TACIS PROJECT
EUROPAID/120653/C/SV/Am

Support to the Energy Policy of Armenia

Renewable Energy Economic Potential of Gegharkunik marz

Feasibility Study Report

FINAL REPORT Volume II.

November 2007
Yerevan, Republic of Armenia

Danish Energy Management
A part of Danish Management Group
British Energy
amec nnc
International Consulting

ACKNOWLEDGMENT

This report is a part of the results of the **EU financed Project "Support to the Energy Policy of Armenia".** The Project consists of two parallel components and provides support to the Government of Armenia (GoA) in the realization of its energy policy with a view to the decommissioning of Armenian Nuclear Power plant (ANPP) and increasing the use of renewable energy (RE).

This reports deal only with renewable energy.

The renewable energy component of the project has assessed the technical and economical potential for renewable energy options (hydro, wind, solar and potentially biomass and geothermal) of the Republic and, in particular, in the Lake Sevan basin (Gegharkunik marz).

The results of the Project are reported in the following main documents:

Assessment of the Technical Potential

- Renewable Energy Technical Potential of Armenia and Gegharkunik marz of the Republic. Final report, October 2007;
- Annexes to "Renewable Energy Technical Potential of Armenia and Gegharkunik marz of the Republic". Final report, October 2007;

Assessment of the Economical Potential

- Renewable Energy Economic Potential of Gegharkunik marz. Vol.1, Final report, November 2007; ANNEX to Renewable Energy Economic Potential of Gegharkunik marz. Vol. I, Final report, November 2007;
- **Renewable Energy Economic Potential of Gegharkunik marz. Feasibility Study Report. Vol. II. Final report, November 2007;**
- ANNEX to Renewable Energy Economic Potential of Gegharkunik marz. Feasibility Study Report. Vol. II. Final report, November 2007.

All results are presented on the first Armenian bilingual RE web portal developed by the project (www.renewableenergyarmenia.am).

Working Groups

Local working groups have been set up along with the Steering Committee of the project. The working group on the renewable energy component has been managed by a key-international expert Mr. Morten Sondergaard and the local long-term expert Mr. Ara Marjanyan. The Project Partner has nominated experts to the group.

The Renewable Energy working group consists of representatives from the Project Partner, long term experts of the Project as well as short term international and local experts.

Our sincere thanks to the full working group and other experts and institutions from Armenia for their generosity and resources provided for the projects activities. Without their help, this work would never have been completed and the project team express their appreciation for all support, comments and ideas provided under the implementation of the project.

Renewable Energy Component Working Group

Name	Area of expertise
Ara Marjanyan	General renewables, Wind power, Sensitivity Analysis. Working group manager.
Levon Vardanyan	Strategy of development, Legal issues of renewables. Ministry of Energy, Republic of Armenia.
Gayane Bakhchisaraytseva	Junior local consultant, renewable energy.
Silva Hovsepyan	General hydro power, small hydro power plants. ArmHydroProject Institute.
Leonid Manoukyan	Wind power monitoring. ZodWind LLC.
Artem Kharazyan	Biomass, CDM. Designated National Authority on Clean Development Mechanism
Arthur Lalayan	Solar PV systems, Wind power feasibility analysis. Solaren LLC.
Viktor Afyan	Solar heaters, solar PV systems. Solaren LLC.
Arkady Karakhanyan	Geothermal energy (direct use and power generation), geophysics. National Academy of Science RA, Georisk LLC
Vahe Kharazyan	Economical and break-even tariff analysis. Local expert
Vahan Sargsyan	Strategy, Economical potential. Energy Strategy Center, CJSC.
Aida Arshakyan	Technical Renewable Energy Potential. Energy Research Institute, CJSC.
Martynas Nagevicius	CDM projects, Economical Analysis. International expert on renewable energy. Ekostrategija JSC.
Annegrete Lausten	Web portal. International expert on Renewable energy. Danish Energy Management A/S.
Allan Christensen	Renewable Energy Data Base. International expert. Danish Energy Management A/S.
Jorn Lykou	Feasibility studies. Project financing. International expert. Danish Energy Management A/S.
Peter Kovacs	Renewable Energy, Solar Energy. International expert. Danish Energy Management A/S.
Morten Sondergaard	General renewables. Renewable energy Team leader. Danish Energy Management A/S.

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Support to the Energy Policy of Armenia

Feasibility Study Report - Wind

Gegharkunik marz of the Republic of Armenia

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Renewable Energy Feasibility studies Gegharkunik marz of the Republic of Armenia

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ABBREVIATIONS AND ACRONYMS

a.s.l.	-	above sea level
AMD	-	Armenian Dram (Armenian national currency)
ANPP	-	Armenian Nuclear Power Plant (Metzamor Nuclear Power Plant)
DC/AC (converter)	-	Direct Current / Alternating Current (converter)
GEF	-	Global Environmental Facility
GTP	-	Geothermal Plant
HPP	-	Hydro Power Plant
HTW	-	Hot Tap Water
IEA	-	International Energy Agency
IFI	-	International Financial Institutions
IPCC	-	Intergovernmental Panel of Climate Change
IRR	-	Internal Rate of Return
MoE	-	Ministry of Energy RA
NPP	-	Nuclear Power Plant
NREL	-	US National Renewable Energy Laboratory
PSO (Program)	-	Technical Assistance of the government of the Netherlands
PSRC	-	Public Services Regulatory Commission
PV	-	Photovoltaic
R2E2 Fund	-	Armenian Renewable Resources and Energy Efficiency Fund
RA NAS	-	RA National Academy of Science
RA RA	-	Republic of Armenia
RE	-	Renewable Energy
SHPP	-	Small Hydro Power Plant (up to 10 MW)
STC	-	standard solar-test conditions
TPP	-	Thermal Power Plant
VAT	-	Value Added Tax
VS	-	Volatile solids
WPP	-	Wind Power Plant

1. SEMYONOVKA PASS WIND PROJECT FEASIBILITY STUDY

1.1. General description

The Semenovka Pass wind project is based on data collection from one year wind monitoring at the site in the period from August 2006 to August 2007. Background information on monitoring data can be found in Annex 2 of the "ANNEX to the Feasibility Study Report Vol. II".

In July 2006 field inspection trips to Lake Sevan basin (Gegharkunik Marz) was carried out in order to select the sites for one windpower monitoring unit installation. The selection reflects the requirements of the Terms of Reference of the Project to select the best possible site for a grid connected wind park in the Northern part of l. Sevan basin as well as the results of Wind Atlas of Armenia developed by National Renewable Energy Laboratory (USA). A 40 m tall wind power monitoring unit on the site, located at Semenovka Pass area not far from the TV tower (northern shore of Lake Sevan), was successfully installed in 2 August 2006. Measurements of the wind speed and direction (2 different heights), ambient temperature, air pressure and humidity started in 3-rd of August 2006, 12:00. The result of the Wind Monitoring is presented as an annex to this Feasibility study.

The project site for the wind farm is located at Semenovka pass area at elevation of 2435 m above sea level with geographic coordinates: 40° 39′ 26″N and 44° 56′08″ E. The site is at distance of 5 km from the Tsovagyugh village. The site has well developed infrastructure with access roads, proximity to railway and grid (35 and 110 kV air transmission lines).

Figure 1.1.1 Wind park location

Based on an analysis of the landscape the project is evaluated for installment of 17 wind turbines each with an installed capacity of 850kW[1]. The selection of wind turbine generators is limited by the size the components (basically length of tower section, blades and gear-box), bringing the totaled installed capacity to 14.45 MW

[1] **Equipment sizing**: Due to transportation limitation (especially the length of the blades) only blades with length up to 28m (or rotor diameter up to 58m) can be delivered to Armenia by rail or roads. Longer blades can be delivered by air but that is not economically justified. The most suitable turbines in this term are those close to 850kW or 900kW.

The layout of 17 turbines of Semenovka pass wind farm is presented in figure 1.1.2.

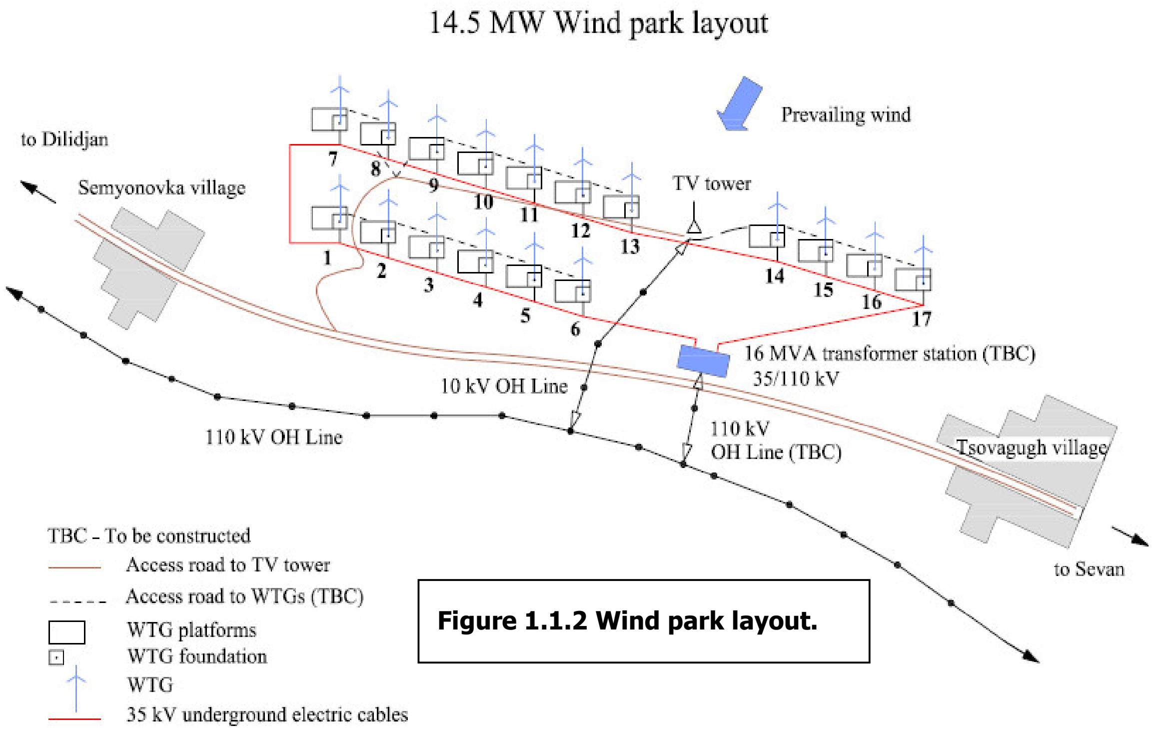


Figure 1.1.2 Wind park layout.

