WIND ENERGY IN ARMENIA: OVERVIEW OF POTENTIAL AND DEVELOPMENT PERSPECTIVES

ASSISTANCE TO ENERGY SECTOR TO STRENGTHEN ENERGY SECURITY AND REGIONAL INTEGRATION

CONTRACT NUMBER EPP-I-08-03-00008-00

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1. SUMMARY

Most of the existing power plants in Armenia exceeded their operation life time. The development of renewable energy sources is crucial to the security and quality of Armenia's electricity supply. Utilization of the indigenous sources will reduce Armenia's dependence on imported fossil and nuclear fuels, and thus enhance country's energy security and independence.

The total wind energy potential for grid-connected plants in Armenia is assessed to be over 1,000MW though about 500MW with annual generation potential of more than 1 billion kWh currently is considered as feasible. These wind plants could generate electricity equal to 17% of current consumption in Armenia. The Government is taking steps to promote renewable energy development in Armenia, having set a target to develop up to 500MW wind energy potential by year 2025. This is to open a new market for wind energy technologies and projects in the country, as well as forming a new industry and promoting economic growth.

The investment and trade policies of Armenia are considered to be among the most open in the CIS by international organizations. The government adopted a mandatory obligation for the grid to purchase all electricity generated by the wind power plants for at least during 15 years after start-up of operation. Although this is an important step, large wind projects often require 20 years for not leaving investors with uncertainty about return on investment. Armenia established a wind energy generation tariff set and regulated by the government and is intended to offer secure return on investment. The current feed-in tariff rate for wind is set at 32.8 AMD/kWh. Despite this, investment climate and legislative framework for wind energy development in Armenia still needs additional improvements to make wind projects economically attractive.

Large scale wind energy development will require grid extension and some upgrade; the government plans mid-term and long-term grid improvements to keep pace with overall energy market and wind plants needs.

Further, international financing institutions such as the EBRD, IFC, ADB, and BSDB have expressed interest in cooperating with potential investors in wind energy projects development in Armenia. Thus, having favorable regulation and along with favorable project financing structure, wind energy projects in Armenia can be economically viable, attracting foreign direct investments and contribute significantly in overall generation mix.

2. INTRODUCTION

2.1 INTERNATIONAL TRENDS

Electricity generation and consumption is increasing at high rates worldwide. Most of the power currently is generated at conventional thermal, hydro and nuclear power plants. Potential for wind energy is being recognized, making wind the fastest growing new source for electricity.

Depleting supplies of fossil fuel and negative impact on the environment from burning coal, oil and natural gas, as well as dependency on imported fuel impose risks to prosperity of many states. Since the wind is free, the cost of wind energy does not increase with time.

Consequently it is not surprising the states rethink their energy strategies towards clean and environmentally sound solutions as well as utilization of indigenous renewable energy sources.

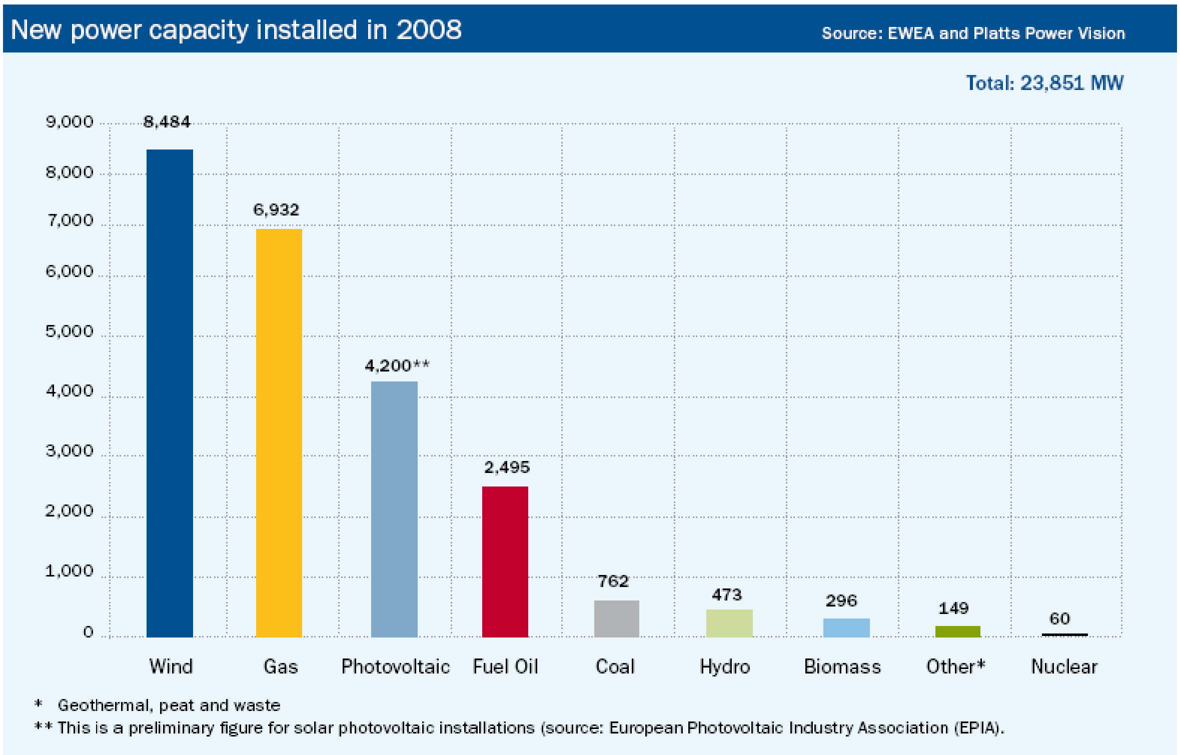
Nuclear energy plants, despite an absence of greenhouse emissions impose increasing demand on water use, emit significant heat and raise concerns about potential risks related to radioactive wastes and risks to human health. Due to increasing requirements on safety standards and technological improvements the cost of construction of nuclear power plants is getting high (the installation cost for the modern nuclear power plants is in range of USD 4-7 million per MW). The ecologists are also concerned about nuclear fuel storage and transportation issues while state security officials - about the potential threat of international terrorism on nuclear power plants and use of nuclear fuel.

Societies who are concerned about clean environment and safe human health as well as reduced dependency on foreign fuel supplies, consider intensive utilization of indigenous renewable energy sources. In some places renewable energy technologies are presently considered economically competitive to conventional plants. Considering the cost of environmental damage and threat to human health and other externalities these technologies become even more attractive.

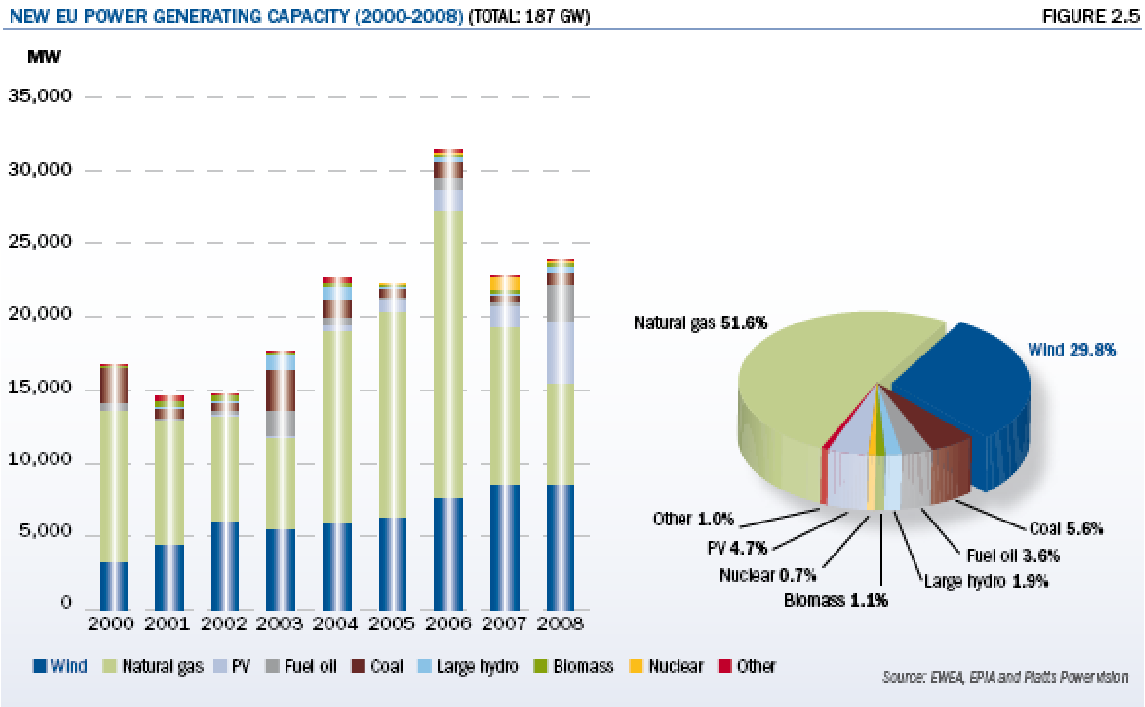
Growing population and increasing energy use drive the need for more water sources for public consumption, agriculture, and often overlooked is electricity generation. This water consumption and environmental concerns put pressure also on the use and management of hydro resources.

In this respect, wind energy does not use or consume water during electricity generation. Conventional thermal plants for example consume large amounts of water for cooling, generating and condensing steam, purging boilers and washing stacks. Older plants can consume as much as 190 liters/kWh of electricity produced. Although newer plants re-circulate water or use dry cooling, once-through cooling is a common technology. Water quality is affected by use at power plants because of the discharge temperature and water conditioning chemicals used. Many areas in Armenia are arid and water is a valuable commodity. Wind energy could displace water consumed in thermal plants totaling 250 million liters of water annually.

Wind energy markets are accelerating worldwide as its benefits are recognized. At the end of 2008, there were 65 GW of wind power capacity installed in the EU-27 producing 142 TWh hours of electricity, and meeting 4.2% of EU electricity demand. A binding target of 20% renewable energy has been set for the EU to achieve by 2020, which would mean approximately 35% of electricity coming from renewables by then. These goals are implemented through lucrative feed-in-tariffs, carbon-offset trading and other incentives. During 2008, about 8,500 MW of new wind capacity was installed in EU countries. In 2009, the US added 10,000 MW and China installed more than 12,000 MW. A myriad of strong financial incentives in the form of tax credits, Federal grants, individual state mandated Renewable Portfolio Standards and others drive the US market. Currently 14 states have over 1,000 MW installed. One state, Minnesota, is already getting 25% of electricity from wind and a detailed DOE national study showed 20% by 2030 is possible. In China, the growing demand for new indigenous clean energy sources is accelerating both wind and nuclear deployment. Wind turbines operating worldwide total 157.9 GW by the end of 2009.



One of the most important economic benefits of wind energy is that it reduces the exposure of state economies to fuel price volatility and pressure on the environment. Wind industry growth internationally during the last 5 years was at 25%-30% annual rate. According to the data of the European Wind Energy Association in 2008 about 30,000 MW capacity was put into operation worldwide. The European Commission's 1997 White Paper on Renewable Sources of Energy set a target for 40,000 MW of wind power to be installed in the EU by 2010. That target was reached in 2005, five years ahead of schedule. The overall White Paper target included an increase in electricity production from renewable energy sources of 338 TWh between 1995 and 2010. As EWEA's analysis shows, wind power is expected to produce 177 TWh in 2010, thereby meeting 52% of the overall White Paper target (EWEA, 2009).



Obviously, the ultimate goal for EU and many other countries is securing energy independence from foreign supplies and price fluctuation, making counties' economics more predictable and less vulnerable from political risks imposed by fuel (natural gas) exporting states as well as developing clean and safe energy alternatives.

2.2 STATE OF THE ENERGY SECTOR IN ARMENIA

The energy sector of Armenia is a core economic sector that supports economic development of the country. Under current economic growth rates one can anticipate that operation of the existing energy infrastructure should support the development of a more energy intensive economy in the upcoming years. This imposes challenges to the energy sector that suffer from the absence of domestic fossil fuel resources, dependency from imported fuel, non-diversified supplies, and luck of investments for the sector modernization.

The main components of the Armenia's energy sector are (i) thermal generation plants with total installed capacity of over 1,700 MW, (ii) large hydro power plants with total installed capacity of over 950 MW, (iii) small-medium hydro power plants – about 80 MW, (iv) nuclear power plant Unit #2 – 405 MW, (v) wind power plant – 2.6 MW, (vi) distribution network, (vii) transmission (high voltage) network, (viii) national dispatching center, and (ix) settlement center. There is a 210 MW combined cycle combustion turbine plant now under construction and additional 440 MW combined cycle plant planned. Of existing 3200 MW total generation capacity about 60% is privately owned (mostly by Russian companies). The nuclear power plant is under financial management of a Russian company and the distribution network is owned by another Russian company. The only wind power plant (built under an Iranian governmental grant program) is owned by state High Voltage Company.

Power Plants in Armenia - by Installed Capacity

PLANTS	CAPACITY	Output 2007	DESCRIPTION
THERMAL			
Three plants, dual fired	1,775 MW	1,489 GWh	Fuel is imported natural gas and fuel oil (mazout). Fuel oil use is minimal since 1997. Plants are aging, inefficient and in need of rehabilitation.
1 Hrazdan	1,110 MW Section 1: 2x50 and 2x100; Section 2: 3x200 and 1x210		Dry cooling towers, generally condensing type turbines
2 Yerevan	550 MW Section 1: 5x50; Section 2: 2x150		Wet cooling towers, condensing and heating (stem extracting) type turbines.
3 Vanadzor	96 MW 2x12, 1x25, and 1x47 MW		Wet cooling towers, backpressure type turbines, common header type.
4 Yerevan	210 MW	Under construction	Natural gas-fired combined cycle plant supported by JICA
HYDRO			
	1,027 MW	1,855 GWh	Current state of plants varies, most need major investment.
1 Lake Sevan cascade	556 MW		Lake Sevan feeds plants along the Hrazdan river primarily in the irrigation regime.
2 Vorotan River cascade	400 MW		There are three large plants totaling 400 MW.
3 Small HPP	115 MW		Dzora HPP (26 MW) and more than 70 small private HPPs.
4 Megri, Shnokh & Lori-Berd	140 MW 75 MW 60 MW	Planned	Feasibility studies have been completed
5 Numerous SHPP	184 to 305 MW	Future potential	Resource potential; including 158 MW licensed (not yet constructed)

NUCLEAR			
	408 MW	2,553 GWh	
Metzamor	408 MW		Only Unit 2 is operational. Unit 1 is not in use.
WIND			
Lori-1	4x660kW = 2.6 MW	2.5 MWh	Constructed with grant from Iran
TOTAL	3,209 MW	5,940 GW	
Source: US DoC ITA, with minor amendments.			

The natural gas for the thermal power plants is delivered in pipelines connected to Russia and to Iran. The entire natural gas transmission and distribution system is owned and operated by Armrusgazprom, a joint venture between the Russian company Gazprom, Itera (with a low quantity of shares), and the Armenian state. The principal stake of the shares is held by Gazprom.

Presently, Armenia has sufficient electricity generating capacity to meet electricity demand, but new capacity is a high priority, as demand (expected to grow at 2-3 percent annually) is estimated to outstrip supply when the 400 MW nuclear plant ends its operating life. Also, electricity supply is affected by aging and deteriorated thermal and hydropower plants; 70 percent of the country's hydroelectric plants are more than 35 years old and 50 percent are more than 50 years old; overall, 40 percent of the power plants are more than 30 years old.

