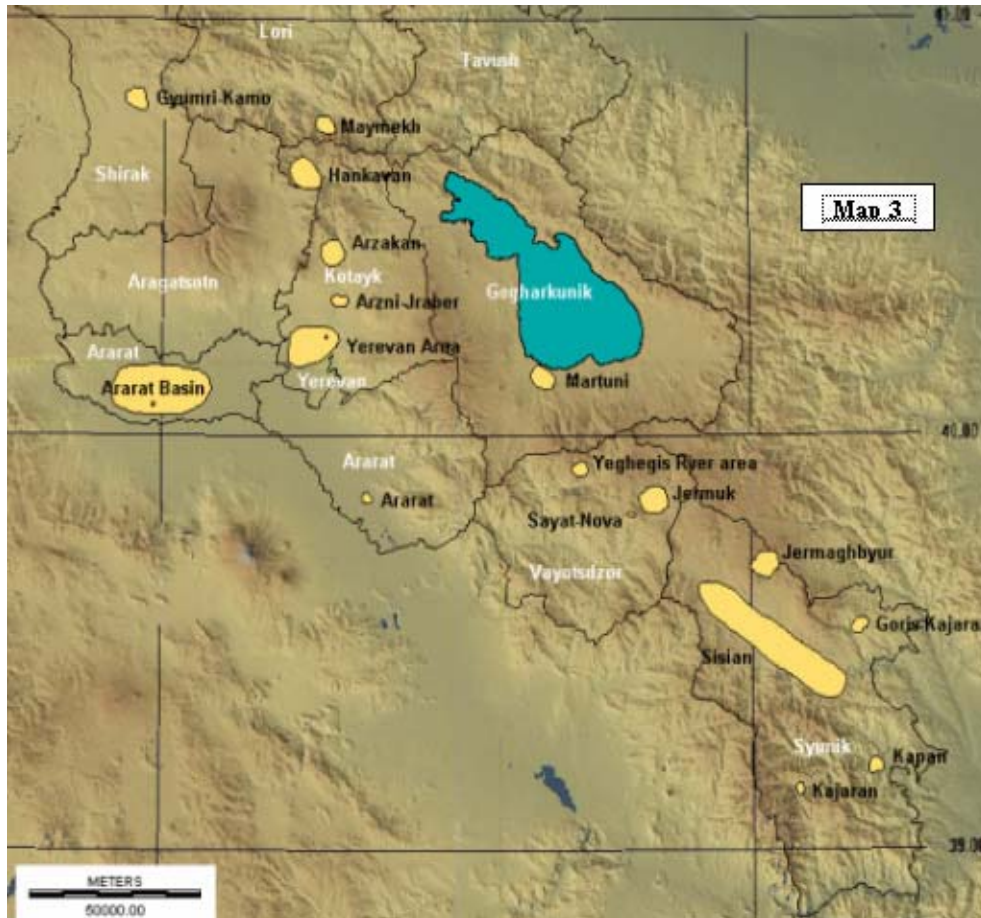
- Inflows of thermal water with temperature of 110 °C were obtained in the upper cretaceous sediments in wells with a depth of 2.5 km (Bajandur, Dilidjan, Vanadzor);
- Temperatures of thermal water of 100 °C were recorded at a depth of 2.6 km in the upper cretaceous sediments of Ararat basin (Razdan). It is projected that at a depth of 3.6 km the temperature might be up to 160 °C.

Considerable inflows of low-temperature thermal water were obtained in two regions:

- Martouni: prospecting wells with a depth of 1200 m investigated the reservoirs with the thermal water. Its temperature is 32-40 °C, mineralization 2-3 g/l, inflows- 2-50 l/s. The total thermal capacity is estimated as 8 MWt;
- Sisian: prospecting wells investigated the adjoining hydrothermal system, where the temperature of thermal water is 36-43 °C, its mineralization 4-6 g/l, the inflows 20-100 l/s. The total thermal capacity is estimated as 8 MWt.

Past and present information regarding geothermal energy in Armenia enabled researches to estimate 16 potential zones for geothermal energy utilization. The sites have are displayed below.

Map of Potential Geothermal Site in Armenia



From these sixteen zones, the highest temperatures were recorded for the Jermouk zone (63 °C). More than 30 wells have been drilled near the city of Jermouk. The Sayat Nova sites are only five miles from the Jermouk zones, but temperatures at Sayat Nova could exceed those of Jermouk. The Sayat Nova sites however are less researched.

The EuropeAid Project, "Support to the Energy Policy of Armenia," identified three zones with potential for a pilot project for geothermal energy utilization. The three zones are Gridzor-Noradus, Martuni-Armghan, and Karchakhpyur-Porak.

The Gridzor-Noradus and Martuni-Armaghan zones are the most studied potential sites; they could potentially be from the same geothermal system. The springs are located near the towns of Gavar and Martuni, so infrastructure could be available for geothermal energy consumption. The average temperature of these sites has not been concluded, but it is believed that the temperatures do not exceed 100 °C.

The Karchakhpyur-Porak zone is less studied, but it could proven to have better resource. Temperatures between 42-49 °C at depths of 550-750 m have been measured at the center of the zone. This zone encompasses Jermouk, the site listed as having the highest temperature in the study above (Renewable Energy Armenia, 2008).

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.

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7. Hydroelectric

The hydro potential of Armenia has been evaluated to be about 21.8 billion kWh/year, including 18.6 billion kWh from large and medium rivers and 3.2 billion kWh from small rivers. According to the Renewable Energy Armenia webpage, the economically feasible hydropower potential is about 3.6 billion kWh, with 1.5 billion kWh already utilized. The remaining hydropower potential is to be developed during the next 15 years.

Considering that the electricity production has been about 5.5 billion kWh during the last few years, utilization of hydro potential would satisfy 50 per cent of the current demand and not only avoid an energy crisis but also contribute to the development of the economy and increase the stability of improvements.

Currently, the total installed capacity of hydropower plants is approximately 1000 MW. The privately-owned Sevan-Hrazdan HPP Cascade has an installed capacity of 405.46 MW while the state-owned Vorotan HPP Cascade totals 556.3 MW.

Given the adoption of the "Energy Sector Development Strategies in the Context of Economic Development in Armenia" in June 2005, the Republic of Armenia plans to install 207 MW of new HPPs by 2025. This installation is planned to yield 1.34 TW of annual average production.

Potential hydro resources of Armenia are rather scarce, but through concentration of hydro resources on the territory, the potential is significant. The Razdan River, Lake Sevan, the Vorotan, Debed, Aras Rivers have the largest potential.

In estimation of total hydropower potential of Armenia, small hydro development was singled out. A small hydropower plant is considered to be less than 10 MW. The largest small hydro potential is concentrated in the Northern part of Armenia (the Kura River basin), Central part (Lake Sevan basin) and in the south of the Republic (the Aras River basin). As of September 2006, Armenia has 41 small hydropower plants (SHPP) with an installed capacity of 53.9 MW. Also, 51 SHPPs are either under construction or licensing. These unfinished SHPPs have an installed capacity of 118.7 MW. A study was completed in 2006 that estimated the potential for 53 new SHPPs that could have a combined capacity of 113 MW (Renewable Energy Armenia, 2008).

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8. Relevant Links

Please see webpage for relevant links.

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10. Country Contacts

Contacts made in the preparation of this assessment are gratefully thanked for their contribution to this report. Please see webpage for contacts listing.

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