The average annual wind speed is based on existing monitoring data - 6.4 m/s (see enclosed wind monitoring report) extrapolated for the hub height. The Average annual electricity production is calculated to 25 GWh. The project cost is calculated to be about € 22.1 million, based on quotes from suppliers and local construction firms (see cost details at RET Screen's Financial Summary Model below).

The economic viability of the Semenovka pass wind farm project is evaluated through a feasibility study conducted with the use of RetScreen software. This includes also an evaluation of the impact of a possible impact of the CDM mechanism.

Normally the commercial economically viability of a project means positive parameters for project net present value (NPV), acceptable rates of return, as well as favourable benefit-to-cost ratio. The RetScreen software additionally provides outcomes of large number of other financial parameters that are allowing the decision maker to understand the debt expenses, project risks, cash flows and other project related sensitive financial information.

1.2. General Technical and Economic Assumptions

The main technical and economic assumptions for the analysis are provided in the table below. In the later paragraphs each module of the RetScreen and additional context specific assumptions will also be described.

Table 1.2

	Item	Assumptions	Comments
1.	*Technical*		
1.1	Equipment	3 blade WTG with pitch-control and horizontal hub, up to 850 kW capacity	Market product, historical track record, transportation limitation
1.2	Hub height	40m – 50m	Low and sometimes negative wind share component (complex terrain effect, air compression at surface layer)
1.3	Losses: -icing -array/wake	 2% 1.7%	 Usual for elevation higher than 1500m a.s.l. Usual for raw layout in most pass or ridge

	-shape factor -downtime -miscellaneous	1.5% - 2% 7% 3%	sites Weibull distribution, usual for pass site Availability number from qualified equipment supplier Mostly grid connection loses
2.	*Economic*		
2.1	Cost -main equipment -balance of plant -transportation (17 turbines) -spare parts -other equipment -contingency -O&M -component replacement -component replacement Interest during construction	 € 930/kW € 310/kW € 1,020,000 3% of turbine cost or € 403,155 € 660,000 4% € 0.01/kWh Drive train 12 years € 750,000 Blades 15 years € 750,000 10% for 9 month € 800,000	 Usual for qualified EU manufacturers Usual for plant electric and control equipment Usual for Armenia Design & Engineering estimates Design &Engineering estimates Accuracy of estimation Calculated estimates Recommended by suppliers Recommended estimates Capital market and technical figures
2.2	Debt -debt ratio -debt interest rate -term	 70% 10% 10 years	 Recommendation of banks Recommendation of banks Recommendation of banks
2.3	Project -inflation -project life -discount rate	 4% 20 years 10%	 Country's average Recommended by suppliers Recommendation of consultants
2.4	Tariff -tariff -escalation rate	 0,0077 €/kWh 0,4%	 PSRC tariff for wind (= 35 AMD/kWh) PSRC new tariff scheme, effective from May 2007
2.5	GHG -credit -credit duration -escalation rate -baseline -GHG credit transaction fee (share of proceeds)	 7 €/tonn$_{CO2}$ 21 years 0% unchanged 2%	 Estimated Accepted period for CDM Accepted Accepted UNFCC
2.6	Tax Analysis -effective income tax -depreciation tax basis -depreciation period -depreciation method	 20% 85% 20 years straight-line	

1.3. Analysis of RetScreen runs of Semenovka Wind Project

RetScreen is freeware software and consists of five key spreadsheets imbedded in MS excel environment: Energy Model, Cost Analysis, GHG Analysis, Financial Summary and Sensitivity. Each of these spreadsheets contains input cells and output cells that are used in other Excel sheets as well to generate the final financial summary and sensitivity spreadsheet. In the following subsections the respective input and output fields (cells) is analysed in the context of the Semenovka pass wind farm project.

1.3.1. Energy Model

In Figure 1.3.1.1 the Energy Model worksheet of RetScreen Semenovka pass wind farm project is presented. The worksheet is used to help calculate the annual energy production for a wind energy project based upon local site conditions and system characteristics. It takes input data from equipment data worksheet and from its own input fields to generate the values of Gross Energy Production and Renewable Energy Delivered.

The site conditions parameters include annual average wind speed, height of wind measurement, wind shear exponent; which is a dimensionless number expressing the rate at which the wind speed varies with the height above the ground, wind speed, average atmospheric pressure and annual temperature.

The system characteristics include turbine rated power, wind plant capacity, hub height, power density, array losses caused by the interaction of the wind turbines with each other through their wakes, airfoil soiling and icing losses, etc.

Figure 1.3.1.1

Site Conditions		Estimate	Notes/Range
Project name		Wind Farm	See Online Manual
Project location		Semyonovka, Armenia	
Wind data source		Wind speed	
Nearest location for weather data		Semyonovka, Armenia	See Weather Database
Annual average wind speed	m/s	6.4	
Height of wind measurement	m	40.0	3.0 to 100.0 m
Wind shear exponent	-	0.10	0.10 to 0.40
Wind speed at 10 m	m/s	5.6	
Average atmospheric pressure	kPa	80.0	60.0 to 103.0 kPa
Annual average temperature	°C	4	-20 to 30 °C

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Wind turbine rated power	kW	850	Complete Equipment Data sheet
Number of turbines	-	17	
Wind plant capacity	kW	14,450	
Hub height	m	44.0	6.0 to 100.0 m
Wind speed at hub height	m/s	6.5	
Wind power density at hub height	W/m²	379	
Array losses	%	2%	0% to 20%
Airfoil soiling and/or icing losses	%	2%	1% to 10%
Other downtime losses	%	7%	2% to 7%
Miscellaneous losses	%	3%	2% to 6%

Annual Energy Production		Estimate Per Turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	850	14,450	
	MW	0,850	14,450	
Unadjusted energy production	MWh	2,080	35,365	
Pressure adjustment coefficient	-	0.79	0.79	0.59 to 1.02
Temperature adjustment coefficient	-	1.04	1.04	0.98 to 1.15
Gross energy production	MWh	1,709	29,056	
Losses coefficient	-	0.87	0.87	0.75 to 1.00
Specific yield	kWh/m²	699	699	150 to 1,500 kWh/m²
Wind plant capacity factor	%	20%	20%	20% to 40%
Renewable energy delivered	MWh	1,485	**25,251**	
	kWh	1,485,332	25,250,641	
				Complete Cost Analysis sheet

The resulting output list of annual energy production parameters includes total wind plant capacity, unadjusted energy production, gross energy production, specific yield, plant capacity factor and finally renewable energy delivered that is a key input component for financial analysis algorithm.

The Figure 1.3.1.1 represents the energy model worksheet for Semenovka Pass wind power project all the described input and output values are noticeable. Some values in that worksheet, especially ones relating to various losses, are based upon assumptions from project team expertise and previous projects experience and will also be applied to other wind projects studied with use of RetScreen. The list of these assumptions can be found in table 1.2.

1.3.2. Cost Analysis

In figure 1.3.2.1 the Cost Analysis worksheet of Semenovka pass project RetScreen simulation is presented. This worksheet is used to help estimate costs associated with a wind energy project. These costs are addressed from the initial, or investment, cost standpoint and from the annual, or recurring, cost standpoint. The initial, annual and periodic costs sections (herein presented in simplified version) include all sorts of investments on the design, licensing, construction and operation phases. In the case of Semenovka pass project the needed expense categories have been used based on the prepared design document. The initial capital cost section categories that have been used in this feasibility study are engineering expenses, energy equipment costs (turbines, spare parts and their transportation cots), balance of plant (wind turbine(s) foundations(s) and erection, road construction, transmission line, substation, control and O&M building(s) and transportation costs) and other miscellaneous costs. The values for different categories have been taken from the table of assumptions 1.2, the designed document, and the project team experience and other project documentation.

Figure 1.3.2.1

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs
Feasibility Study					
Feasibility study	Cost	1	€ -	€ -	
Sub-total:				€ -	0.0%
Development					
Development	Cost	1	€ -	€ -	
Sub-total:				€ -	0.0%
Engineering					
Engineering	Cost	1	€ 565,000	€ 565,000	
Sub-total:				€ 565,000	2.6%
Energy Equipment					
Wind turbine(s)	kW	14,450	€ 930	€ 13,438,500	
Spare parts	%	3.0%	€ 13,438,500	€ 403,155	
Transportation	turbine	17	€ 60,000	€ 1,020,000	
Other - Energy equipment	Cost	1	€ 660,000	€ 660,000	
Sub-total:				€ 15,521,655	70.2%
Balance of Plant					
Balance of plant	Cost	1	€ 4,500,000	€ 4,500,000	
Sub-total:				€ 4,500,000	20.4%
Miscellaneous					
Contingencies	%	4%	€ 20,586,655	€ 720,533	
Interest during construction	10.0%	9 month(s)	€ 21,307,188	€ 799,020	
Sub-total:				€ 1,519,552	6.9%
Initial Costs - Total				€ 22,106,207	100.0%

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs
O&M					
O&M	Cost	1	€ 300,000	€ 300,000	
Contingencies	%	10%	€ 300,000	€ 30,000	
Annual Costs - Total				€ 330,000	100.0%

Periodic Costs (Credits)		Period	Unit Cost	Amount
Drive train	Cost	12 yr	€ 750,000	€ 750,000
Blades	Cost	15 yr	€ 750,000	€ 750,000
				€ -
End of project life	Credit	-	€ -	€ -

From the worksheet in Figure 1.3.2.1 the total initial capital investment costs for Semenovka wind project are equal to 22,1 mln. €. The annual operation and maintenance costs estimated to be 330000 € and periodic costs incurred by the project 750000 € once in 12 years for the main drive train and 750000 € once per 15 years for blades.