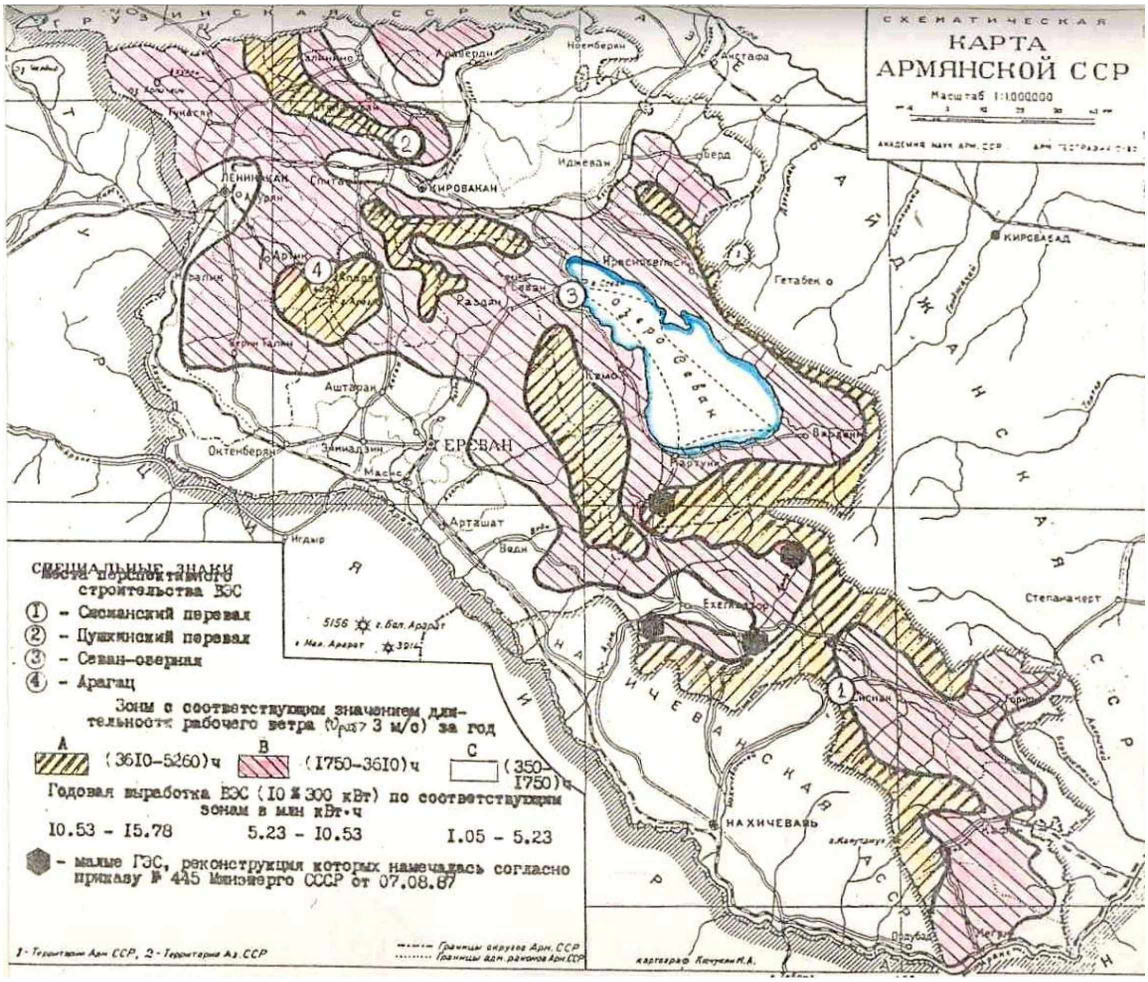
Armenia's government has taken steps towards overcoming the above mentioned challenges also by promoting renewable energy. Indigenous renewable energy resources, wind energy along with hydro energy potential is considered as one of the most promising and competitive areas for electricity supply in Armenia.

Wind energy potential in Armenia, that could be economically feasible for commercial utility scale wind farms at this stage is assessed at about 500 MW with annual generation potential of more than 1 billion kWh. There are a number of perspective areas in Armenia. On the other hand, micro scale wind energy measurements are still needed to validate the wind energy potential at the most promising areas.

3. WIND STUDIES

Wind energy studies in Armenia began in late 1980s. In the beginning most of the wind energy potential studies were based on synoptic data from meteorological stations (historically since early 1900s over 80 stations were installed in Armenia that covered most of the area). Most of those stations are out of operations now. Unfortunately, the wind data recorded at those stations were and are not trust-worthy as measurements were not done by accurate tooling and approaches, and data collected only few times during a day.

The first wind energy map of Armenia was actually developed by an Armenian Ecotech scientific association back in 1989-1990. This map, however, highlighted at very macro scale level the possible perspective areas for wind energy development.



In the beginning of 1990s a 10m wind measurement station was installed at Pushkin pass. In the mid 1990s, based on the above data, a Japanese TOMEN company had developed pre-feasibility studies for two sites for wind farms development at Pushkin and Kochbek (Vorotan) passes.

The next phase of actual wind energy potential studies started in 1999-2000 when two wind monitoring projects launched in Armenia. One of those projects was funded by the SolarEn company (USA). Monitoring was conducted at Sotk (Zod) pass area, where seven measurement masts were installed (10m, 20m, and 40m towers). In parallel, five 50m measurement masts were installed in Karakhach pass, Pushkin pass, Selim pass, the Lake Arpi area and northern coast of Lake Sevan (Ardanish) under an Armenian-Dutch project funded through the government of the Netherlands. Advanced wind and climatic measurement equipment were used for both projects. As a result, the two projects identified three most promising areas for utility scale projects (at Karakhach, Zod and Pushkin passes).

Back in 2001-2003 a major study – Wind Atlas of Armenia was completed under USAID funding. Based on three data sources – NASA, Armenian meteorological stations, and five measurements done by SolarEn (USA) at Karakhach pass, Aparan site, Zod pass, Gagarin site and Vorotan pass areas the National Renewable Energy Lab (USDoE) has developed wind energy atlas of Armenia. The study came up with rather accurate macro-scale mapping of wind energy potential and most perspective areas for utility scale wind farms. It indicated the nature of wind in complex Armenian terrain and classified the wind potential.

Good-to-Excellent Wind Resource at 50 m

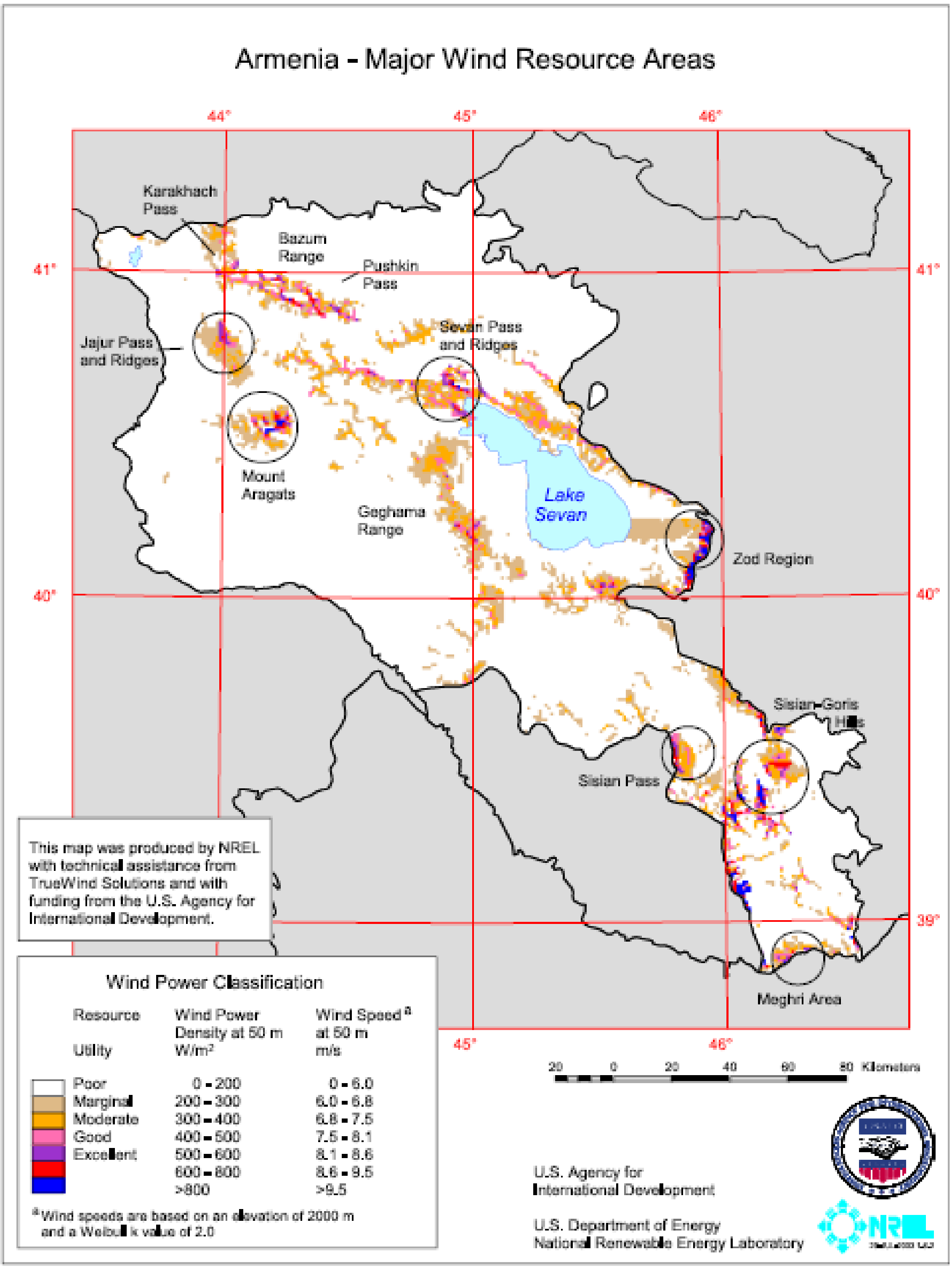
Wind Resource Utility Scale	Wind Class	Wind Power at 50 m W/m^2	Wind Speed at 50 m m/s*	Total Area km^2	Percent Windy Land	Total Capacity Installed MW
Good	4	400-500	7.5-8.1	503	1.8	2,500
Excellent	5	500-600	8.1-8.6	208	0.7	1,050
Excellent	6	600-800	8.6-9.5	165	0.6	850
Excellent	7	>800	>9.5	103	0.4	500
Total				979	3.5	4,900

Moderate-to-Excellent Wind Resource at 50 m (Utility Scale)

Wind Resource Utility Scale	Wind Class	Wind Power at 50 m W/m^2	Wind Speed at 50 m m/s*	Total Area km^2	Percent Windy Land	Total Capacity Installed MW
Moderate	3	300-400	6.8-7.5	1,226	4.3	6,150
Good	4	400-500	7.5-8.1	503	1.8	2,500
Excellent	5	500-600	8.1-8.6	208	0.7	1,050
Excellent	6	600-800	8.6-9.5	165	0.6	850
Excellent	7	>800	>9.5	103	0.4	500
Total				2,205	7.8	11,050

[*] Wind speeds are based on an elevation of 2000 m and a Weibull k value of 2.0

<u>Assumptions</u>
Installed capacity per km^2 = 5 MW
Total land area of Armenia = 28,400 km^2



The main outcome of the study was not only the perspective areas but also the data on seasonal and diurnal wind distribution. Due to different influences (terrain, thermal circulations) the seasonal pattern of wind regime in Armenia is complex. At some locations there are distinct resource maximums in winter, and some in summer, while nearby sites could have much different seasonal patterns some with both a winter maximum and summer maximum. As for diurnal distribution, it is influenced by site elevation and terrain. Also, as another study indicates (S.A.Arustamyan, 1988) strong winds are observed during winter months when cold fronts pass the terrain and low pressure cyclones during valley-mountainous circulations. For the Lake Sevan area for example, the winds have certain diurnal pattern: in day and evening time winds mostly blow from the lake to the cost, while in the morning and at night – from the cost to the lake. In general, diurnal changes of winds occur due to significant thermal gradients between mountainous ranges slopes and valleys as well as water and ground surfaces.

Generally, both Wind Atlas and further monitoring show that about 1/3 of high winds occur in winter while during the day strong winds at ridges occur at night and the evening wind maximums occur during summer.

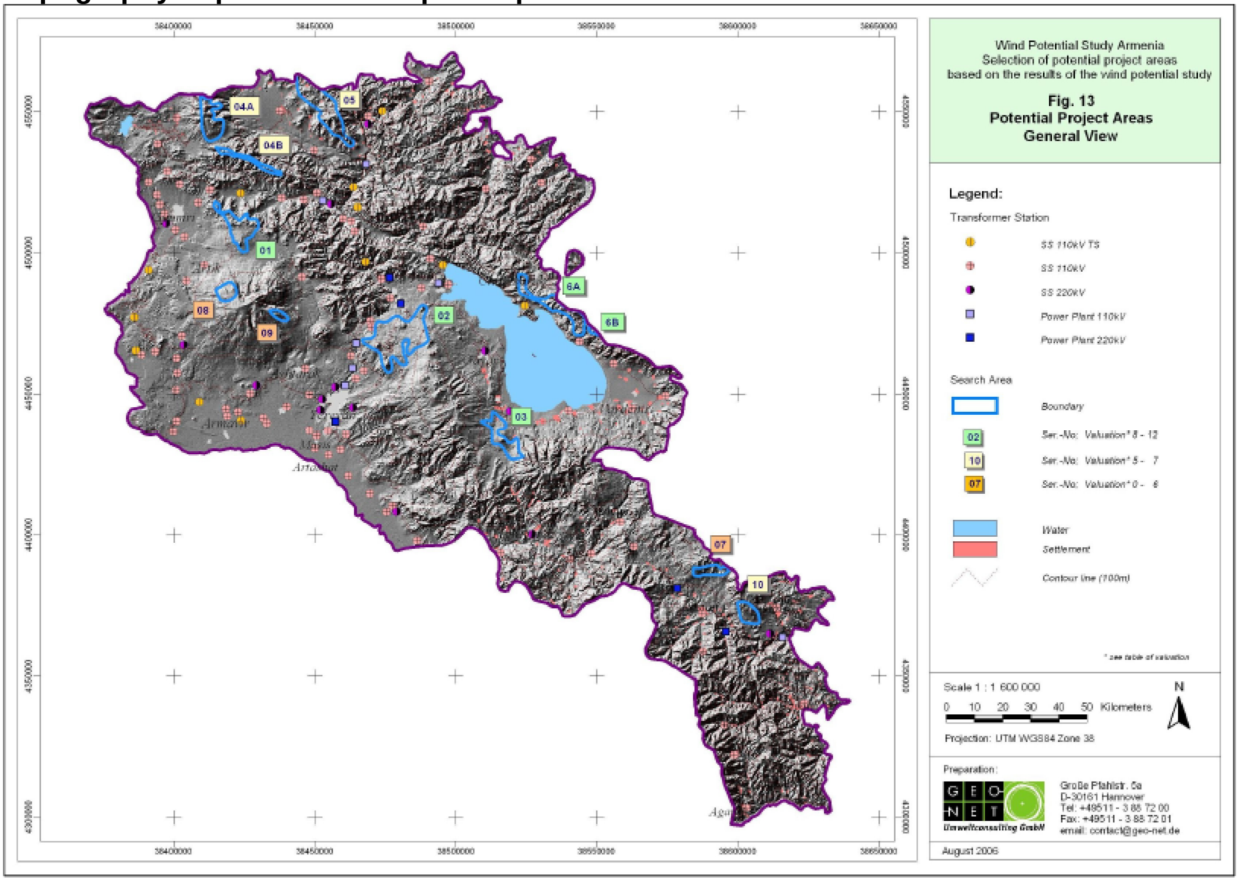
At the same time, mapping had certain limitation especially for such complex terrain areas in Armenia and on mountain ridges. Although the wind resource map and other characteristic information provided by NREL help in identifying prospective areas (9 sites) for wind energy development it was highly recommended to conduct micro-scale wind measurement to validate the resource estimates and evaluate precise power projection.

In 2003-2004 SolarEn company conducted wind measurement at two sites (Pushkin Pass and Sisian airport areas) funded by Iranian government. Based on data validation there was a final decision to build a pilot wind farm project at Pushkin pass with total capacity of 2.6MW (Lori-1 wind power plant with 4 x 660kW wind turbine generators). The project cost about 3.2 million USD and was funded by the Islamic Republic of Iran.

Lori-1 wind power plant with four 660 kw turbines funded by Iran

In 2006-2007 German GEONET GmbH (funded by KFW) conducted a selection of potential wind farm project areas based on the results of a wind potential study for Armenia. The contents of this assignment included a 3-D-FITNAH-simulation of the expected long-term annual mean wind potential based on actual, long-term meteorological input data. The study based on developed valuation technique has identified 12 sites of which two - at Fontan and Chambarak - are the most promising areas.

Topography at potential wind power plant sites



Identification		Criteria for Grading						
		Wind Speed		Distance Transformer Station		Elevation above Ground		
Ser.-NO*	Name	MEAN (m/s)	Valuation-1	km	Valuation-2	MEAN (m)	Valuation-3	Sum of Valuation, Rank Order
2	YEREVAN-O	7,0	4	9	4	2116	4	**12**
6A	CHAMBARAK-S	7,0	4	6	4	2425	2	**10**
6B	CHAMBARAK-S	7,2	4	7	4	2679	0	**8**
3	GAVAR-S	6,5	2	6	4	2342	2	**8**
1	GYMRI-O	6,6	2	12	2	2194	4	**8**
4A	GYMRI-N	7,3	4	12	2	2727	0	**6**
4B	GYMRI-N	7,1	4	14	2	2665	0	**6**
10	GORIS-N	6,4	0	9	4	2326	2	**6**
5	TUMANIAN-W	6,3	0	12	2	1868	4	**6**
8	ARTIK-S	6,6	2	11	2	2863	0	**4**
7	SISIAN-N	6,9	2	16	2	2747	0	**4**
9	APAHAN-S	6,4	0	17	0	2646	0	**0**

In 2007 Danish Energy Management and SolarEn completed a wind measurement project (at 40m height) funded by EU/EuropAID at Semyonovka pass area. The study showed the site has moderate wind energy potential (annual average wind speed of about 6.5 m/s). A pre-feasibility study for 35MW (with over 60 million kWh/year generation) wind farm was developed.

Project team at wind measurement installation (Semyonovka pass)

In 2007 SolarEn conducted a privately funded study and highlighted 20 potential sites of which 10 are most promising for wind energy farms projects.

In 2008 funded by the World Bank/GEF the Armenian R2E2 Fund highlighted 5 promising sites in Armenia for further wind energy development projects.

Confirmed by monitoring	Currently (February 2008) not confirmed by monitoring
Pushkin pass: 19.5 MW total installed capacity, about 48.9 mln. kWh annual average production **Karakhach pass** (Eastern gate): 125 MW total installed capacity, about 320 mln. kWh annual average production. **Zod pass:** 50 MW total installed capacity, about 120 mln. kWh annual average production	**Karakhach pass** (Western gate): 125 MW total installed capacity, about 300-320 mln. kWh annual average production. **Sisian pass** (Bichanag pass): 155 MW total installed capacity, about 420-430 mln. kWh annual average production. **Charentsavan region (Fontan)**: 20 MW total installed capacity, about 45 mln. kWh annual average production.
Subtotal: 195 MW with about 490 mln. kWh	Subtotal: 300 MW with about 765 mln. kWh
495 MW total installed power, about 1.26 billon kWh annual average production	

In the same year, the Greek government funded a wind potential study. The study was based on data analysis on OptiRES and RETScreen software. Similar to the NREL's Report the study highlighted about 5,000 MW wind capacity of which about 500 MW as economically feasible.

It is worth to mention that during 2000-2010 there were a number of other privately funded studies and wind measurement projects conducted by two companies, SolarEn and Arenergy, mostly at areas identified by Wind Atlas of Armenia with a purpose to validate the wind data at micro-scale level and assess the power generation potential at selected sites. At the same time, Arenergy is planning to launch further wind measurement activities at a number of perspective areas.

Currently there is an on-going wind measurement project at 50m height above ground level that is conducted by German MVV-Decon and Arenergy companies (funded by KfW) at the Fontan area to evaluate potential for 50-75MW wind energy farm.

Two project development companies, Arenergy and ZodWind, have completed feasibility studies for wind farms at Karakhach pass and Zod pass areas. In 2009 Arenergy had applied for construction licenses for building a 20 MW project while ZodWind is to apply for construction license in 2010. Presently, two companies are in negotiations for tariff revision to make projects economically viable and secure project financing.

4. WIND MEASUREMENTS

All of the wind resource measurement campaigns in Armenia have been conducted using portable masts that are limited to 50 m height above ground level. Although measured data generally agrees with the theoretical wind flow model results and resource estimates, there is an important limitation. Modern utility-scale wind turbines are typically installed on tall 60 to 80 m towers. The blades operate much of the time in the air flow another 20 to 30 m above the hub height of the turbine. Consequently it is important to have wind measurements at least to hub height. These data are essential to obtain bank financing for large scale projects.

Normally wind velocity increases with height above the ground but this is not always the case. The changing wind at various heights above the ground is described as wind shear. Wind shear can be determined by placing wind speed anemometers at three heights above the ground. Shear is normally driven primarily by large scale weather patterns and upper air jet streams that drag along air atmospheric boundary layer near the ground where turbines operate. Uneven heating and the shape of terrain and bodies of water also affect air flow and shear and cause turbulence. In some cases wind blowing over a hill can cause local velocity acceleration near the ground with wind speed actually decreasing 80 to 150 m above ground.

Most of the measurement campaigns completed in Armenia included three levels of measurements, but extrapolating wind substantially above the highest anemometer introduces uncertainty that can result in bankers arbitrarily reducing resource estimates in project financing applications. This is often referred to as P-90 or P-80 where wind resource estimates are assumed to be 90% or less than the applicant’s estimates. This significantly reduces the attractiveness of debt financing and overall project economics.

There is another important limitation in prior measurements. All wind measurements were made with unheated anemometers. During and following snow and ice storms the rotating cups can freeze up and can be covered with black ice that can persist for days or even weeks in very cold weather. Ice changes the rotation inertia and aerodynamic properties of anemometers causing underestimates of wind resources. The average annual temperature is 2 degrees centigrade and much lower at prospective wind sites and it is likely that icing has resulted in significant underestimates of the wind resource.

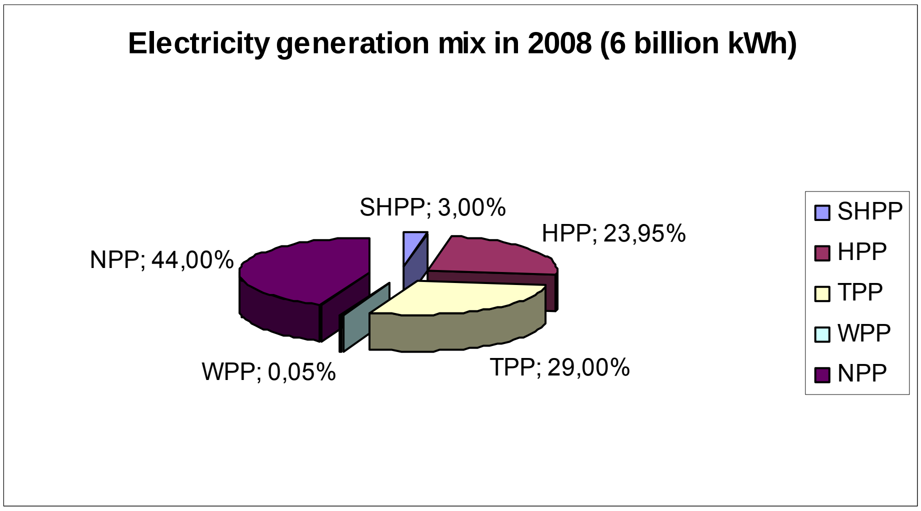
To overcome icing problems it is necessary to employ heated “Ice Free” instrumentation. These sensors draw substantial power and consequently require connection to an AC power source. These measurements are needed to accurately estimate energy production during winter months that are typically the windiest. Investors normally demand this information.

It should be noted that icing does not present structural problems or significant operational limitations for wind turbines. Turbines can operate during rain, snow and ice storms. The weight of ice or snow accumulated during no-wind periods does present any structural problem, as wind machines are designed to endure much higher loads during extreme wind events. Following an ice storm when winds come up, flexibility of wind turbine blades results in ice shedding and the area should be avoided, as is the case around any tall structure.

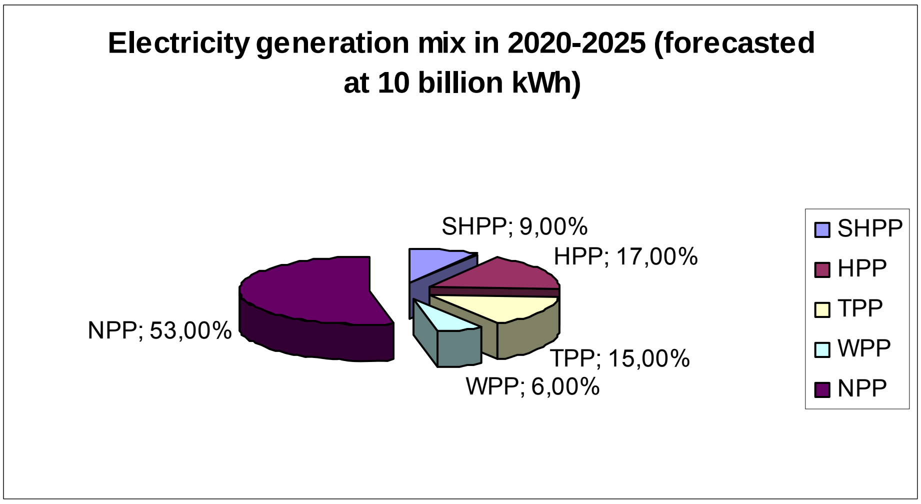
5. WIND ENERGY POTENTIAL

Armenia possesses significant wind energy resources. As indicated above a number of studies showed the most promising areas for commercial wind power plants development. Theoretical wind energy potential is assessed at over 11,000 MW, of which about 5,000 are those areas with good to excellent wind energy potential. In terms of technical feasibility a number of perspective sites can support development of over 1,000 MW wind farms in Armenia. However, only few sites with total potential of about 500 MW can be most economically feasible.

In its development strategy paper the Ministry of Energy and Natural Resources of the Republic of Armenia emphasized the importance of wind energy in the country and plans to develop up to 500 MW wind energy potential by year 2025. In 2008 the electricity generation mix in Armenia by various generating plants was about 6 billion kWh. The share of wind energy generation was negligible (lower than 3.5 million kWh).

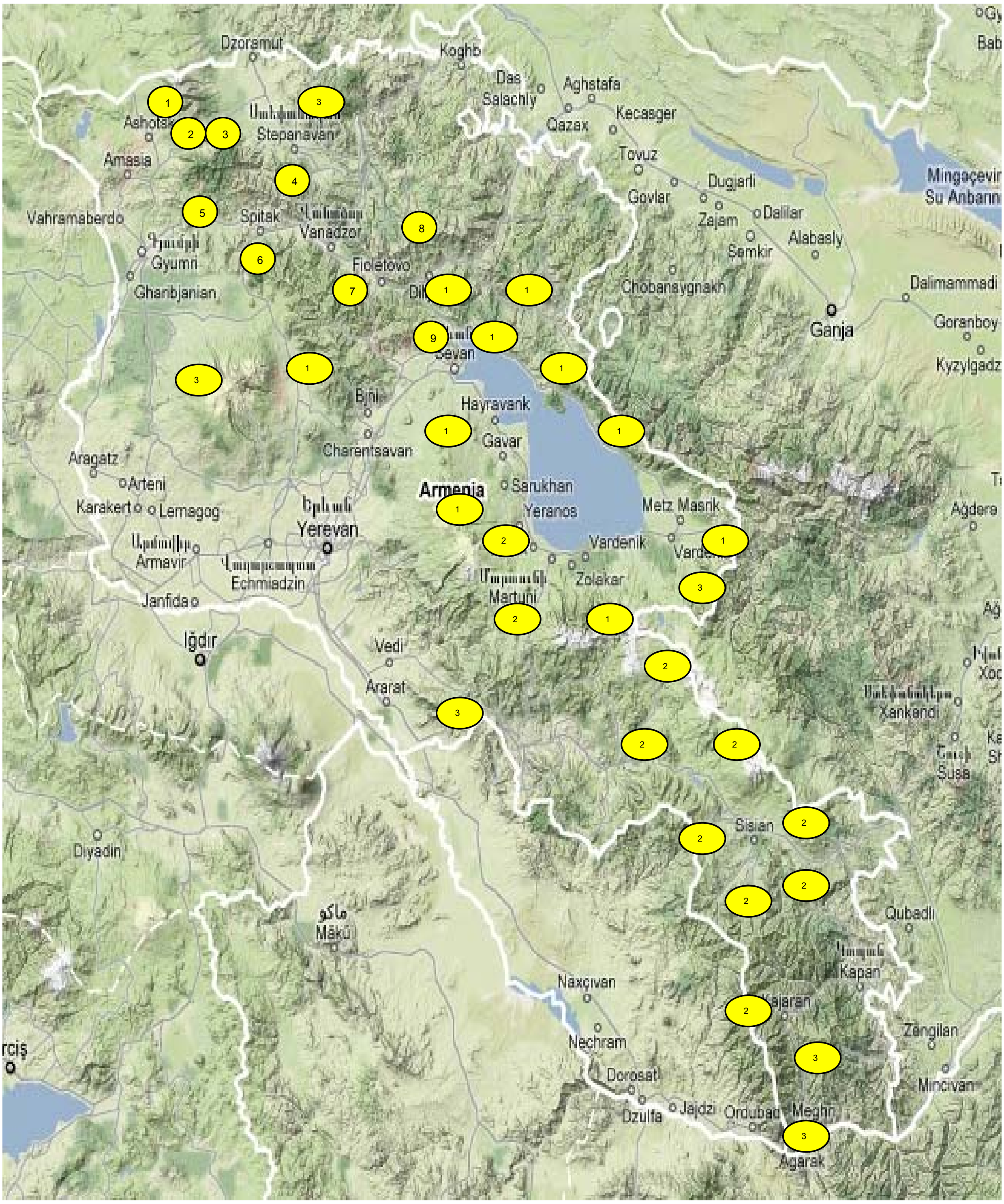


On the other hand, based on the government's development strategy to develop 450 MW-500 MW capacity wind power plants by 2025 one could expect a significant increase in the wind energy generation share (from 6%-10%) in the overall electricity generation mix that by the Ministry of Energy is forecasted to reach about 10 billion kWh/year.



Based on the analysis of the previous wind studies a map with perspective locations for wind energy farms projects has been developed under this task. It indicates 35 main areas for potential utility scale wind energy projects.

Potential wind power plant sites



The table below summarizes the sites with an indication of preliminary assessed capacities and power projections. Again, to assess the exact location of the sites and their wind energy potential accurate wind measurement is required. The sites have been identified based on the macro-scale wind mapping, terrain, land availability, infrastructure closeness as well as closeness of protected areas. The average capacity factor for wind power sites is in range of 20%-22%.