1.3.3. GHG Emission Potential

In Figure 1.3.3.1 the GHG Analysis worksheet of Semenovka pass wind project is presented. This worksheet is intended to help estimate the greenhouse gas emission reduction (mitigation) potential of the Semenovka pass wind project. This GHG emission reduction analysis worksheet contains four main sections: Background Information, Base Case System (Baseline), Proposed Case System (Project) and GHG Emission Reduction Summary.

The Background Information section provides project reference information as well as GHG global warming potential factors. The Base Case System section provides a description of the emission profile of the baseline system, representing the baseline for the analysis. The Proposed Case System section provides a description of the emission profile of the proposed project. The GHG Emission Reduction Summary section provides a summary of the estimated GHG emission reduction based on the data entered in the preceding sections and from values entered or calculated in the other RetScreen worksheets (e.g. annual energy delivered). Results are calculated as equivalent tones of CO2 avoided per annum. Inputs entered in this worksheet affect GHG related income categories that appear in the

Financial Summary and Sensitivity worksheets.

Figure 1.3.3.1

Background Information

Project Information

Project name	Wind Farm	Project capacity	14.45 MW
Project location	Semyonovka, Armenia	Grid type	Central-grid

Base Case Electricity System (Baseline)

Fuel type	GHG emission factor (tCO2/MWh)	T & D losses (%)	Base case GHG emission factor (t_{CO2}/MWh)
Electricity system			
Combined Margin Approach	0.399	17.0%	0.481

Does baseline change during project life? No

Proposed Case Electricity System (Wind Energy Project)

Fuel type	Proposed case GHG emission factor (tCO2/MWh)	T & D losses (%)
Electricity system		
Wind	0.000	17.0%

GHG Emission Reduction Summary

	Base case GHG emission factor (tCO2/MWh)	Proposed case GHG emission factor (tCO2/MWh)	End-use annual energy delivered (MWh)	Gross annual GHG emission reduction (t_{CO2})	GHG credits transaction fee (%)	Net annual GHG emission reduction (t_{CO2})
Electricity system	0.481	0.000	20,958	10,075	2.0%	**9,874**

In the work sheet on the figure 1.3.3.1 the pre-calculated values from independent Baseline Study have been used to calculate the Net Annual GHG Emissions Reduction. Despite the availability of embedded baseline calculation tool in RetScreen, the software also allows to import user-defined baseline from stand alone study. The detailed information on project team baseline study can be found in later chapters. The combined margin emission factor defined in this study equals **0.481 CO_2 ton/MWh**. This value can be used for Armenian wind and solar project studies. Another input figure is the transmission and distribution losses which represent about 17% for Armenian power energy sector. Additionally, UNFCC share of proceeds equal to 2% has been incorporated into study. Baseline is considered unchanged for the purpose of this study. Resulting annual GHG emissions reduction equaled to 9874 tons per year.

The obtained results in parallel with the base-line study for Armenia were used as foundation for the preparation of the Project Design Document (PDD) for 14.5 MW Semenovka WPP. The PDD can be found in Annex 3 of the "ANNEX to the Feasibility Study Report Vol. II".

1.3.4. Financial Summary

In figure 1.3.4.1 the Financial Summary worksheet of Semenovka pass wind project RetScreen simulation is presented. This financial analysis worksheet contains six sections: Annual Energy Balance, Financial Parameters, Project Costs and Savings, Financial Feasibility, Yearly Cash Flows and Cumulative Cash Flows Graph. The Annual Energy Balance and the Project Costs and Savings sections provide a summary of the Energy Model, Cost Analysis and GHG Analysis worksheets associated with studied Semenovka pass project. In addition to this summary information, the Financial Feasibility section provides financial indicators (e.g. IRR, simple payback, NPV etc.) of the project analyzed based on the data entered in the Financial Parameters section (e.g. avoided cost of energy, discount rate, debt ratio, etc.). The Yearly Cash Flows section allows visualizing the stream of pre-tax, after-tax and cumulative cash flows over the project life.

Picture 1.3.4.1

Annual Energy Balance

Project name		Wind Farm			
Project location		Semyonovka, Armenia			
Renewable energy delivered	MWh	25,251	Net GHG reduction	t_{CO2}/yr	9,874
Excess RE available	MWh	-			
Firm RE capacity	kW	-	Net GHG emission reduction - 21 yrs	t_{CO2}	207,344
Grid type		Central-grid	Net GHG emission reduction - 20 yrs	t_{CO2}	197,470

Financial Parameters

Avoided cost of energy	€/kWh	0.0770	Debt ratio	%	70.0%
RE production credit	€/kWh		Debt interest rate	%	10.0%
			Debt term	yr	10
GHG emission reduction credit	€/t_{CO2}	7.0	Income tax analysis?	yes/no	Yes
GHG reduction credit duration	yr	21	Effective income tax rate	%	20.0%
GHG credit escalation rate	%	0.0%	Loss carryforward?	-	Flow-through
			Depreciation method	-	Straight-line
			Depreciation tax basis	%	85.0%
Energy cost escalation rate	%	0.4%			
Inflation	%	4.0%	Depreciation period	yr	20
Discount rate	%	10.0%	Tax holiday available?	yes/no	No
Project life	yr	20			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	€	-	O&M	€	330,000
Development	0.0%	€	-			
Engineering	2.6%	€	565,000	Debt payments - 10 yrs	€	2,518,378
Energy equipment	70.2%	€	15,521,655	**Annual Costs and Debt - Total**	**€**	**2,848,378**
Balance of plant	20.4%	€	4,500,000			
Miscellaneous	6.9%	€	1,519,552	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**€**	**22,106,207**	Energy savings/income	€	1,944,299
				Capacity savings/income	€	-
Incentives/Grants		€	-			
				GHG reduction income - 21 yrs	€	69,115
				Annual Savings - Total	**€**	**2,013,414**
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	%	-1.5%	Energy production cost	€/kWh	0.1224
After-tax IRR and ROI	%	-1.3%	Calculate GHG reduction cost?	yes/no	No
Simple Payback	yr	13.1			
Year-to-positive cash flow	yr	more than 20	Project equity	€	6,631,862
Net Present Value - NPV	€	(8,045,128)	Project debt	€	15,474,345
Annual Life Cycle Savings	€	(944,978)	Debt payments	€/yr	2,518,378
Benefit-Cost (B-C) ratio	-	(0.21)	Debt service coverage	-	0.64

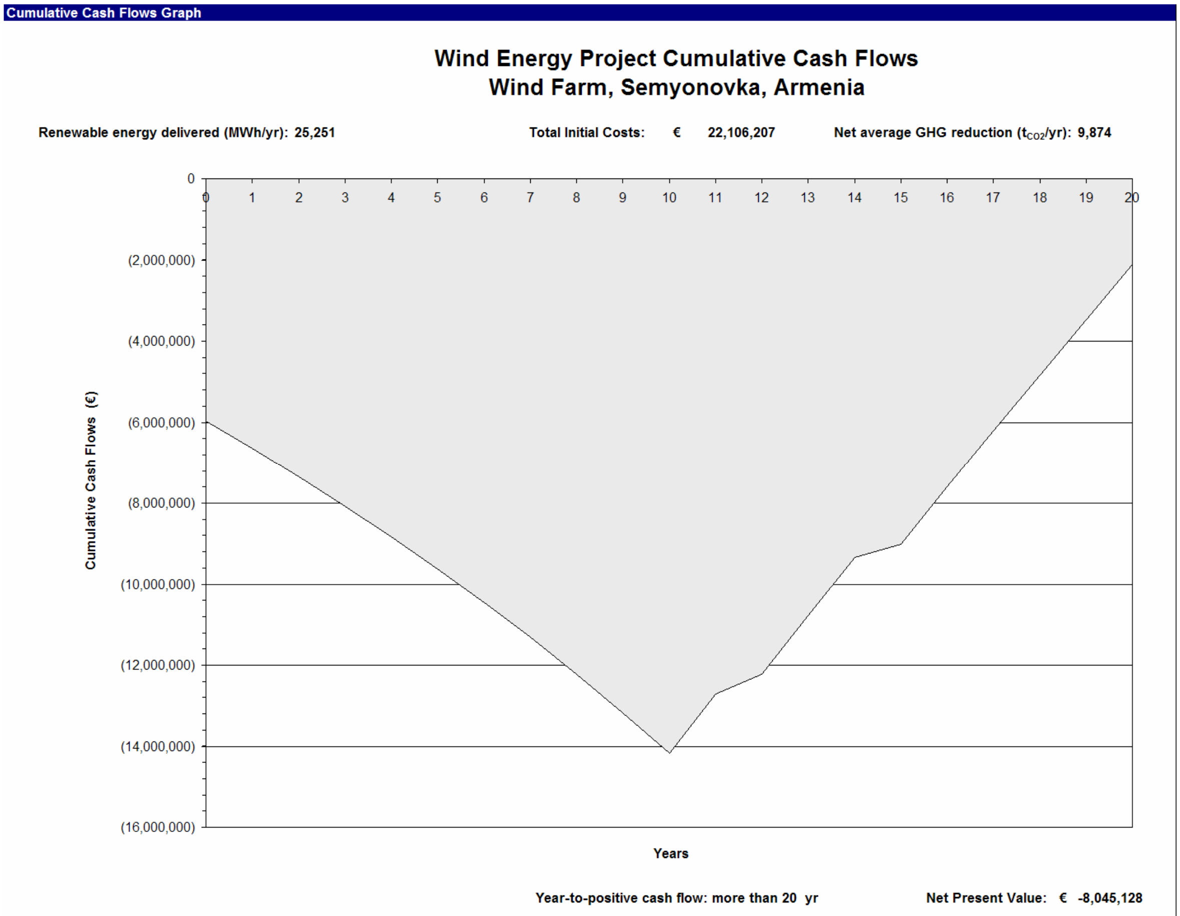
In order to understand this key worksheet a special chapter has been devoted to economics of RetScreen (DESCRIPTION OF THE ECONOMICS OF RET Screen). Furthermore a financial glossary has been added at the end of that chapter to help to understand some of the theory underlying the feasibility analysis.

According to financial summary the Semenovka wind power project is not directly economically viable. The pre-tax and after-tax IRRs are negative, the NPV negative (8 045 128 €) and it takes more than the project lifetime to have positive cash flow. The project on average amounts to loosing each year of it 944978 €. Such negative economic parameters can be understood when the calculation of the necessary grid feed in tariff have to be increased with app. 50% for the project to have a zero economic profit (NPV = 0) or the break even tariff (BET). The economical parameters by including the GHG emission reduction income, will improve the BET with app. 3%.

In the conclusions and recommendations section there can be found further description of the financial worksheet outputs and interventions that can support and improve the project economic viability and accelerate the implementation of projects like the Semenovka wind power project.

The cumulative cash flow graph of the Semenovka wind project (Graph 1.3.4.1) shows that the cash flow never turns to be positive during the project life time. By the end of project the life time cumulative cash flow reaches - 2 mln €.

Graph 1.3.4.1



1.3.5. Sensitivity and Risk Analysis

To understand the sensitivity of the project for various input parameters it is important to consider the Sensitivity Analysis worksheet output of model presented in Figure 1.3.5.1. It helps to understand the key role playing parameters of the projects that contribute to the project being beneficial/detrimental and also to recommend the measures that can improve the project even further.

The worksheet is provided to help to estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This sensitivity and risk analysis worksheet contains two main sections: Sensitivity Analysis and Risk Analysis. Each section provides information on the relationship between the key parameters and the important financial indicators, showing the parameters which have the greatest impact on the financial indicators. The Sensitivity Analysis section gives a general idea of how much a "mistake" (underestimate or overestimate) in one of the parameter can influence the resulting IRR of the project.

The sensitivity analysis for Semenovka wind project has been conducted with a 15% sensitivity range and no combination of misestimating of input parameters results in a viable IRR for the project. In most cases the after-tax IRR actually remains negative. In other words, the project is economically unfeasible.

Figure 1.3.5.1

Sensitivity Analysis for After-tax IRR and ROI

RE delivered (MWh)		Avoided cost of energy (€/kWh)				
		0.0655 -15%	0.0712 -8%	**0.0770** 0%	0.0828 8%	0.0886 15%
21,463	-15%	negative	negative	negative	negative	negative
23,357	-8%	negative	negative	negative	negative	negative
25,251	0%	negative	negative	**negative**	negative	negative
27,144	8%	negative	negative	negative	negative	negative
29,038	15%	negative	negative	negative	negative	3.1%

Initial costs (€)		Avoided cost of energy (€/kWh)				
		0.0655 -15%	0.0712 -8%	**0.0770** 0%	0.0828 8%	0.0886 15%
18,790,276	-15%	negative	negative	negative	negative	-11.2%
20,448,242	-8%	negative	negative	negative	negative	negative
22,106,207	0%	negative	negative	**negative**	negative	negative
23,764,173	8%	negative	negative	negative	negative	negative
25,422,139	15%	negative	negative	negative	negative	negative

Annual costs (€)		Avoided cost of energy (€/kWh)				
		0.0655 -15%	0.0712 -8%	**0.0770** 0%	0.0828 8%	0.0886 15%
280,500	-15%	negative	negative	negative	negative	negative
305,250	-8%	negative	negative	negative	negative	negative
330,000	0%	negative	negative	**negative**	negative	negative
354,750	8%	negative	negative	negative	negative	negative
379,500	15%	negative	negative	negative	negative	negative

Debt interest rate (%)		Debt ratio (%)				
		59.5% -15%	64.8% -8%	**70.0%** 0%	75.3% 8%	80.5% 15%
8.5%	-15%	negative	negative	negative	negative	79.0%
9.3%	-8%	negative	negative	negative	negative	115.6%
10.0%	0%	negative	negative	**negative**	negative	155.8%
10.8%	8%	negative	negative	negative	negative	198.9%
11.5%	15%	negative	negative	negative	negative	244.2%

Debt interest rate (%)		Debt term (yr)				
		8.5 -15%	9.3 -8%	**10.0** 0%	10.8 8%	11.5 15%
8.5%	-15%	negative	negative	negative	negative	negative
9.3%	-8%	negative	negative	negative	negative	negative
10.0%	0%	negative	negative	**negative**	negative	negative
10.8%	8%	negative	negative	negative	negative	negative
11.5%	15%	negative	negative	negative	negative	negative

Net GHG emission reduction - 21 yrs (t_{CO2})		GHG emission reduction credit (€/t_{CO2})				
		6.0 -15%	6.5 -8%	**7.0** 0%	7.5 8%	8.1 15%
176,242	-15%	negative	negative	negative	negative	negative
191,793	-8%	negative	negative	negative	negative	negative
207,344	0%	negative	negative	**negative**	negative	negative
222,894	8%	negative	negative	negative	negative	negative
238,445	15%	negative	negative	negative	negative	negative

The Risk Analysis section, which is a much more complicated study compared to the sensitivity analysis provides the investor with a cardinal ranking of factors uncertainties that might impact the outcome IRR and the direction of impact (negative vs. positive).

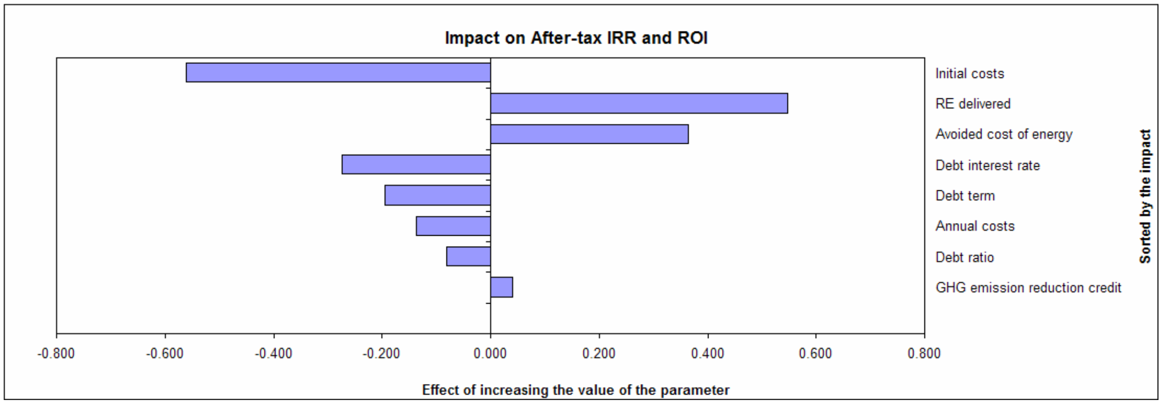
This section allows to perform a Risk Analysis by specifying the uncertainty associated with a number of key input parameters and to evaluate the impact of this uncertainty on project IRR. The risk analysis is performed using a Monte Carlo simulation that includes 500 possible combinations of input variables resulting in 500 values of project IRRs. The risk analysis allows assessing if the extent of each impact on the financial indicators caused by possible variation in input parameters is acceptable, or not. An unacceptable impact will be an indication of a need to put more effort into reducing the uncertainty associated with the input parameters that were identified as having the greatest impact on the financial indicator.

In Figure 1.3.4.1 the Risk Analysis section of Semenovka pass wind project RetScreen simulation is presented with its key output the impact graph.

Figure 1.3.4.1

Risk Analysis for After-tax IRR and ROI

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Avoided cost of energy	€/kWh	0.0770	10%	0.0693	0.0847
RE delivered	MWh	25,251	15%	21,463	29,038
Initial costs	€	22,106,207	20%	17,684,966	26,527,449
Annual costs	€	330,000	15%	280,500	379,500
Debt ratio	%	70.0%	10%	63.0%	77.0%
Debt interest rate	%	10.0%	30%	7.0%	13.0%
Debt term	yr	10	20%	8	12
GHG emission reduction credit	€/t_{CO2}	7.0	50%	3.5	10.5



The impact graph shows the relative contribution of the uncertainty in each key parameter to the variability of the financial indicator. The X axis at the bottom of the graph does not have any units, but rather presents a relative indication of the strength of the contribution of each parameter. The longer the horizontal bar, for a given input parameter, the greater is the impact of the input parameter on the variability of the financial indicator. The input parameter at the top, the initial capital costs (Y axis) contributes the most to the variability of the financial indicator while the input parameter at the bottom, GHG emission reduction credit contributes the least. The direction of the horizontal bar (positive or negative) provides an indication of the relationship between the input parameter and the financial indicator (e.g. if the capital costs go up, it will have a negative effect on IRR).

From graph we can see that the after-tax IRR, under given conditions of uncertainty, is most sensitive to initial capital costs (negative relation), energy delivered (positive), grid feed-in tariff (positive) and debt interest rate (negative).

The assumptions on the degree of uncertainty for various input parameters have been made in accordance with working group experience and common sense. Recommendation on possible policy improvements to help a project like Semenovka to become commercially attractive are also based on the outcomes of Sensitivity and Risk analysis results.

1.4. Permits, Tariff and Legal issues

Presently the law of the RA mandates the grid operator to purchase all electricity generated by renewable energy source during 15 years upon receipt of the Operation License. The current tariff for wind energy generation is at 35 AMD/kWh (about 0,076 € cent/kWh) and each year the tariff will be recalculated according to the methodology set by the GoA:

a) The tariff for 2008 and the following years for sale of electricity to be delivered from the Plants shall be set and revised according to the following formula:

$$T = T_1 \left[k_1 \frac{PI}{100} + k_2 \frac{ER_1}{ER_2} \right]$$

where,

T the value of the set tariff (AMD/kWh)

T_1 the value of the currently effective tariff (AMD/kWh)

k_1 the portion of the currently effective tariff that is subject to adjustment to the rate of inflation and is accepted equal to 0.1

PI the index of consumer prices for the period of January-September of the current year towards the same period of the previous year

k_2 the portion of the current tariff that is subject to adjustment to the € by changing the average monthly exchange rate of the RA AMD and is accepted equal to 0.9

ER1 the average arithmetic value of average monthly exchange rates of AMD towards € during the period of January-September of the current year

ER2 the average arithmetic value of average monthly exchange rates of AMD towards € during the period of January-September of the previous year

The Present tariff is set at **35 AMD/kWh**. Tariff revision shall be carried out each year before December 1 of the current year. Tariffs set as a result of revision shall become effective from January 1 of the year following the current year. If the 6-month period of effectiveness of tariffs for electricity delivered from the Plants is not expired yet, the tariffs set as a result of revision shall become effective after the expiration of the 6-month period of the tariff effectiveness.