	Conventional name	Installed capacity, MW	Projected generation, kWh/year	Location from the nearest populated area
1	North Karakhach	80	160000000	16 km south-east of Ashotsk
2	Karakhach Pass	100	245000000	12 km north-east of Musayelyan
3	Eastern Karakhach	40	75000000	15 km south-west of Tashir
4	Pushkin Pass	25	50000000	6 km west of Pambak
5	Jajur Pass	15	25000000	16 km west of Spitak
6	Spitak Pass	30	45000000	16 km south-east of Spitak
7	Tsakhkunyants mountains	20	30000000	4 km south of Meghradzor
8	Tavoush	10	15000000	4 km north of Teghut
9	E. Pambak mountains	60	105000000	8 km north of Ddmashen
10	Semyonovka Pass	35	60000000	4 km north of Semyonovka
11	Areguni mountains	50	85000000	10 km east of Tsovagyugh
12	North Chambarak	10	15000000	18 km north-east of Chambarak
13	Chambarak	15	25000000	4 km west of Chambarak
14	South-East Chambarak	15	25000000	2 km north of Tsapatagh
15	Sotk Pass	50	125000000	15 km east of Sotk
16	Eastern Aragats	10	15000000	6 km west of Kuchak
17	Fontan	75	140000000	10 km east of Fontan
18	Eratumber	10	15000000	15 km west of Yeranos
19	South Vardenis	10	15000000	20 km south-west of Vardenis

20	South Gavar	10	15000000	10 km south of Upper Getashen
21	Selim Pass	40	65000000	6 km east of Selim Pass
22	North-Eastern Jermuk	10	15000000	12 km north-east of Jermuk
23	Vorotan Pass	20	30000000	4 km north of Vorotan Pass
24	North Shaki	20	30000000	15 km north-east of Shaki
25	Sisian Pass	100	265000000	12 km west of Angeghakot
26	Western Goris	50	85000000	8 km west of Goris
27	South Shamb	60	120000000	8 km west of Tatev
28	South Harjis	50	90000000	4 km north of Dastakert
29	Western Kajaran	15	30000000	8 km west of Kajaran
30	Kajaran	10	15000000	10 km north of Shishkert
31	Agarak	10	15000000	6 km north-east of Agarak
32	Privolnoe	40	55000000	6 km south-east of Privolnoe
33	Aragats	60	100000000	6 km west-north of Mastara
34	Urtslanj	10	15000000	4 km north-east of Urtslanj
35	Nerkin Shorzha	20	35000000	3 km east of Nerkin Shorzha
	Total	**1 185**	**2 250 000 000**	

6. DEVELOPMENT PERSPECTIVES

As indicated in the previous section the technically feasible wind power capacity for utility scale projects is over 1,100MW with annual generation potential of 2.25 billion kWh. At the same time, development of wind farms will not be economically feasible at all sites due to complexity of access, remoteness from the infrastructure as well as in terms of overall energy system stability. Moreover, current regulation does not support even starting construction of wind farms at the most promising sites (with strong winds and highest capacity factors). Sometimes, as said earlier, some good locations could be far from the grid or require grid upgrade or difficult to access.

On the other hand, there are also a number of limitations that should be considered while assessing the development perspectives of wind energy in Armenia. Regulative and legal aspects or limitations for wind energy development have been discussed in Sub-task 2.1 Report of this Task# 2. Economic aspects of wind development will be discussed in coming section.

6.1 TECHNICAL LIMITATIONS

Transportation. Wind turbines (generally manufactured in North America, Europe or Asia) will have to be transported to Armenia by ship (to the closest sea port in neighbor state), rail and truck to the project site. Major roads and rail routes for Armenia are shown below.

The road interconnects Armenia and Iran in the south, and rail and road interconnect Armenia and Turkey. The interconnects with Turkey and Azerbaijan are presently closed due to the absence of diplomatic relations between Armenia and those states.

Transportation companies' officials indicate that transportation of components over 30 meters in length could be problematic due to some sharp turns on the roads in Armenia. On the other hand, rail transport of the longer components (up to 36m) could be possible. The allowable standard width of components for rail transport in Georgia and Armenia is 3.25 meters. At the same time, transportation companies' officials indicate that transportation of components up to 4.0 meters in width and height was possible with special permits; however, the width of rail tunnels along the route would prevent any larger objects from being transported. Road transport of objects with a height greater than 4 meters was considered impractical due to the relatively low nature of bridges.

Thus, transportation is a limiting factor that determines the maximum turbine size that can be used for wind energy project, and due to the relatively complex terrain at most of the potential sites turbines of up to 1.5 MW can be installed at the sites.

At the same time, the use of lattice towers is also limited as the cold winter environment of the sites makes maintenance of the turbines on lattice towers difficult and their use in these environments is generally not recommended.

Electricity Grid. The electricity grid consists of 1,323 km transmission lines at 220 kV. Current peak demand in winter is due primarily to space heating loads. Daily highest demand is typically 1.200 to 1,400 MW in winter while in summer 800-900 MW. The grid system has long runs and lines are generally heavily loaded. Additional transmission capacity upgrades are planned to reinforce existing lines and to transfer power throughout the Caucus Region. Distributed wind plant could provide support on these existing lines in rural areas. The distance to populated areas from most wind sites is less than 20 km.

The summer load is expected to increase due to more air conditioning use. The 407 MW nuclear plant is the primary source of energy in summer except when it is shut down for about one month for refueling. This plant currently provides 42% of the electricity year round. As a base load unit the nuclear plant has limited flexibility to decrease output during low demand periods and could eventually result in curtailment of wind plant production if installed wind capacity grew large. That scenario is unlikely in the foreseeable future.

At the same time, development of large wind projects (over 100 MW) in one location may require grid extension and possibly upgrades in substation infrastructure. None of these issues are unique to wind and are typical for adding any conventional generating systems.

As new wind plants are connected, grid stability and loading are important and need to be studied. Experience in other countries has shown that wind penetration of 20% or less is not disruptive to the grid system, but it is important to properly engineer the interconnection.

Tower Erecting. Presently, Armenia lacks in specialized equipment (cranes and trucks) and tools needed for transporting the wind turbine generators components (mostly tower parts) in complex terrain as well as erecting heavy parts at required height (50-60m).

High Elevation. Due to high elevation of most potential sites (2200m above sea level (a.s.l.) – 2600m a.s.l.) and low air density the actual power generation in Armenia is 22%-27% less than for offshore locations for the same wind speed. High elevation also is characterized by icing phenomena that may hamper operations of the plant.

Cold Climate. Another point for technical and economic implications can be cold climate at most of sites where winter extreme temperature could be lower than minus 20 degree Celsius, that will require installation of heated (more expensive) equipment. On the other hand, low temperature and denser air can compensate generation losses due to high elevation (an average annual temperature close to 0C, that is common for the most highlands in Armenia, make air up to 5% denser compared to +15C standard for rating turbine output).

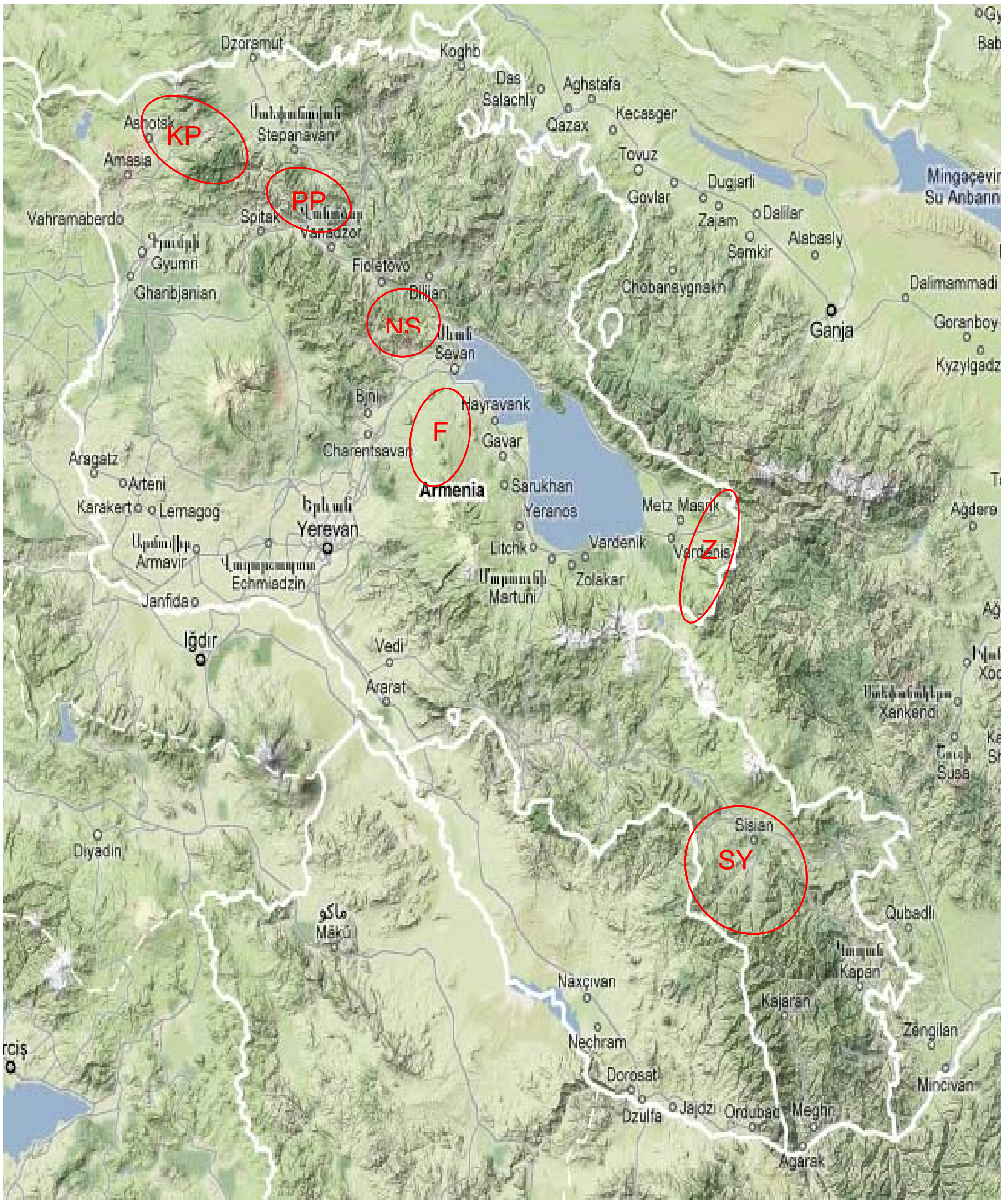
Wind Data. Available data for most of hydro-meteorological stations in Armenia are not representative for wind resource assessment as they are located in low wind areas, close to facilities or natural barriers that do not allow plausible wind speed measurement. Measurements at these sites are recorded by hand registration in a log book, normally four times per day. Also, most of stations are equipped with old equipment (drag plates, heavy rotating anemometers, etc.). For this reason most of this data can not be used as indicator of reliable resource data. The latter fact was also indicated in most of wind studies. Any wind farm development project will require conducting new wind measurement programs.

Complex Terrain. Most of the windy sites in Armenia are located at complex mountainous areas or ridges, also with complex geology. This imposes difficulties in transporting wind turbine components as well as significantly increases the construction costs.

6.2 PERSPECTIVE SITES

In this respect, of those 35 areas only a few with strong wind regime (most validated through measurements), available infrastructure and land, closeness to the grid and out of protected areas can be considered as the most perspective ones. The total capacity of those sites is over 500 MW with annual generation potential of over 1 billion kWh. The perspective areas are indicated on the map below. One should expect construction of wind farms most probably at these sites in coming 15-20 years.

Topographic areas for six high potential wind power plants



These are six main areas with over 10 perspective sites. The total installed capacity at those sites is preliminarily assessed to be about 800 MW with annual generation potential of over 1.6 billion kWh.

	Conventional name	Installed capacity, MW	Projected generation, kWh/year	Location and available infrastructure
KARAKHACH PASS AREA				
1	North Karakhach	80	160000000	16 km south-east of Ashotsk:

				-access roads in summer -about 12km from 110kV line
2	Karakhach Pass	100	245000000	12 km north-east of Musayelyan: -access roads -about 10km from 110kV line
3	Eastern Karakhach	40	75000000	15 km south-west of Tashir: -access roads in summer -over 15km from the 110kV line
PUSHKIN PASS AREA				
4	Pushkin Pass	25	50000000	6 km west of Pambak: -access roads in summer -about 3km from 220KV and 110kV lines
NORTH-EAST SEVAN AREA				
5	E. Pambak mountains	60	105000000	8 km north of Ddmashen: -access roads in summer -closeness of railway -about 8km from 110kV lines
6	Semyonovka Pass	35	60000000	4 km north of Semyonovka: -access roads -about 2km from 110kV lines
7	Areguni mountains	50	85000000	10 km east of Tsovagyugh: -access roads in summer -closeness of railway -about 3km from 110kV lines
SOTK PASS AREA				

8	Sotk Pass	50	125000000	15 km east of Sotk: -access roads -closeness of railway -about 8km from 110kV lines
9	Nerkin Shorzha	20	35000000	3 km east of Nerkin Shorzha: -access roads in summer -about 11km from 110kV lines
FONTAN AREA				
10	Fontan	75	140000000	10 km east of Fontan: -access roads -closeness of railway -about 7km from 110kV lines
SYUNIK AREA				
11	Sisian Pass	100	265000000	12 km west of Angeghakot: -access roads -about 8km from 220KV and 110kV lines
12	Western Goris	50	85000000	8 km west of Goris: -access roads -about 8km from 110kV lines
13	South Shamb	60	120000000	8 km west of Tatev: -access roads in summer -about 2km from 110kV lines
14	South Harjis	50	90000000	4 km north of Dastakert: -access roads in summer -about 3km from 220KV and 110kV lines
	Total	**795 MW**	**1 640 000 000**	

The Energy Sector Development Strategy in the Context of Economic Development in Armenia Paper (adopted by the Government of Armenia at June 23, 2005 session N 1 resolution of N 24 protocol) indicates that during the next 15-20 years Armenia should maximize use of domestic renewable energy resources for power generation, which may amount to about 5,100 GWh, including about 1,500 GWh for wind energy. The projection for wind energy development in the above mentioned paper highlighted some timing and capacity as shown below:

Period 2005-2010	Construction of wind power plants with a total capacity of 100 MW
Period 2011-2016	Construction of 200 MW of wind power plants
Period 2017-2025	Construction of wind power plants with a total capacity of 200 MW (the remaining 500 MW capacity will be built if the price per unit significantly decreases)

These planning goals have not been due to the barriers discussed later. There are also concerns about grid capacity and stability when these wind plants are added. Grid interconnection studies are needed for each plant larger than 20 MW, but experience in other countries has shown that wind energy penetration at these levels will be disruptive. Preliminary information from the Ministry of Energy indicates that additional grid improvement and regional network development is needed to absorb more than 250 MW-300 MW wind capacity in 10-15 years term. This area will be further analyzed by expert consultants.