If the Resolution No 353-N of the Public Service Regulatory Commission of 31 August 2007, on setting tariffs for sale of electricity delivered from the Plants of the entities that submitted power generation license applications becomes effective before December 1 of the current year, then the value of the tariff to be set shall be assumed equal to the value of the tariff currently effective for such types of the Plants. If the Resolution of the Commission on setting tariffs for sale of electricity delivered from the Plants of the entities that submitted power generation license applications becomes effective in December of the current year, then the value of the tariff to be set shall be assumed equal to the value of the tariff effective for such Plants from January 1 of the year following the current year.

The current tariffs for sale of electricity delivered from the Plants shall be revised and become effective from January 1, 2008. The tariffs effective as of the moment of setting tariffs for sale of electricity delivered from the Plants during 2008 (T_1) shall be assumed equal to the values of tariffs set according to point 2 of this Resolution.

Under this policy, and taking into account the fact that investment cost for wind energy projects in Armenia is at 1,350-1,550 €/kW of installed capacity (depending on the size, landscape and existing infrastructure) the current tariff and methodology can be favorable only for "good-excellent" sites (over 400W/sq.m power density, or with more than 7m/s of average annual wind speed) as well as under proper financing schemes (long term debt with low interest).

The Required permission to build and operate a wind park includes the following permits:

a) Land.
Currently the land code provides three forms of ownership – regional government lands, rural community lands and private.

b) Technical expertise.
Any project should pass technical expertise review to get construction permit

c) Environmental impact assessment.
Any project should get environment impact assessment and permit for construction.

d) Grid connection.
Utility scale plants would be needed to get grid interconnection requirements and permit from the grid operator.

e) Construction license.
To start construction of a wind park the developer needs to get license from the public regulatory commission.

f) Operation license.
To start operation of a wind park the developer needs to get license from the public regulatory commission

An overview of necessary permits and the procedures to obtain them for the construction and operation of requirement to power generation are outlined on PSRC website.

1.5. Conclusions

As the RetScreen analysis shows the current wind energy tariff of 0.076 €/kWh does not ensure the projects commercial viability. The calculated break even tariff (the tariff that makes the project viable) is close to € 0.12/kWh (and that break even tariff incorporates also benefits under CDM mechanism). At the same time, the new tariff calculation methodology does not sufficient provide the investor with ability to make a reliable long-run feasibility calculations as the tariff review includes consumer price index and foreign exchange rate fluctuation from year to year and therefore introduces uncertainty in the project evaluation.

For a project like Semenovka pass to turn feasible it is important to cut down initial capital cost by looking for a cheaper equipment provider, avoiding taxation and overall cuts in construction costs. It is important to get access to low-rate debt opportunity and have the wind energy tariff increased. There exist of course locations in Armenia with a higher average wind speed as well, this will improve the feasibility much.

It can be recommended for PSRC to review both initial tariff rate and the tariff methodology to making wind energy attractive for investors. At the same time a favorable legislation can offer the investors better investment environment (on VAT for imported technological equipment, profit tax, etc.) and provide access to low rate debt opportunity is also crucial for success and has to be addressed by the government.

1.6. References

RetScreen Textbook, 2007, http://www.retscreen.net

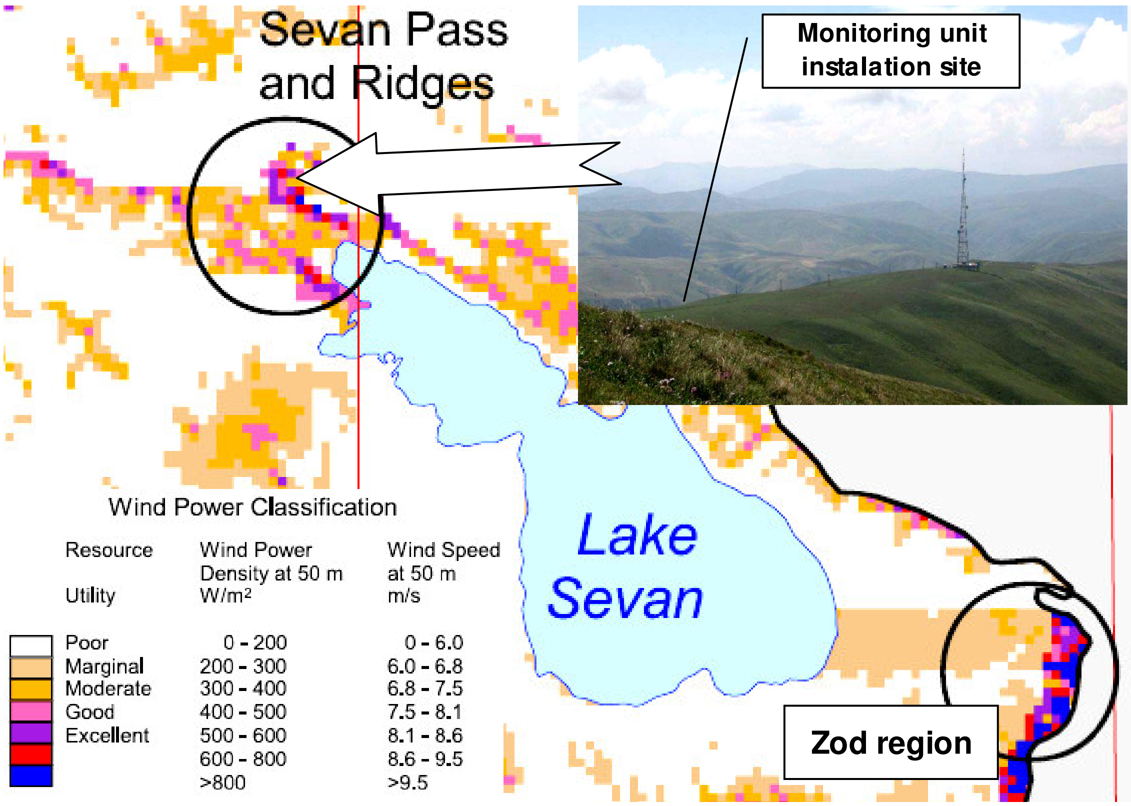
RetScreen On-line manual, 2007, http://www.retscreen.net

Wind Power Potential Assessment at Semenovka Pass Area, Armenia, Final Report, August 2007, Solaren, LLC, http://www.solaren.com

2. WIND POWER POTENTIAL ASSESSMENT AT SEMYONOVKA PASS

2.1. Introduction

According to the subject contract the site for wind monitoring has been selected at Semenovka Pass area not far from the TV tower. The 40m monitoring station was installed on July 25, when data registration started. The site is located on 2435 m above sea level and has the following geographic coordinates: N40.39.26 and E44.56.08. The wind monitoring station is installed at the 2 km distance from the road connecting Tsovagiugh and Semenovka villages.



2.2. Equipment

For the monitoring purpose the NRG Systems (USA) equipment is used.

Towers: *40 m mast.* Tall Tower TM is made of tube sections with 1.5m and 3m length and 6,0" (152 mm) diameter. This mast is supported by steel ropes with diameter of 4.78 mm. Sensors have been installed on special stainless beams on corresponding levels of the mast.

Sensors: The following wind sensors have been used: Wind speed sensors: NRG Max # 40 C Anemometer, Wind direction sensors: NRG # 200P Wind direction vane

Climatic sensors: Temperature sensor of 110S type; Barometer of BP-20 type; Humidity sensor of RH-5 type

The technical characteristics of the sensors are given in the Table 1 below.

Table 1.Sensor parameters

Sensors type	Raw Sensor Output	Scale Factor	Offset	Data Output Range	9300 Resolution
Maximum #40 Anemometer	0 to 120 Hz	0.76369 m/s/Hz	0	0 to 01.63 m/s	0.271%
200P Wind Direction Vane	0 to 10K ohm 0 to 2.5 V 8° dead band about north	N/A	0	0 to 359 degrees	0.271%
110S Temperature Sensor	0 to 2.5 V	0.1356 (°C)	-86.39°C	-40°C to 52.5°C	0.271%
BP-20 Pressure Sensor	0 to 5 V	0.04255	65.03 kPa	78.5 to 108.6 kPa	0.271%
Relative Humidity Sensor #RH-5		0.098	0		0.271%

Sensors mapping is shown on Table 2.

Table 2. Sensor map

Wind Speed Sensors				Wind Direction Sensors			Climate sensors		
Type	NRG #40 maximum anemometer			NRG #200P Direction vane			Temperature	Humidity	Pressure
Height (m)	40	20		40	20	-	6	3	3
Counter inputs channel	#1	#2		-	-	-	-	-	-
Analog inputs channel	-	-	-	#1	#2		#4	#5	#6

2.3 Logger

NRG Systems DL9300 Logger has been installed when monitoring has stared but due to failures it has been replaced with NRG “Symphony” type logger in December 2006. The technical characteristics of loggers are provided:

- Low power consumption provides high reliability in a wide range of environmental conditions and allows the use compact batteries and low wattage solar panels
- Standard RS-232 serial port connects the 9300 Logger to the NRG TermReader or laptop computer for easy setup and review of all operating parameters and inputs
- Easy configuration of parameters with a laptop PC or the TermReader.
- Average and standard deviation recorded at the end of each averaging interval including daily summary for all inputs.
- 256 kilobyte non-volatile PCMCIA FLASH DataCards store up one year of data.
- 5-watt solar panel and internal 12-volt get cell battery provide continuous and rechargeable power.

• 12 external signal inputs (6 analog and 6 counter channels) plus internal battery voltage and internal temperature channels.
• Removable circuit boards or "SIM cards" allow customization and capability to accept data from a wide range of analog or digital sensors.
• Programmable real-time clock adjusts automatically for leap years.
• Fully compatible with most meteorological sensors.
• Reliable operation in extreme temperatures: -40o to +70o C .

2.3. Equipment Maintenance

Data collection, processing and maintenance Collecting and monitoring data was carried out during the regular site visits. During each trip a special Visit Protocol was completed describing activities of the monitoring team. The main activities that were fulfilled during the site visits were:

- Maintenance of the mast with checking of all guy-wires clips, base plate, grounding cable and anchors. This activity includes visual check of sensors and necessary repair (adjusting of guy-wires, replacing of clips, etc.).
- Checking of data logger. This includes visual check of data logger status by appropriate LED blinking. Checking of power supply voltage and logger clock.
- Standard data collection procedure includes replacing of used memory card by the new one.

PART I. Wind Data Analysis

Wind data have been collected for 12 months from July 26, 2006 to July 23, 2007. During the monitoring of wind power equipment failure was observed and as a result the data for some period were missing. The missing data were correlated with long term data of nearby hydro-meteorological station for the same period, and been restored on the basis data consistency using the regression analysis.

At the same time icing of wind measurement sensors was observed during February, March and April. Based on the climatic of the site one also can expect icing in October – November, but due to lack of information the latter period has not been analyzed (only correlated with long term data). Difference between monthly average wind speed with icing and without taking it into consideration it are shown in the Table 3.

Table 3. Average wind speed (m/s) with and without icing.

January		February				March				April			
Not Icing		Icing		Without Icing		Icing		Without Icing		Icing		Without Icing	
40m	20m	40m	20m	40m	20m	40m	20m	40m	20m	40m	20m	40m	20m
10.41	9.86	5.94	5.75	6.72	6.43	3.31	3.59	6.26	5.95	4.08	4.18	7.52	6.99

Note: cut out all data with clear indication of icing from the final data file

As can be seen from tables the monthly average wind speed in March and April without taking icing into consideration grows up approximately twice. The results of monitoring show that the average annual wind speed taking into account the icing effect at 40m height was 6.4 m/s*:

2006						2007						AVG (11 months)
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	
4.2	4.9	6.3	n/a	5.9	10.4	6.7	6.3	7.5	6.1	5.2	6.1	6.4

**Note: Data for July 2007 (3 weeks) is calculated with data of July 2006 (1 week)*

Data for August, September and October 2006 are half month data (considered the same for the month)

Data for November 2006 were not available (considered the same for the month)

Data for December 2006 are half month data (considered same for the month)

Prevailing wind direction was distributed as follows:

2006						2007					
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

NEE	N	n/a	n/a	n/a	SW	SW	SW	SW	SW	NE	NE

As it can be seen the wind has a seasonal pattern: mostly North-east in summer, south-west in spring and winter.

More advanced wind data analysis was made by use the WindPro software. The software provides the following analysis results:

a) Annual histograms of wind speed and directions
b) Weibull data analysis
c) Wind energy analysis
d) Power generation for selected wind turbine

The correction of wind flow and data has been made based on the site elevation (plus site specific pressure and temperature) that was used by WindPro software for data analysis results. The data analysis is made for the height 20m and 40m while power generation forecast is extrapolated by the software for 50m height (considering calculated wind share).

The data analysis results are shown on the following figures:
Figure 1: Annual wind speed and direction frequency at 20m (also turbulence analysis)
Figure 2: Weibull data analysis at 20m
Figure 3: Main results of wind speed and direction data analysis at 20m
Figure 4: Wind data analysis for 40m

For the purpose of data analysis VESTAS V52/850kW wind turbine was selected (see PART II for explanation and justification for it).

Figure 1. Annual wind speed and direction frequency at 20m

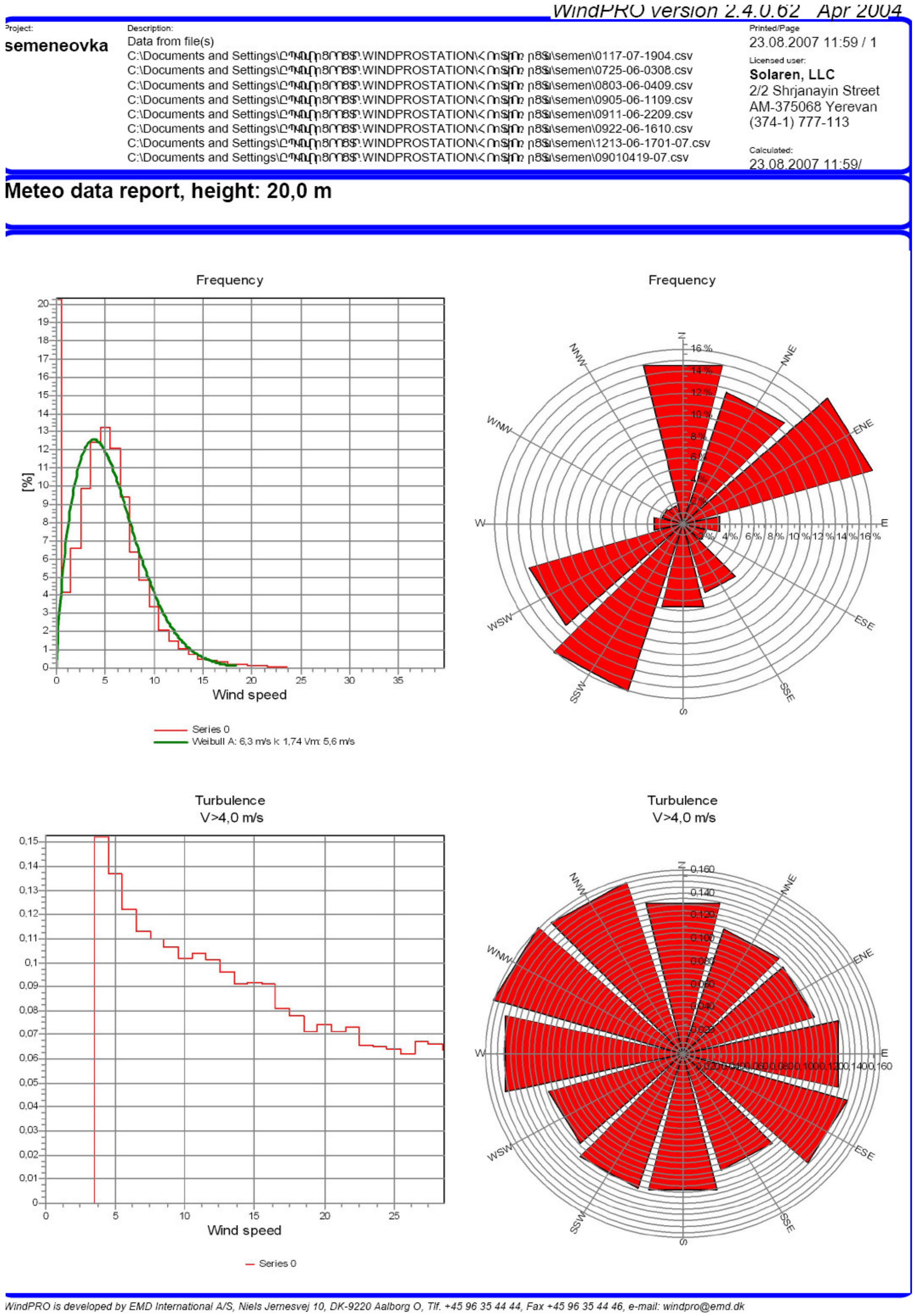


Figure 2. Weibull data analysis at 20m

WindPRO version 2.4.0.62 Apr 2004

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Description:
Data from file(s)
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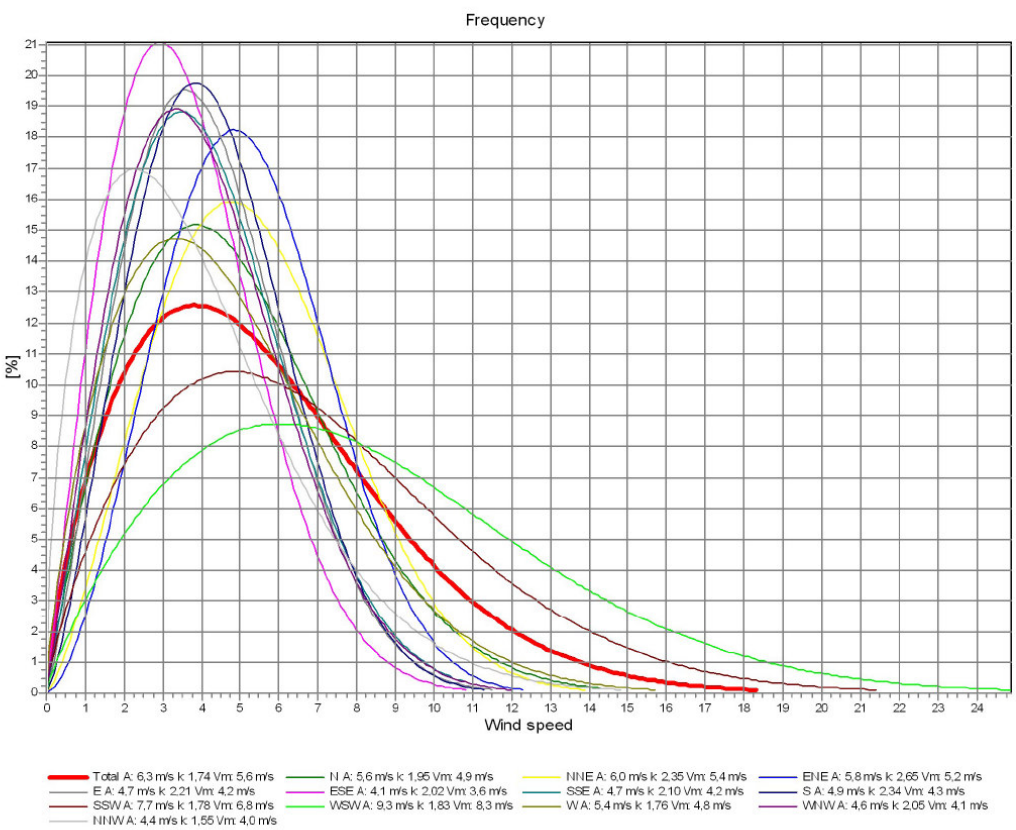
Meteo data report, height: 20,0 m

Weibull Data

k-parameter correction: 0,0080/m

Sector	A- parameter [m/s]	Mean wind speed [m/s]	k- parameter	Frequency	Frequency [%]	Wind shear
0-N	5,56	4,93	1,950	14,89	14,9	0,00
1-NNE	6,05	5,36	2,349	12,65	12,6	0,00
2-ENE	5,80	5,15	2,645	16,90	16,9	0,00
3-E	4,70	4,17	2,206	3,19	3,2	0,00
4-ESE	4,10	3,63	2,021	2,08	2,1	0,00
5-SSE	4,72	4,18	2,104	6,60	6,6	0,00
6-S	4,86	4,30	2,344	7,83	7,8	0,00
7-SSW	7,68	6,83	1,783	16,07	16,1	0,00
8-WSW	9,30	8,26	1,832	13,66	13,7	0,00
9-W	5,39	4,80	1,756	2,50	2,5	0,00
10-WNW	4,61	4,08	2,047	1,90	1,9	0,00
11-NNW	4,44	3,99	1,552	1,73	1,7	0,00
mean	6,28	5,60	1,736	100,00	100,0	0,00



WindPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg O, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, e-mail: windpro@emd.dk

Figure 3. Main results of wind speed and direction data analysis at 20m

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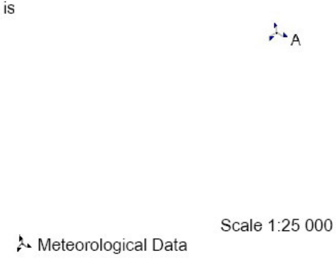
METEO - Main Result

Name	Measure and Weibull data
Site Coordinates	Geo East: 44°48'22"12 North: 40°24'05"6
Air density	0,945 kg/m3
Height above sea level	2 435 m
Mean temperature	4,0 °C

Calculation is based on "Measure and Weibull data", giving the Weibull distribution for the wind speed on the site.
Using the selected power curve, the expected annual energy production is calculated.