In this respect, most probably this is the cap capacity that one should expect for wind development in Armenia by 2020-2025. Accordingly, the wind energy development timing and scaling will probably be different than planned; and the estimation is that in short term and medium term perspectives one should expect in overall about 300-350MW of wind capacity development in Armenia:

Site	**Total Potential**		**By 2015**		**Accumulated by 2020**	
	Capacity MW	**Generation kWh/year**	**Capacity MW**	**Generation kWh/year**	**Capacity MW**	**Generation kWh/year**
Karakhach	220	480 000 000	20	50 000 000	140	300 000 000
Zod	50	125 000 000	20	50 000 000	20	50 000 000
Pushkin	25	50 000 000	-	-	15	30 000 000
East Pambak	60	105 000 000	-	-	60	105 000 000
Fontan	75	140 000 000	-	-	75	140 000 000
Total:	**430**	**900 000 000**	**40**	**100 000 000**	**310**	**625 000 000**

This estimate basically relies on the fact that wind measurement at those sites either have been done or are in process, and best sites as of today are selected. The investors will be interested in developing those sites where monitoring and feasibility studies are completed rather starting development at zero stage. Also, the development of wind energy will directly depend on investment climate, particularly on tariff. Without increased wind tariffs it is unlikely that development will proceed, or only one or two best sites will be developed. As of today, development at two best sites – at Karakhach and Zod has been stopped because of failure to secure investment under current tariff rate of AMD 32.8/kWh (or USD 8.2 cents/kWh).

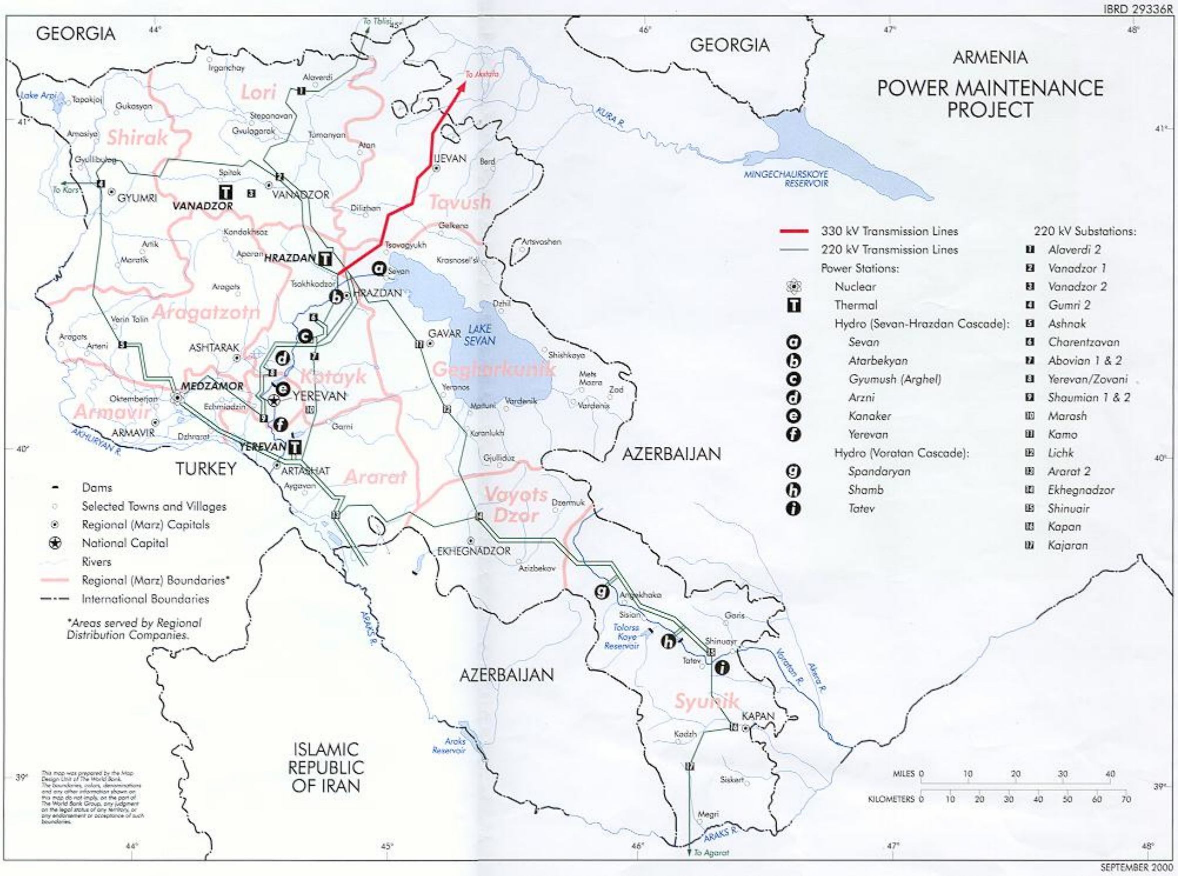
As the wind energy is capital intensive one should expect that large wind farm projects (such as at Karakhach, East Pambak and Fonatn areas) will be financed mostly with foreign capital, and thus heavily dependent on foreign investors and international banks expectations for their return on capital.

Projects can not normally bare the cost of grid upgrades. Consequently, some of the planned projects can not begin until grid upgrades are completed. This can limit the pace of wind energy development in some areas. In this respect, a conservative estimate is that up to 250 MW capacity could be expected by 2020.

6.3 GRID INTERCONNECTION

Armenia has a total of 11 power stations and seventeen 220 kV substations. Power from wind plants is typically transmitted at 110 kV to an existing substation that is expanded with step-up transformers and switch gear to allow connection to the grid. The grid map shows the close proximity between most of wind plant sites and substations in the existing power system.

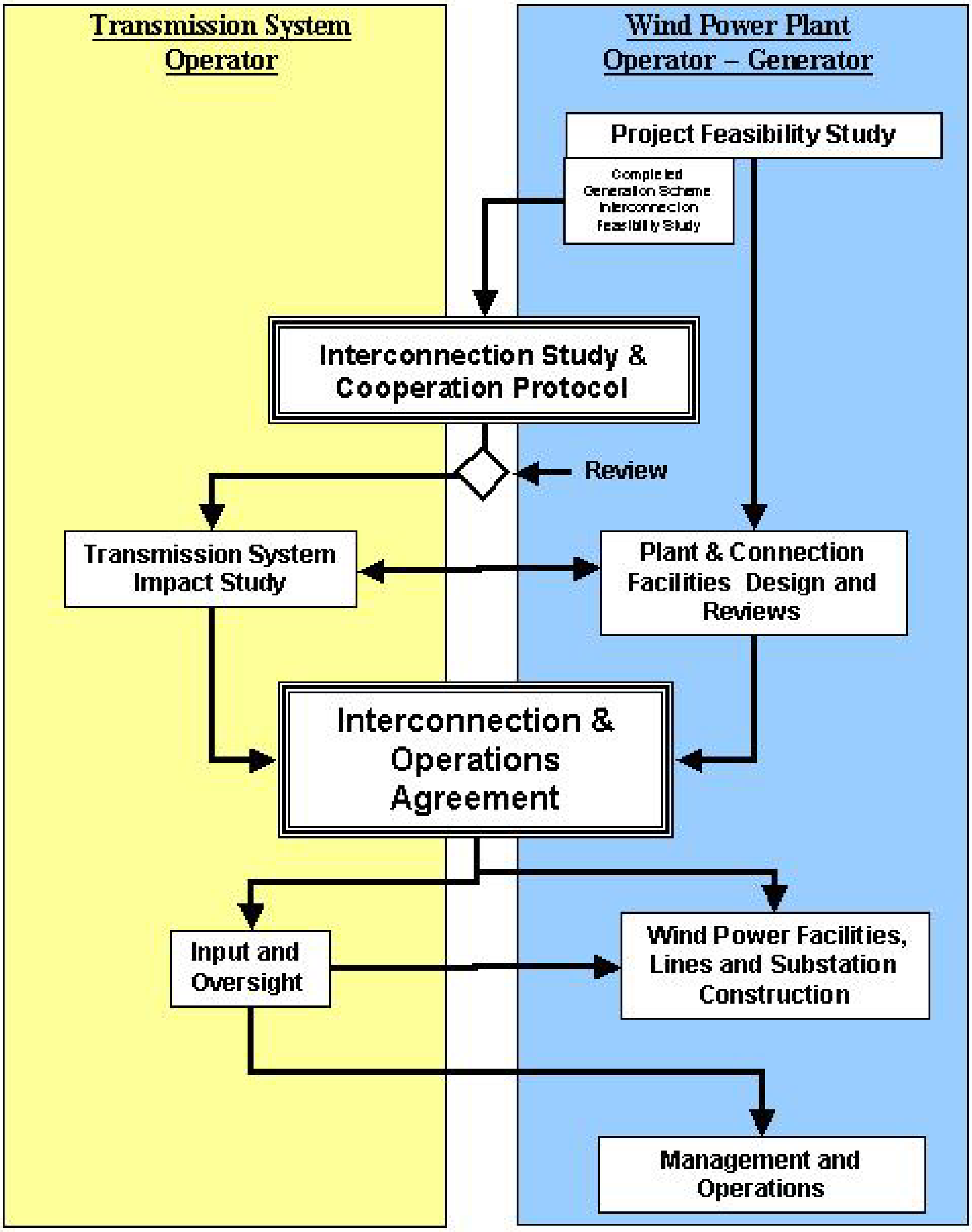
Proximity of wind sites to substations



Connecting a wind power plant to the existing grid in Armenia will follow a well defined process that has been accomplished successfully in many other countries. There are rigorous steps and procedures that must be followed to insure safe and compatible operation. The result will be improved power system reliability in addition to using a clean and sustainable energy source that is available locally.

To connect to the grid it is necessary to work cooperatively between the Electricity Networks of Armenia (ENA), the System Operator (SO), and the wind power plant developer/operator to assure safe reliable operation. There are a series of grid-related studies and agreements that are required and are being completed as the project moves toward operation. See flow diagram below. Initial load flow and static modeling of the connection are done during the project feasibility study leading to an Interconnection Protocol. More detailed dynamic studies are completed after the project is financed and the model of wind turbine is selected. This study is a primary input for an Interconnection and Operations Agreement between the developer and SO. These efforts and mutual agreement documents will draw on model agreements previously developed by the Global Environment Facility for the International Finance Corporation Renewable Energy Tool Kit.

Interconnection process steps between the Wind Power Project (the Generator) and the Transmission System Operator (Armenia System Operator)



Wind power can play a role in electricity trading with Georgia and other countries in the Caucasus network. At a meeting of the Black Sea Regional Transmission Planning (BSTP) working group in September 2009, the System Operator for Russian United Power System (SO-UPS) reported on the need for significant grid reinforcement for energy transfer to meet the expected needs for the 2014 winter Olympic Games to be conducted in Sochi. Wind plants can be online in Armenia to help provide needed energy and winter is the windy season.

The interconnection to Georgia is on an existing 220 kV line that passes near prospective wind plant sites. Steady state load flow and dynamic models for the region were reviewed by the BSTP group. One result was the assessment of the maximum transfer capacity of synchronous interconnection between Armenia and Georgia. Its analysis revealed that the net transfer capacity between the two countries if operated synchronously amounts to 800 MW. This large transfer capacity can accommodate the balancing energy demand between the two countries especially during winter months when winds are strongest and most hydro resource is sequestered in ice and snow.

6.4 ECONOMIC LIMITATIONS

Economic limitations are associated to high installed costs, low and intermittent generation potential and low tariff. Analysis of these factors is discussed in further sections.

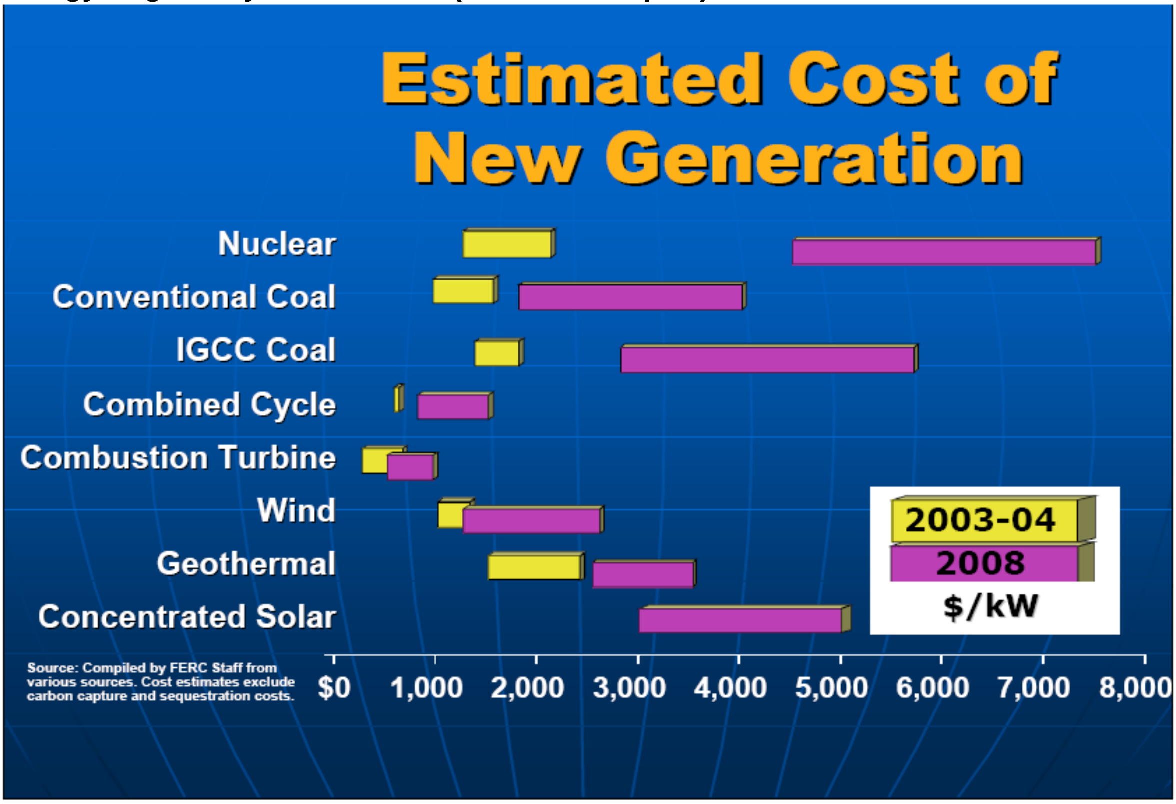
7.1 PROJECT COSTS

In recent years adjusting for fuel price risk and externalities of conventional power plants in economic assessment for wind energy (and other renewables such as solar for example) technologies and comparison between various energy technologies become more common practice, though it not yet fully accepted by many governments and IEA (EWEA, 2009). However, the EU states gradually expanding methodology of including carbon-price risk in power projects evaluation, especially given the EU's December 2008 agreement to introduce a real price on carbon pollution in the EU.

Today in the US, wind energy is competitive with some of conventional fossil fuel technologies. As it is illustrated in the graph below, wind energy at an installed cost of about USD 2000/kW (based on 2008 costs) is more competitive than conventional coal and nuclear (USDOE/FERC, 2008).

In addition, there is the obvious advantage of using local indigenous, clean and sustainable energy sources that are distributed throughout the grid system and located nearer to some of the rural loads reducing transmission loses. Distributed technologies have an obvious national security benefit, as well as their contribution in enhancing energy independence and reducing the trade imbalance from importing fuels for electric power generation.

Wind is among the lowest cost electricity generating sources (Source: US Federal Energy Regulatory Commission (FERC A-3 Report)



Still, as of today, wind energy technologies are capital intensive due to the use of high-techs especially in manufacturing of blades and control electronics, as well as the cost of advanced generator technologies. Over 75% of the total cost of energy for a wind turbine is related to upfront costs such as the cost of the turbine, foundations, electric equipment and grid-connection. Obviously, it has no fuel cost in O&M. Thus, a wind turbine is capital-intensive compared to conventional fossil fuel (such as natural gas for example) technologies where the fuel cost is at 50%-70% of O&M.