Weibull data 20 m above ground level

Sector	A- parameter [m/s]	Wind speed [m/s]	k- parameter	Frequency [%]	Wind gradient exponent
0 N	5,56	4,93	1,950	14,9	0,150
1 NNE	6,05	5,36	2,349	12,6	0,150
2 ENE	5,80	5,15	2,645	16,9	0,150
3 E	4,70	4,17	2,206	3,2	0,150
4 ESE	4,10	3,63	2,021	2,1	0,150
5 SSE	4,72	4,18	2,104	6,6	0,150
6 S	4,86	4,30	2,344	7,8	0,150
7 SSW	7,68	6,83	1,783	16,1	0,150
8 WSW	9,30	8,26	1,832	13,7	0,150
9 W	5,39	4,80	1,756	2,5	0,150
10 WNW	4,61	4,08	2,047	1,9	0,150
11 NNW	4,44	3,99	1,552	1,7	0,150
All	6,28	5,60	1,736	100,0	

Calculation Results

Key results for height 50,0 m above ground level
Wind energy: 2 240 kWh/m2; Mean wind speed: 6,4 m/s;

Calculated Annual Energy

WTG type						Power curve		Annual Energy			
Valid	Manufact.	Type	Power [kW]	Diam. [m]	Height [m]	Creator	Name	Result [MWh]	Result-10% [MWh]	Mean wind speed [m/s]	Capacity factor [%]
Yes	VESTAS	V52	850	52,0	44,0	EMD	Noise opt. 104.2(8m/s), 105.1(10m/s) 07-2002	1 493,9	1 345	6,3	20,0

Figure 4. Wind data analysis for 40m

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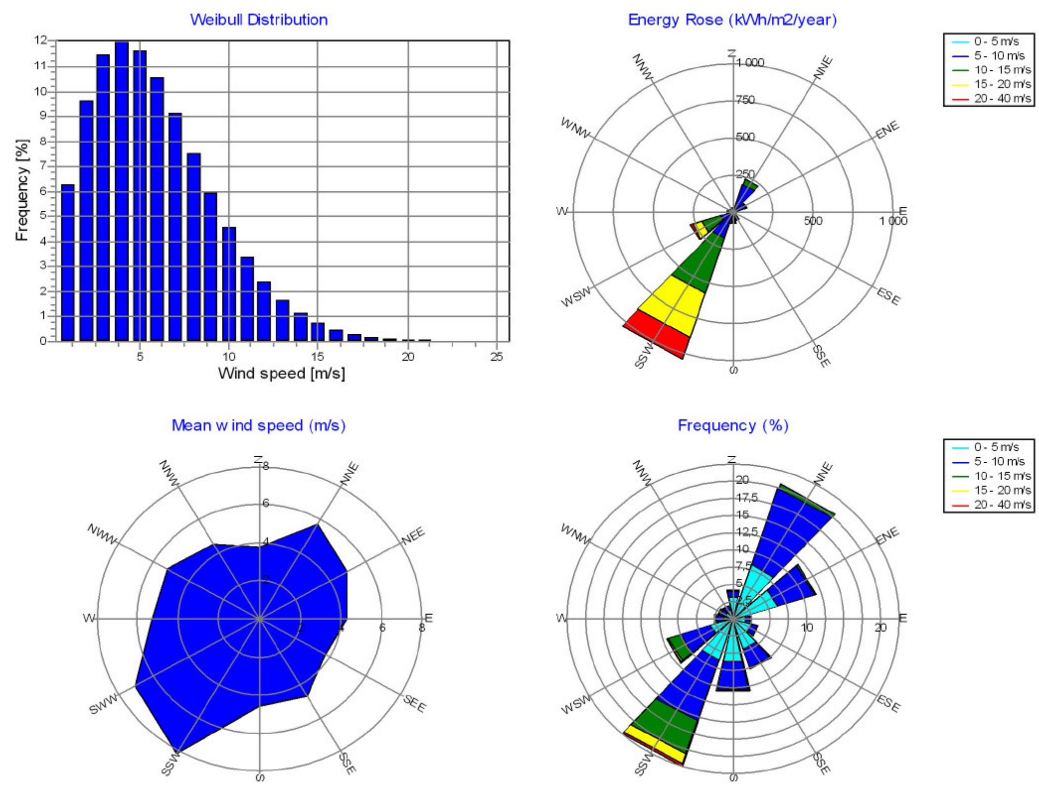
PARK - Wind Data Analysis

Wind data: A - Measure and Weibull data; Hub height: 40,0

Weibull Data

Sector	A- parameter [m/s]	Wind speed [m/s]	k- parameter	Frequency [%]	Wind gradient exponent
0 N	4,10	3,79	1,301	4,3	-0,381
1 NNE	6,41	5,70	2,708	20,6	0,089
2 ENE	5,55	4,92	2,557	11,8	-0,066
3 E	4,86	4,31	2,228	2,5	0,048
4 ESE	4,24	3,77	1,755	3,6	0,055
5 SSE	5,26	4,66	2,057	7,7	0,158
6 S	5,22	4,63	2,186	10,6	0,104
7 SSW	9,15	8,13	1,853	22,6	0,250
8 WSW	7,98	7,08	1,911	9,5	-0,224
9 W	5,92	5,27	1,770	2,6	0,135
10 WNW	5,87	5,23	1,752	2,1	0,358
11 NNW	5,05	4,51	1,664	2,1	0,176
All	6,58	5,86	1,744	100,0	



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Long term climatics. Analysis of long term and historical climatic data (Ref. "Научно-прикладной справочник по климату СССР". *Серия 3 Многолетние данные. Выпуск 16 Арм. ССР*. Гидрометеоиздат 1989) for the area have been also processed and are summarized in Table 4.

Table 4. Long term climatic data of the area

Description	Months												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Average T (C°)	-7.4	-7.0	-3.9	2.3	7.4	10.4	13.3	13.4	10.0	5.7	0.4	-4.7	3.3
Average atmospheric pressure hPa	803	802	802	803	805	805	805	806	808	808	807	804	805
Average partial pressure of vapour hPa	2.9	3.0	3.8	5.5	7.8	10.1	12.5	11.9	9.5	6.5	4.8	3.5	6.8
Average relative air humidity (RAH) %	77	79	79	77	78	80	81	79	80	74	75	76	78
Numbers of day with RAH <30%	0.1	0.3	0.1	1	2	2	0.7	1	5	3	0.5	0.1	16
Numbers of day with RAH >80%	11	11	12	9	9	8	7	8	7	6	8	12	108
Rainfall amount (mm)	35	44	63	83	114	104	67	49	52	62	49	34	756
Average height of snow mantle (cm) — ten-day period 1 / 2 / 3; Winter max avg / max / min	19 / 23 / 28	33 / 35 / 41	42 / 42 / 36	23 / 10 / 2							3 / 6 / 13	20 / 26 / 33	69 / 113 / 33
Average number of foggy days	9	9	11	12	10	10	10	10	15	12	9	8	125`
Average number of thunderstorm days			0.4	3	11	14	8	7	6	2	0.2	0.05	52
Average number of blizzard days	4	3	2	0.4						0.03	0.5	2	12
Average number of hailly days			0.02	0.2	1.1	1.4	0.6	0.6	0.4	0.2			4.5

Wind gust. Based on the available software, unfortunately, there was no possibility to make wind gust analysis. However, based on visual analysis of wind speed data the gust can be observed during less than 1% of the time on monthly bases.

PART II. Energy generation potential and plant layout

For estimation of site appropriateness and building there a wind power station power projection analysis was made by using two software WindPro (one turbine) and RetScreen (14.5MW plant).

For the purpose of analysis VESTAS V52/850kW/44m turbine was selected taking into account the following justification:

a) Equipment sizing. Due to transportation limitation (especially the length of the blades) only blades with length up to 28m (or rotor diameter up to 58m) can be delivered to Armenia by rail or roads. Longer blades can be delivered by air but that is not economically justified. The most suitable turbines in this term are those close to 850kW or 900kW.
b) Vendor. Two manufacturers with good track record of the equipment operation of that size at many sites worldwide are GAMESA (Spanish) and VESTAS (Danish). VEASTS was selected due to their willingness to enter in to Armenian market.
c) Hub height. Due to the complex terrain the effect of wind share in he are is not significant in average. Thus for cost effective reason lower tower height was selected (44m)

The results for the specified turbine are very close: generation forecast for one turbine by WindPro is at 1,494MWh/year while by RetScreen it is at 1,485MWh/year, and the park analysis takes into account the losses. Both WindPro and RetScreen analysis for (it is considered less than 15MW for simplified CDM proceedings) power generation forecast are shown on Figure 5-7.