Per EWEA's data, the average cost for medium to large size turbines (2-3MW) installed in EU in 2006 was at 1,230 EURO/kW with a cost structure as follows:

	Investment (EURO 1,000/MW)	**Share of total cost %**
Turbine	931	75.7
Grid connection	109	8.9
Foundation	80	6.5
Land rent	47	3.8
Electric installation	18	1.5
Consultancy	15	1.2
Financial costs	15	1.2
Road construction	11	0.9
Control systems	4	0.3
TOTAL	**1,230**	**100**

The installed cost for smaller turbines is higher, and could range between EURO 1,300-1,500/kW (also depending on the site conditions). Turbine costs, reported by the IEA wind member countries averaged from a low of 977 €/kW (U.S.) to a high of 1,800 €/kW (Austria) for 2008. Total installed costs land-based installations for 2008 in the reporting countries ranged from a low of 984 €/kW (Mexico) to a high of 1,885 €/kW (Switzerland).

The cost of wind systems has increased in the last several years but is still one of the lowest cost new sources for generation. International Energy Agency Wind Agreement, 2008 Annual Report, showed an increase for 2007 and 2008 on the installed cost for wind. See bar chart for installations in IEA member countries where turbine cost ranged from a 977 €/kW (U.S.) to a high of 1,800 €/kW (Austria) for 2008. Total installed cost for land-based installations for 2008 in the reporting countries ranged from a low of 984 €/kW (Mexico) to a high of 1,885 €/kW (Switzerland). For Armenia, the current installed cost is estimated to be 2260 €/kW, including a 20% remote site adder. These extra costs for remote sites are attributable to risk for an initial project in a new market where specialized construction equipment (cranes etc.) and skilled labor may not be available, and to overcome unanticipated construction difficulties in rugged terrain.

International Energy Agency 2008 – wind plant installed cost trend

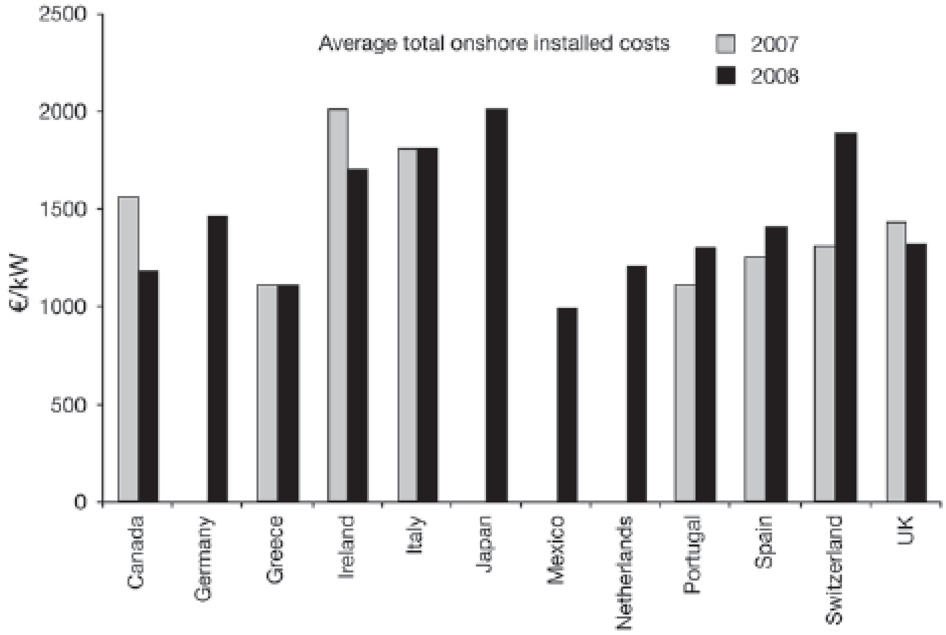


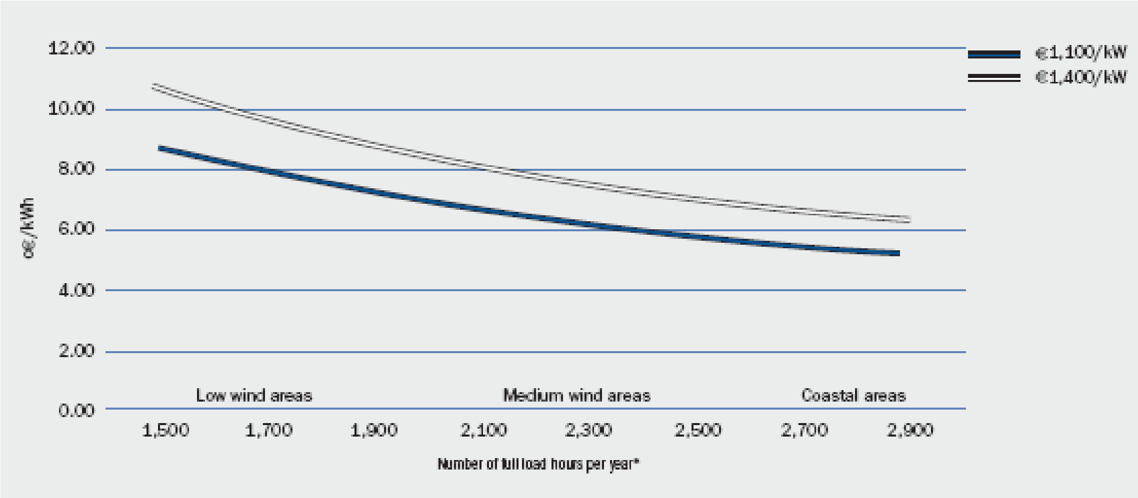
Figure 2 Average total installed costs of wind projects 2007–2008 as reported by IEA Wind member countries. These include costs for turbines, roads, electrical equipment, installation, development, and grid connection.

O&M costs for onshore wind farms are generally estimated to be around EURO 1.2-1.5 cent/kWh of wind produced over the total lifetime of a turbine that is usually over 20 years (EWEA, 2009). In the US O&M costs are about $0.005 to $0.011/kWh (DOE-LBL 2009). The O&M cost structure is split as:

- Labor - 30%
- Spare parts - 35%
- Insurance - 10%
- Land rental - 12%
- Overheads - 13%

The costs per kWh of wind-generated power (not tariff), calculated as a function of the wind regime ranges from EURO 7-10 cent/kWh at sites for low average wind speeds (capacity factor of less than 30%), about EURO 7 cent/kWh for average wind speeds capacity factor between 30% to 35%), and EURO 5 cent/kWh for coastal areas (capacity factor over 35%).

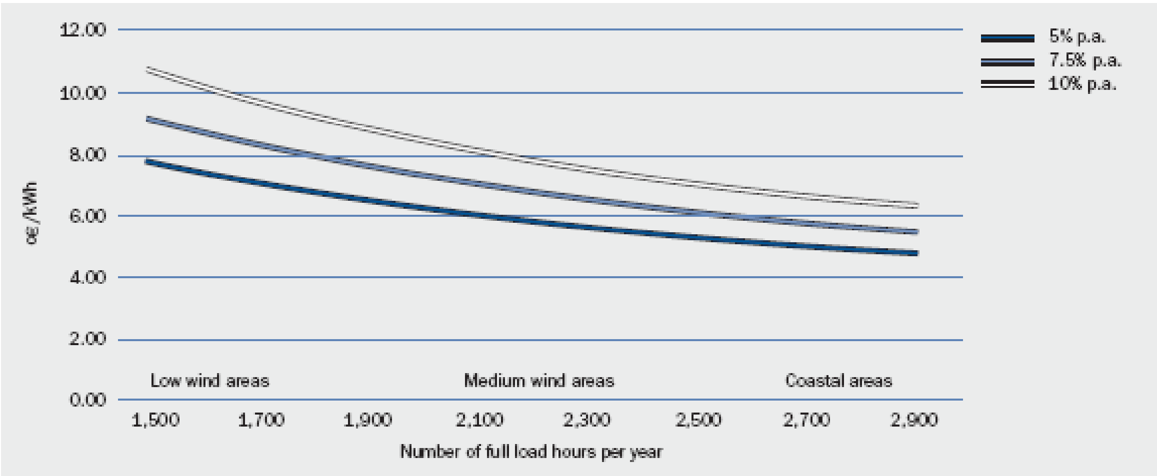
The graph below illustrates the calculated production costs per kWh of wind generated power as function of the wind regime for two scenarios (i) installed cost of EURO 1,100/kW and (ii) installed cost of EURO 1,400/kW.



* Full load hours are the number of hours during one year during which the turbine would have to run at full power in order to produce the energy delivered throughout a year (i.e. the capacity factor multiplied by 8,760).

Source: Risø DTU

At the same time, the discount rates affect wind power generation cost as it is illustrated below (for the given installed cost of EURO 1,225/kW).



Source: Risø DTU

Specifics of wind energy development in Armenia

There are a number of economic considerations associated to wind energy development in Armenia. Wind energy project economics in Armenia has the following key aspects for consideration:

a) development costs,

b) imported equipment cost,

c) local costs,

d) other associated costs,

e) power output,

f) debt investment terms,

g) generation tariff, and

h) terms of power purchase agreement.

Today the cost of building a wind power plant in Armenia is higher compared to the similar projects in Europe. Extra costs are imposed by complicated terrain, lack of special equipment (cranes), experience and transportation to the sites. Higher wind energy production costs, on the other hand, are explained by low generation (because of high elevations), cost of spare parts, high financing costs, etc. Other factors that increase installed costs are requirements to have upgrades of the equipment and reinforced foundations for seismic risks, turbulence, cold climate, etc. For Armenia wind turbines under Class IA of IEC standards are required. This brings extra costs for developer as well.

Wind energy development projects costs in Armenia, depending on the site complexity, equipment type and vendor, closeness to the infrastructure and economies of scale, can be in range of EURO 1,800/kW – EURO 2,000/kW, of which about 70% of the costs could be associated with imported equipment prices.

The cost structure for small-to-medium size a wind farm (15MW-50MW) in Armenia is as follows:

	Investment, EURO 1,000/MW	**Share in total cost %**
Wind turbines (ex-works)	1,350	68.9
Transportation	135	6.9
Foundations, roads, installation	270	13.8
Interconnection and grid connection	150	7.6
Development	30	1.5
Land	5	0.2
Legal and financial	20	1.1
TOTAL	**1,960**	**100**

Although O&M costs could be 30%-40% lower than in EU states (for labor, land rental and overheads parts) they are estimated to be in range of EURO 0.8-1.0 cent/kWh. Spare parts however, will still be mostly imported.

Power generation specifics in Armenia are explained by the fact that most of best sites are located at areas with elevation of over 2000m above sea level. The air density at perspective sites use to be 25%-27% lower to those at coastal areas and thus power per swept area ratio is respectively low; while low temperature compensates that slightly. Technical losses assessed by consultants who investigated the grid conditions in Armenia compared to those in EU states are high and can reach 17%. Because of these reasons the power generation at wind farms is up to 30% lower for the same wind speed than coastal areas. The average capacity factor for wind farms in Armenian is assessed to be 20%-25%; while at the best sites it can reach 28%. Armenian wind resource is compatible to EU medium class resources. In some cases higher tariffs are allowed for altitude sites.

Wind energy developers for projects larger than 20 MW will have to rely on international equity investors and debt financing from foreign banks as very few local banks are able to finance the project. Due to lack of knowledge and experience in financing of wind projects and expected financing risks in Armenia foreign commercial banks look for short-term financing and offer higher interest rates that range 9%-10%. Moreover, to guaranty their investment foreign commercial banks look for fund matching from international financial institutions such as IFC, EBRD, ADB, etc. This adds additional financing costs and makes project financing complicated and unattractive for developer.

Finally, local developers have different expectations than international investors. A local developer may be satisfied with project after-tax IRR at 10%-20%, where foreign investors look for higher than 20% return on equity for initial projects being implemented in Armenia where the perceived risk is higher due to market uncertainties and lack of experience in this business sector.

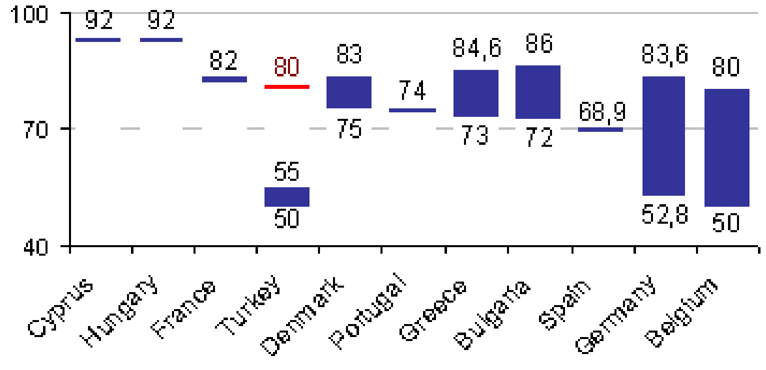
7.2 TARIFF ASSESSMENT

As discussed in an earlier section, wind energy production costs in EU countries differ depending on installed costs (plant size) that could range from EURO 1,100/kW to 1,500/kW as well as the projected energy production, including time spent on routine scheduled maintenance as well as unscheduled down time (plant capacity factor). The wind energy production costs can differ significantly and are in range of EURO 5 cent/kWh to EURO 11 cent/kWh.

Depending on project financing and investors expectation on return on capital the tariffs then vary in different countries. Below are tariff comparisons in different states obtained from some available sources.

Turkey. As of today, Turkey has almost 490 MW of installed capacity, and by the end of 2010 it is projected to reach 1,500 MW — around 3.5% of the country's total energy capacity. Currently, the feed-in tariff for renewables is limited to 55 EUR/MWh. The new proposed amendment to the law would offer 80 EUR/MWh for on land wind power applications (Turkish Market Authority EMRA, 2007).

Graph 2- Wind Energy Feed-in Prices
in selected countries for 2006-2008 (EUR/MWh)



Another study comes with tariffs in Great Britain. The wind electricity rate consists of the green certificate trading price, tax exemption credits for renewable energy (Law on Climate Protection/Climate Change Levy – about 0.50 cents/kWh) and the market price for electricity. This gives an overall rate of roughly 10.1 cents/kWh. (www.nfpa.co.uk).

By Paul Gipe (Wind Works, 2010) the tariffs in some of countries differ between EURO 7.8 cent/kWh to EURO 12 cent/kWh.

Country	Tariff in EURO cent/kWh
Germany	9.2
Ontario, Canada	9.6
France	8.2
Spain	7.8
South Africa	11.8
Vermont, USA	9.2
Austria	10
Brazil	8
Czech Republic	12
Portugal	11
Belgium	10
Bulgaria	9
Croatia	9
Finland	8
Hungary	9
Slovakia	8
Slovenia	9
Switzerland	12
Ukraine	11

It should be noted that in most of those states the PPA is signed for more than 15 years, while some counties offer developers over 20 years of secured PPA.

Another approach is taken in Russia. They calculate the wind energy tariff based on the average wholesale generation tariff in the system and add premium rate close to threefold of the average generation tariff (GretaEnergy Int'l, 2009). Thus at current average generation tariff in the system of RUB 0.8/kWh the premium rate is at RUB 2.5/kWh making the wind generation tariff RUB 3.3/kWh (or EURO 8.1 cent/kWh). Russia is yet to develop their first utility-scale wind power plant.

Tariff specifics in Armenia

Back in 2001, Armenia's regulatory commission had come up with the concept of fixed feed-in tariff denominated in USD (USD 5 cent/kWh). It has been changed several times since then but usually the wind tariff was set lower than required by developers to finance projects. As a result no development has occurred in the past 10 years. The new approach of denominating the tariff in local currency and its revision each year with adjustments for local inflation and FOREX rates makes the tariff unpredictable for investors (especially taking into account the fact that official indexes do not necessarily correspond to actual values).

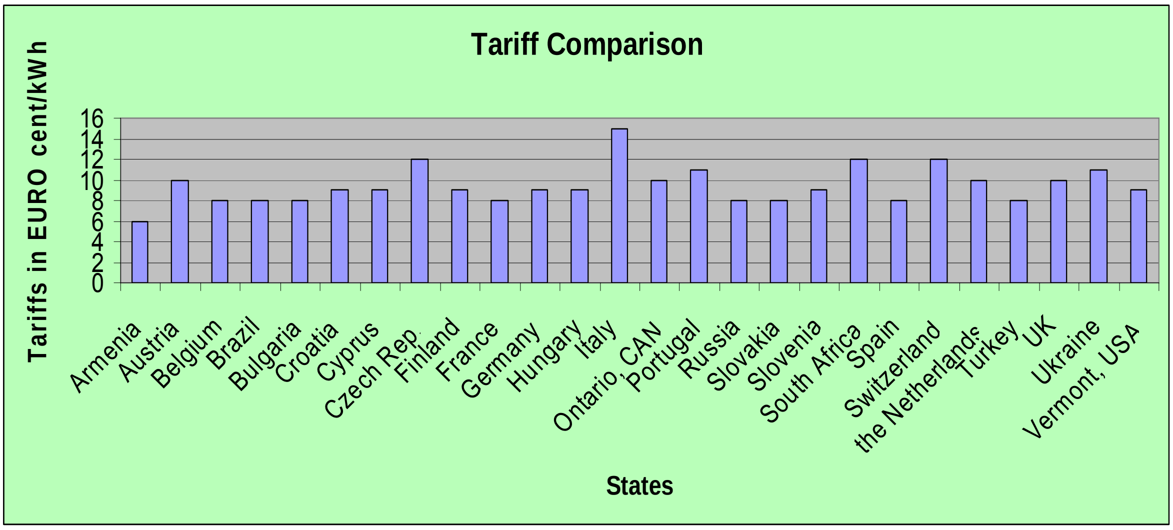
It should be noted that tariff adjustment or indexation approach (for Consumer Purchase Index) is used in a number of countries. To attract foreign investors it is essential to index revenues for current (real time) FOREX rates.

For 2010 the following generation tariffs were set in Armenia:

Generators	Tariff per kWh, AMD (without VAT)	EURO cent equivalent at current FOREX rate
Metzamor NPP	3.8	0.7
Hrazdan TPP	27.2	5
Yerevan TPP	25.8	4.7
Vorotan HPP	1	0.2
Sevan-Hrazdan HPP	1	0.2
SHPP on natural flow	18.4	3.4
SHPP on irrigation channel	12.2	2.3
SHPP on drinking water	8.1	1.5
Biogas plants	35.1	6.5
Wind power plants	**32.8**	**6**

It should be noted that despite some tariffs are denominated in foreign currency (for natural gas imports, etc.) the formal standing is to set wind energy tariffs in Armenian dram, and all requests and justifications by wind developers to denominate that in foreign currency were refused (the PSRC refers to the corresponding Law that all denominations in Armenia should be in local currency).

The comparison of wind energy tariffs in some countries and Armenia is shown below.



Obviously the reality dictates that for Armenia where the installed cost are high and wind resources are moderate, the tariff needs to be correspondingly higher. While the current tariff rate in Armenia is one of the lowest. More over, in most of countries that go ahead with promoting wind energy development, the tariff used to increase over time or at least there are certain attractive financial schemes to support it. In Armenia the wind tariff, in contrary to the logic, behave in an opposite way. As it is indicated in EBRD's study (IPA Energy&Water Consulting, August 2007) the wind tariff declined from 2004 to 2006.

In tariff assessment studies conducted by IPA Energy&Water Consulting/EBRD in 2007 and R2E2Fund/WB in 2008 they came out with clear indications on potential risks to implement wind projects and on unfavorable wind tariff rates and methodology used in Armenia. The R2E2Fund/WB report in 2008 (referring to before international financial crisis project funding terms) indicated that at the best windy sites in Armenia the break-even tariff was in average range of EURO 7.5-10 cent/kWh.

Finally, recent discussions with two developers, Arenergy, LLC (owned by foreign investor) and ZodWind CJSC (owned by local investor), proved that wind energy development under current regulatory environment is at risk, and thus they formally applied to the government for tariff increase to AMD 50/kWh and policy revision.

7.3 PROJECT ECONOMICS

Discussions with two developers of wind farms at Karakhach pass (20MW) and Zod pass (20MW) revealed that the following assumptions can be applied in project economic evaluation as of today. For a larger, 50 MW project assumptions are adjusted as shown below:

	Assumptions	20 MW	50 MW
	Technical		
1	Turbine capacity, MW	1	1.5-2.0
2	Hub height, m	50	65

3	Rotor diameter, m	60	70
4	Average capacity factor, %	25	28
5	Annual Generation (thousand kWh)	43,800	122,600
	Economic – Year	2010	2012
1	Average installed cost, EURO/kW (w/o VAT)	1,950	2,250
2	Debt ratio, %	70	70
3	Debt payment terms, years	10	12
4	Grace period, years	2	2
5	Debt interest rate, %	8	8
6	Project life-time (PPA), years	15	20
7	Average annual O&M costs during life-time, EURO/kWh	0.9	0.9
8	Inflation rate, %	5	5
9	Tariff escalation, %	0	0
10	Discounting rate, %	10	10

Economic analyses were conducted using the RETScreen model that was developed in Canada with funding from United Nations, Global Environment Facility and other prominent organizations.

Using assumptions for a 20 MW plant and applying today's tariff for wind of AMD 32.8/kWh or EURO 6.1/kWh the resulting economics are not sufficient to reach break even and the project is not economically viable. For these analyses it is assumed that VAT is deferred until it is collected along with electricity sales from the project.

For economic viability in today's markets, a minimum 17 to 20% after tax IRR is needed. Actually, this can be done with increased tariff and longer PPA term, better financing terms, as well as the larger project size. Using similar assumptions the 20 MW project can be economically viable at tariff of EURO 10.9 cent/kWh and a PPA term of 20 years. Actually, this tariff rate is comparable with many other countries. In fact, in case of higher installed cost and lower wind resource the tariff should be even higher. For a 50 MW project, economies of scale should reduce the required tariff slightly.

RETScreen® Financial Summary - Wind Energy Project

Annual Energy Balance

Project name		20MW Wind Farm
Project location		Armenia
Renewable energy delivered	MWh	50 070
Excess RE available	MWh	-
Firm RE capacity	kW	
Grid type		Central-grid

Financial Parameters

Avoided cost of energy	€/kWh	0,1090	Debt ratio	%	70,0%
RE production credit	€/kWh		Debt interest rate	%	8,0%
			Debt term	yr	12
			Income tax analysis?	yes/no	Yes
			Effective income tax rate	%	20,0%
			Loss carryforward?	-	Yes
			Depreciation method	-	Straight-line
			Depreciation tax basis	%	95,0%
Energy cost escalation rate	%				
Inflation	%	5,0%	Depreciation period	yr	10
Discount rate	%	10,0%	Tax holiday available?	yes/no	Yes
Project life	yr	20	Tax holiday duration	yr	5

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0,6%	€	245 200	O&M	€	440 187
Development	1,7%	€	670 292			
Engineering	1,6%	€	610 500	Debt payments - 12 yrs	€	3 622 574
Energy equipment	72,1%	€	28 104 000	**Annual Costs and Debt - Total**	**€**	**4 062 761**
Balance of plant	21,5%	€	8 371 500			
Miscellaneous	2,6%	€	998 508	**Annual Savings or Income**		
Initial Costs - Total	100,0%	**€**	**39 000 000**	Energy savings/income	€	5 457 670
				Capacity savings/income	€	-
Incentives/Grants		€	-			
				Annual Savings - Total	**€**	**5 457 670**
Periodic Costs (Credits)						
Drive train		€	750 000	Schedule yr # 12		
Blades		€	750 000	Schedule yr # 15		
		€	-			
End of project life - Credit		€	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	Yes
Pre-tax IRR and ROI	%	13,2%	Energy production cost	€/kWh	0,1033
After-tax IRR and ROI	%	12,0%			
Simple Payback	yr	7,8			
Year-to-positive cash flow	yr	9,3	Project equity	€	11 700 000
Net Present Value - NPV	€	2 125 403	Project debt	€	27 300 000
Annual Life Cycle Savings	€	249 649	Debt payments	€/yr	3 622 574
Benefit-Cost (B-C) ratio	-	1,18	Debt service coverage	-	1,37

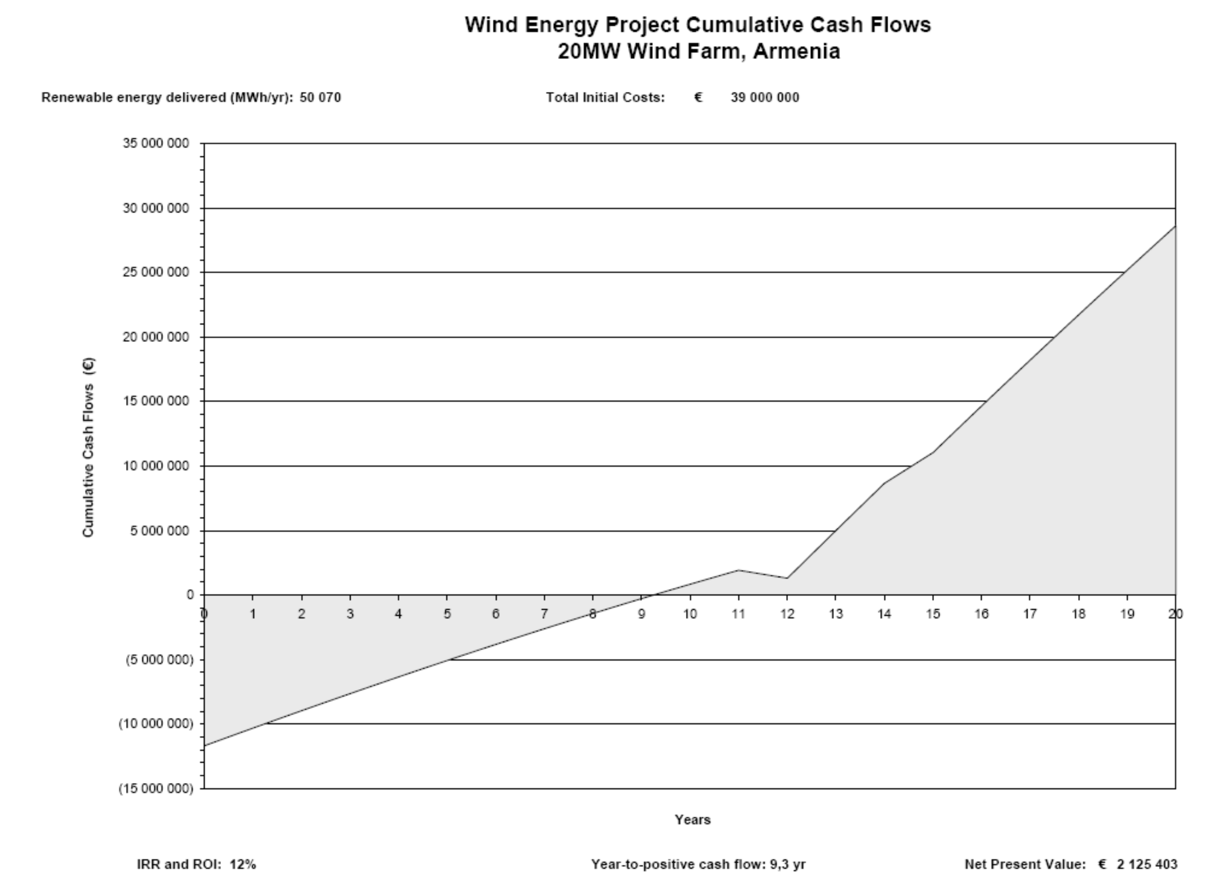
Yearly Cash Flows

Year #	Pre-tax €	After-tax €	Cumulative €
0	(11 700 000)	(11 700 000)	(11 700 000)
1	1 372 900	1 372 900	(10 327 100)
2	1 349 790	1 349 790	(8 977 309)
3	1 325 525	1 325 525	(7 651 784)
4	1 300 046	1 300 046	(6 351 738)
5	1 273 294	1 273 294	(5 078 444)
6	1 245 204	1 245 204	(3 833 240)
7	1 215 709	1 215 709	(2 617 531)
8	1 184 740	1 184 740	(1 432 791)
9	1 152 222	1 152 222	(280 569)
10	1 118 078	1 118 078	837 510
11	1 082 228	1 082 228	1 919 738
12	(302 308)	(625 794)	1 293 944
13	4 627 633	3 702 106	4 996 050
14	4 586 131	3 668 905	8 664 954
15	2 983 358	2 386 686	11 051 640
16	4 496 798	3 597 438	14 649 079
17	4 448 754	3 559 003	18 208 082
18	4 398 309	3 518 647	21 726 729
19	4 345 340	3 476 272	25 203 001
20	4 289 724	3 431 779	28 634 780

Version 3.2 . Minister of Natural Resources Canada 1997-2005. NRCan/CETC - Varennes

RETScreen® Financial Summary - Wind Energy Project

Cumulative Cash Flows Graph



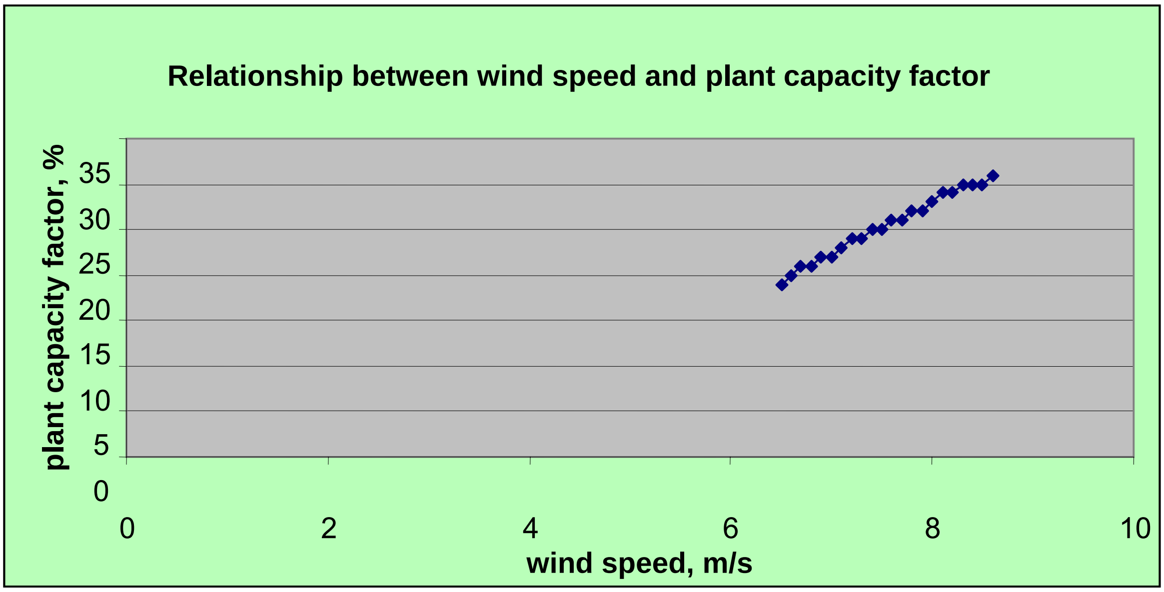
Version 3.2 . Minister of Natural Resources Canada 1997-2005. NRCan/CETC - Varennes

As seen from the above analysis, wind energy development basically depends on wind power plant capacity factor, tariff and installed cost. The first two factors are the most sensitive, i.e. the overall project economics can be changed with slight changes of those factors. The above analysis was made for an average capacity factor of 25%. The capacity factors on the other hand differ from site to site. Respectively, as was shown on the analysis of some EU countries' experience the production cost and tariff depend on the hours the wind power plant can operate and on the characteristics of the wind; specifically the number of hours accumulated at each wind speed. This is called the wind duration curve and is a measure of wind persistence and directly affects capacity factor. Two sites may have the same average wind speed but different capacity factor and energy output. In Armenia, the capacity factors of perspective sites (based on the available wind regime) range between 20%-30%. In this report the term capacity factor for the purpose of analysis is the capacity factor of the plant that include all losses, mechanical, electrical and downtime for scheduled and unscheduled maintenance. In other words the key factor is how much electricity is actually sold to the grid.