Figure 5. Power curve analysis:

WindPRO version 2.4.0.62 Apr 2004

Project:
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Solaren, LLC
2/2 Shrjanayin Street
AM-375068 Yerevan
(374-1) 777-113

Calculated:
23.08.2007 11:48/2.4.0.62

METEO - Power Curve Analysis

WTG: VESTAS V52 850 52.0 !O! Noise opt. 104.2(8m/s), 105.1(10m/s) 07-2002, Hub height: 44,0 m

Name: Noise opt. 104.2(8m/s), 105.1(10m/s) 07-2002
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type
31.07.2002	EMD	16.11.2000	01.10.2002	25,0	Pitch	User defined

Special calculated, guaranteed power curve for noise optimization
For different air densities, different calculated power curves are available at Vestas. Based on EDB no: 946506.R6 dated 31-07-2002. Please conta
Vestas for information on latest power curves.

HP curve comparison

Vmean	[m/s]	5	6	7	8	9	10
HP value	[MWh]	988	1 631	2 300	2 953	3 505	3 994
VESTAS V52 850 52.0 !O!	[MWh]	1 093	1 729	2 385	3 001	3 543	3 989
Check value	[%]	-10	-6	-4	-2	-1	0

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTG's performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see WindPRO manual chapter 3.5.2.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement

Power curve

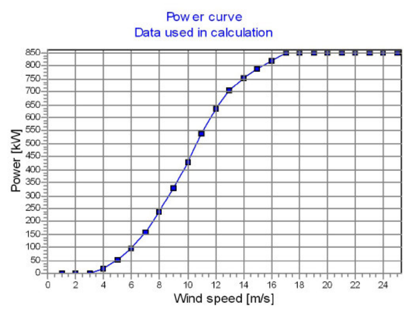
Original data from Windcat, Air density: 1,225 kg/m3

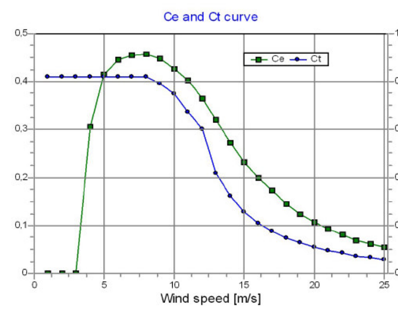
Wind speed [m/s]	Power [kW]	Ce	Wind speed [m/s]	Ct curve
3,0	0,0	0,00	4,0	0,82
4,0	25,5	0,31	5,0	0,82
5,0	67,4	0,41	6,0	0,82
6,0	125,0	0,44	7,0	0,82
7,0	203,0	0,45	8,0	0,82
8,0	304,0	0,46	9,0	0,79
9,0	425,0	0,45	10,0	0,75
10,0	554,0	0,43	11,0	0,68
11,0	671,0	0,40	12,0	0,60
12,0	759,0	0,37	13,0	0,42
13,0	811,0	0,32	14,0	0,32
14,0	836,0	0,27	15,0	0,26
15,0	846,0	0,23	16,0	0,21
16,0	849,0	0,20	17,0	0,17
17,0	850,0	0,17	18,0	0,15
19,0	850,0	0,12	19,0	0,13
20,0	850,0	0,11	20,0	0,11
21,0	850,0	0,09	21,0	0,09
22,0	850,0	0,08	22,0	0,08
23,0	850,0	0,07	23,0	0,07
24,0	850,0	0,06	24,0	0,06
25,0	850,0	0,05	25,0	0,06

Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 0,945 kg/m3

Wind speed [m/s]	Power [kW]	Ce	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1,0	0,0	0,00	0,50- 1,50	0,0	0,0	0,0
2,0	0,0	0,00	1,50- 2,50	0,0	0,0	0,0
3,0	0,0	0,00	2,50- 3,50	5,1	5,1	0,3
4,0	19,7	0,31	3,50- 4,50	26,1	31,2	2,1
5,0	52,0	0,41	4,50- 5,50	64,6	95,8	6,4
6,0	96,4	0,44	5,50- 6,50	109,7	205,6	13,8
7,0	156,6	0,45	6,50- 7,50	148,9	354,5	23,7
8,0	234,5	0,46	7,50- 8,50	171,4	525,8	35,2
9,0	327,9	0,45	8,50- 9,50	172,8	698,7	46,8
10,0	427,4	0,43	9,50-10,50	158,3	857,0	57,4
11,0	538,4	0,40	10,50-11,50	137,1	994,1	66,5
12,0	634,0	0,37	11,50-12,50	114,6	1 108,6	74,2
13,0	704,2	0,32	12,50-13,50	93,1	1 201,7	80,4
14,0	753,4	0,27	13,50-14,50	74,3	1 276,0	85,4
15,0	790,3	0,23	14,50-15,50	58,6	1 334,6	89,3
16,0	821,0	0,20	15,50-16,50	45,6	1 380,2	92,4
17,0	850,0	0,17	16,50-17,50	34,6	1 414,8	94,7
18,0	850,0	0,15	17,50-18,50	25,5	1 440,3	96,4
19,0	850,0	0,12	18,50-19,50	18,3	1 458,5	97,6
20,0	850,0	0,11	19,50-20,50	12,8	1 471,4	98,5
21,0	850,0	0,09	20,50-21,50	8,9	1 480,2	99,1
22,0	850,0	0,08	21,50-22,50	6,0	1 486,3	99,5
23,0	850,0	0,07	22,50-23,50	4,0	1 490,3	99,8
24,0	850,0	0,06	23,50-24,50	2,6	1 492,9	99,9
25,0	850,0	0,05	24,50-25,50	1,0	1 493,9	100,0





WindPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg O, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, e-mail: windpro@emd.dk

Figure 6. Production analysis:

WindPRO version 2.4.0.62 Apr 2004

Project:
semeneovka

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Licensed user:
Solaren, LLC
2/2 Shrjanayin Street
AM-375068 Yerevan
(374-1) 777-113

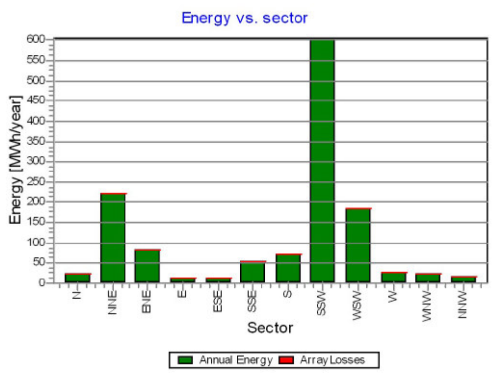
Calculated:
23.08.2007 11:50/2.4.0.62

PARK - Production Analysis

WTG: All existing WTG's, Air density: 0,945 kg/m3

Directional Analysis

Sector		0 N	1 NNE	2 ENE	3 E	4 ESE	5 SSE	6 S	7 SSW	8 WSW	9 W	10 WNW	11 NNW	Total
Roughness based energy	[MWh]	22,7	221,1	80,5	12,6	15,2	54,8	70,2	604,5	183,6	28,6	24,4	15,9	1 334,2
Resulting energy	**[MWh]**	**22,7**	**221,1**	**80,5**	**12,6**	**15,2**	**54,8**	**70,2**	**604,5**	**183,6**	**28,6**	**24,4**	**15,9**	**1 334,2**
Specific energy	[kWh/m2]													628
Specific energy	[kWh/kW]													1 570
Utilization	[%]	37,8	43,3	43,1	42,1	40,9	42,1	42,4	26,0	33,5	38,5	38,0	39,8	32,0
Operational	[Hours/year]	296	1 409	805	168	246	523	727	1 541	652	178	146	141	6 832
Full Load Equivalent	[Hours/year]	27	260	95	15	18	65	83	711	216	34	29	19	1 570



WindPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg O, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, e-mail: windpro@emd.dk

Figure 7. Generation potential:

RETScreen® Energy Model - Wind Energy Project — *Training & Support*

Units: Metric

Site Conditions		Estimate		Notes/Range
Project name		Wind Farm		See Online Manual
Project location		Semyonovka, Armenia		
Wind data source		Wind speed		
Nearest location for weather data		Semyonovka, Armenia		See Weather Database
Annual average wind speed	m/s	6,4		
Height of wind measurement	m	40,0		3.0 to 100.0 m
Wind shear exponent	-	0,10		0.10 to 0.40
Wind speed at 10 m	m/s	5,6		
Average atmospheric pressure	kPa	80,0		60.0 to 103.0 kPa
Annual average temperature	´C	4		-20 to 30 ´C

System Characteristics		Estimate		Notes/Range
Grid type	-	Central-grid		
Wind turbine rated power	kW	850		Complete Equipment Data sheet
Number of turbines	-	17		
Wind plant capacity	kW	14 450		
Hub height	m	44,0		6.0 to 100.0 m
Wind speed at hub height	m/s	6,5		
Wind power density at hub height	W/mЏ	379		
Array losses	%	2%		0% to 20%
Airfoil soiling and/or icing losses	%	2%		1% to 10%
Other downtime losses	%	7%		2% to 7%
Miscellaneous losses	%	3%		2% to 6%

Annual Energy Production		Estimate Per Turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	850	14 450	
	MW	0,850	14,450	
Unadjusted energy production	MWh	2 080	35 365	
Pressure adjustment coefficient	-	0,79	0,79	0.59 to 1.02
Temperature adjustment coefficient	-	1,04	1,04	0.98 to 1.15
Gross energy production	MWh	1 709	29 056	
Losses coefficient	-	0,87	0,87	0.75 to 1.00
Specific yield	kWh/mЏ	699	699	150 to 1,500 kWh/mЏ
Wind plant capacity factor	%	20%	20%	20% to 40%
Renewable energy delivered	MWh	1 485	**25 251**	
	kWh	1 485 332	25 250 641	
				Complete Cost Analysis sheet

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

As it seen from the analysis (production for the park) the expected output for 14.5 MW plant is at 25 250 000 kWh/year.

Plant layout. The 14.5 MW size of the project was determined by complex terrain of the site and the necessity of having the access roads to the foundations of turbines. As such 17 V52/850kW turbines are proposed to be installed along the range of the site. As far the prevailing wind direction has seasonal trend and almost perpendicular to the range, the turbines can be installed at 2.5-3 times rotor diameter distance within the row, and 5 times rotor diameter between the rows. The plant layout on the area (topographic map) as well as the installation, road and grid connection scheme are shown on Figure 8 .

Figure 8. Plant location and layout