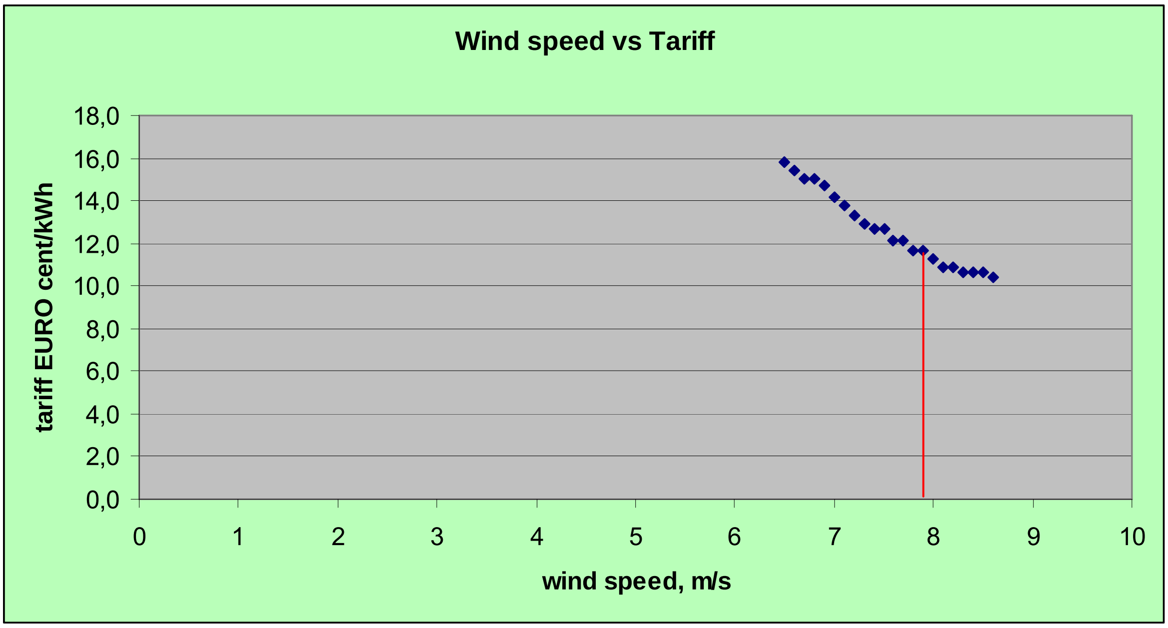
In this respect, for the set tariff those sites with higher capacity factor and low installed cost will be developed first. Obviously, development of all sites would require increase of the tariff correspondingly.

The graphs below show the relationship between:

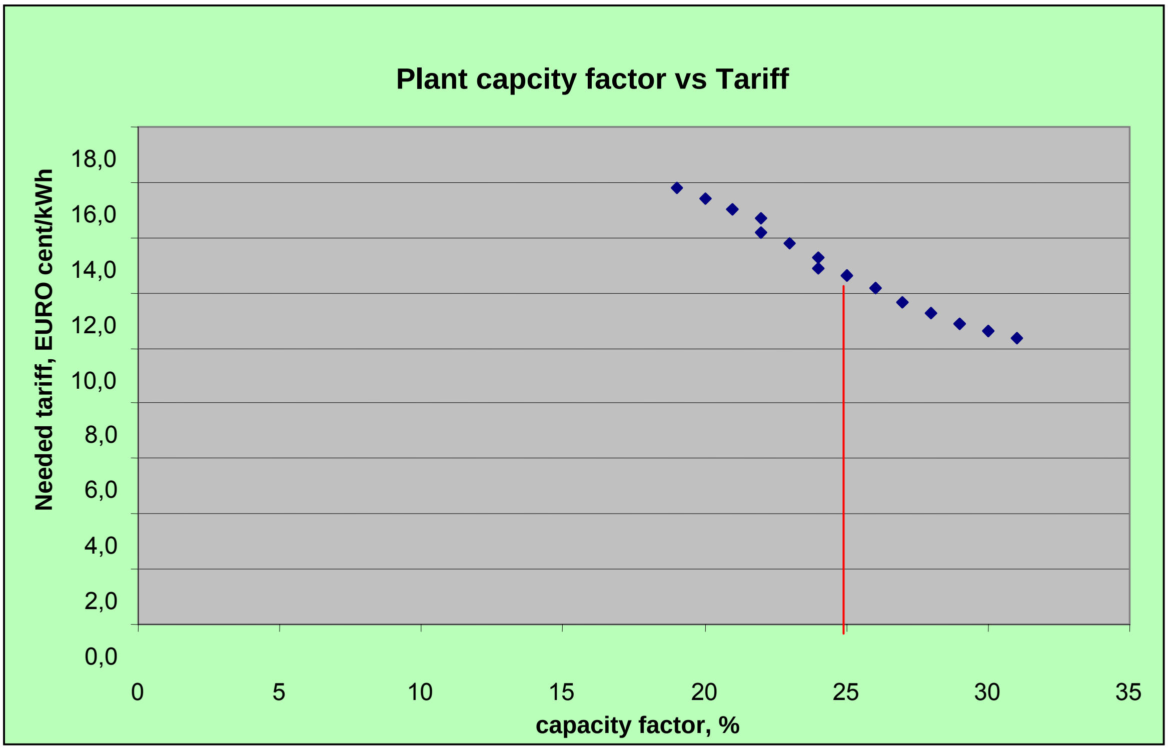
- wind speed and plant capacity factor;
- plant capacity factor and tariff to make the project economically viable (the installed cost is kept constant); and
- plant capacity factor versus tariff.



For simplicity though, to visualize the wind resource versus tariff the relationship between site wind speed and needed tariff can be a better approach. However, one should consider the site elevation effect on plant capacity factor. Simply, the same wind speed at a different site elevation will come up with a different plant capacity factor: higher elevation lower capacity factor.

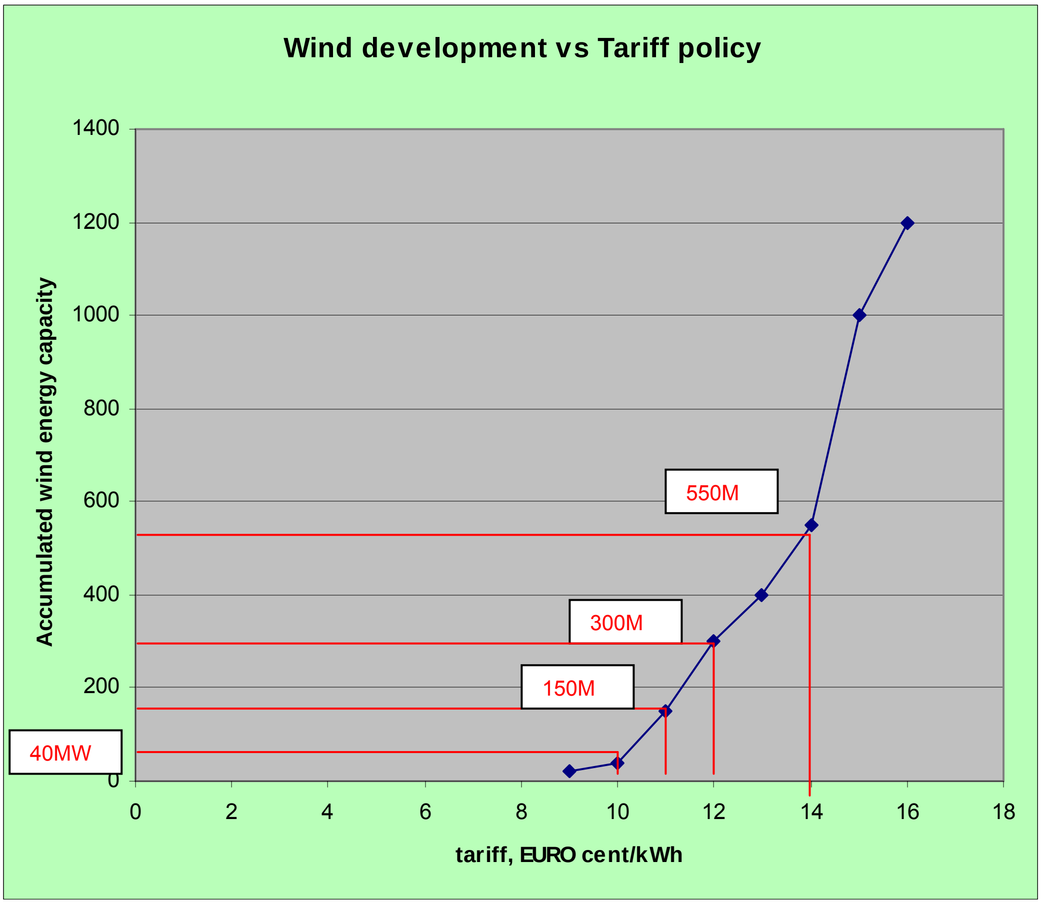


That is why the relationship between plant capacity factor and tariff seems more practical. The tariff policy, similar to one in some of EU states can then be based on the actual plant capacity factor (or hours of wind plant generation at nominal rate).



Obviously, the higher tariff the more windy areas it will be possible to develop. In any case, the best windy sites in Armenia have wind resource at 7.5m/s – 8.5m/s, while the capacity factors for the best sites can be in the range of 25% - 30%. The economics should result in development of wind power plants at those sites first.

The relationship between tariff policy and wind energy development in Armenia can be described by the below graph.



Today, based on the available data, three sites at Karakhach, Zod and Sisian passes are the sites with a capacity factor of higher than 25%. Due to political reasons (boarder between Nakhichevan and Armenia) the Sisian pass site could not be considered as feasible today. The total capacity at two mentioned sites could be over 150 MW.

The next potential areas are those with capacity factor between 20% - 25%; these are sites at Northern Karakhach and Eastern Karakhach, Pushkin pass, Eastern Pambak mountains, South-east Chambarak, Fonatan, Soth Shamb, South Harjis, Western Kadjaran, and Nerkin Shorzha sites. The total capacity of those sites is about 400 MW.

As seen from the above analysis with tariff at EURO 9 cent/kWh – 11 cent/kWh range about 150 MW could be possible to develop, while at tariff of EURO 12 cent/kWh – 14 cent/kWh range an additional 400 MW could be developed.

9. CONCLUSION

Wind power is Armenia's best new and sustainable option to improve energy security. Hydropower is nearly built out, the cost of natural gas will rise, supplies can be uncertain and a replacement for the existing nuclear plant is well in the future. Wind resources have technical potential 5,000 to 11,000 MW although only about 500 MW appears to be economically viable in the next five to ten years. Interconnection and operation on the existing electricity grid system is not expected to present any problems, but technical studies are needed to assure safe reliable operation of this technology that is new to Armenia. The cost of wind energy for initial projects is substantially higher than existing sources, likely in the range of 48-52 AMD/kWh, but these costs will never increase since there is no variable imported fuel cost. Wind power plants consume no water and a 50 MW wind plant can reduce water consumption at current thermal power plants by as much as 250 million liters each year.

Specific findings and outcomes of analysis under this report are as follows:

- Wind energy industry grows at exponential rate where ambitious targets to contribute in overall generation mix are supported with financial incentives. The target for EU states can reach at least 20% renewable (primarily wind) by 2020 and US projects 20% from wind alone is possible by 2030

- About 80% of Armenia's electricity generation depends on imported fuel; this makes the country economically and politically vulnerable

- Armenia possesses excellent wind energy potential and a significant new resource in terms of overall generation mix. The total wind energy potential for grid-connected plants in Armenia is assessed to be over 1,000 MW though about 500 MW, with annual generation potential over 1 billion kWh, is currently considered feasible.

- A number of independent wind studies conducted in the past all agree that perspective areas for utility-scale wind power plants are considered good to excellent sites

- Wind measurement campaigns completed to date validate the theoretical resource model predictions, but both models and measurements were limited to 50 m height above the ground, while blades on modern turbines operate in air stream at twice that height where winds are unknown but are likely much higher

- The distributed energy nature of wind can enhance the country's energy security by having the generating plants distributed over a territory instead on having one large generation facility at one location

- Water consumption at the nuclear plant in Armenia is estimated at 140 liters/second and older thermal power plants in the US consume up to 190 liters/kWh; therefore a 50 MW wind plant offsetting natural gas combustion could save 250 million liters of valuable water annually in Armenia

- Despite the government's intention to develop renewable energy in Armenia there are legal and regulative barriers that deter investment in wind energy projects.

- Changes in tariff structure, VAT processing, taxes, land use limitations and regulatory procedures can eliminate administrative and economic barriers to implementation of wind energy projects in Armenia

- Grid extension and possibly some grid reinforcement may be needed to absorb output from the planned development of utility-scale wind energy plants

- Installed costs in Armenia are about 20 % higher compared to similar projects in Europe due to remote siting, lack construction experience and infrastructure, and the generation potential is lower due to elevation factor and lower air density

- Tariff rates in Armenia are lower than in most of EU states as well as Russia and Ukraine and neighbor states

- The current wind energy tariff in Armenia of 33 AMD/kWh is not sufficient to attract investments in initial projects

- If technical, economic and administrative barriers are removed, wind power can supplement nuclear power and hydro power in supplying electricity in Armenia as a third major generating source.

10. RECOMMENDATIONS

This report has analyzed four main components associated to wind energy development perspectives in Armenia (i) wind energy potential, (ii) perspective areas, (iii) project economics, and (iv) tariff assessment.

If Armenia chooses to develop wind energy, recommendations for enabling development are as follows:

- Government should determine mandatory goals and a clear vision for achieving the national strategy for wind energy development;
- Government should develop a streamlined regulatory and land use strategy to allow current small (20 MW) commercial projects to move forward to be followed by a tender for a larger 50 MW plant;
- Government should establish a wind energy tariff structure with a fixed rate (adjusted for inflation and payment indexed to dollars or Euros) for 20 years;
- Government should be increases the current 32.8 AMD/kWh to 48-52 MWD/kWh to jump-start investments in initial projects;
- Government should allow VAT on imported wind turbine equipment to be deferred indefinitely and collected through electricity sales;
- Government should wave profit and property taxes during the debt period plus two (2) years (typically that is 12 years +2 =14 years) to accelerate debt reduction; and
- Government should explore with International donor organizations to obtain support for a 50 MW project feasibility study that will include tall tower wind measurements at three (3) sites, completing all grid connection, power purchase agreement, land use and environmental study approvals; followed by an open tender for development at the best power price consistent with good design practices;
- International donor organizations should support the government in developing smart or intelligent grid concept that will ease penetration and integration of renewable energy in to the energy system
- International donor organizations should support in lobbying actions to promote renewable energy development.

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