RENEWABLE ENERGY IN ARMENIA: STATE-OF-THE-ART AND DEVELOPMENT STRATEGIES (WIND, SOLAR, AND HYDROGEN ENERGY)

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Abstract: Armenia has no own fossil fuel resources and is completely dependant on supplies from outside. Development of alternative energy resources is strategically important for the country. The inflow of solar energy per square unit of surface is higher for around 70% than in Europe, the assessed wind potential is 400–450 MW. There are definite shifts in hydrogen energy technologies. Some solar and hydrogen technologies are already commercialized. Definite progress is being made, with wind-, hydrogen-, and solar-generated projects. Part B of presented paper examined the current status and development paths of wind, solar, and hydrogen energy applications in Armenia. Following points, which presented specific interest, are in the focus: in what extent Armenia succeeded in keeping up the world tendencies of renewable energy, and what are the preconditions for the speeded-up development of renewable energy in Armenia?

Keywords: alternative energy, renewable energy, sustainable development, energy security, fuel cells

1. Wind energy

Armenia does not have a wind stream that is comparable to the Gulf Stream that exists in the USA, but there is nevertheless some wind potential. At

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present, the economically viable capacity for wind energy is comparable with nuclear, but wind energy development in Armenia is in its infancy. If wind power proves to be feasible, then Armenia could add wind-generated electricity to its portfolio of energy sources. It is too costly to use one windmill to generate electricity for commercial purposes, but a single windmill could be used in places with extensive rural areas. Armenia has large tracts of rural areas, but one of the legacies of Soviet industrialization is, that nearly every place in Armenia has access to the electricity grid, so a remote location that might otherwise need to generate its own energy simply does not need to. The future for wind power in Armenia, therefore, is in large wind farms that generate electricity that is then added to the grid. Some studies [1] have identified a number of such prospective sites in Armenia where wind farms could be erected. The Armenian government hopes one day to be able to generate as much as 10% of its electricity in this way. Start-up costs for establishing wind as an alternative energy source would be insignificant compared to the cost of building a new nuclear power plant. Wind conditions vary strongly in Armenia. Average wind speeds are mostly rather low (<4 m/s), but much higher wind speeds (in excess of 8 m/s) have been reported in several specific locations [1]. At this wind velocity, wind turbines can generate electricity for as little as three cents per kilowatt-hour, which is quite inexpensive.

Some calculations show that in Armenia could be technically possible to get 1.6 billion KWh wind energy yearly [1, 2]. Monitoring of wind energetic potential in Armenia was started in 1999. This research was organized within governmental agreement between Armenia and the Netherland. “ArmNedWind” company have established five monitoring stations, 14 more were setup by “Solaren” company and together with US National renewable energy laboratory (NREL) was worked out the Atlas of Winds in Armenia. Based on the results of the study the assessed total wind energy potential in Armenia for wind farms is 4,550 MW [3] (Table 1). During next five years is planned to construct two wind power plants with 50 MW and 20 MW capacities. The identified sites in Eastern-Sevan Ridge have

TABLE 1. Calculated energy potential of wind power stations in Armenia

Wind speed m/s	Area sq.km	% from total area	Total installed capacity MW
7.5–8.1	451	1.6	2250
8.1–8.6	207	0.7	1050
8.6–9.5	169	0.6	850
>9.5	85	0.3	400
Total	**912**	**3.2**	**4550**

potential for wind farm development with capacity of 50 MW and with power output of 153,000 MWh/year that can reduce over 100,000 ton/year of greenhouse gas emissions.

Zod Wind Company is involved in a 25 million dollar project to build a set of wind turbines in the east of Armenia [3].

Conclusions

Armenia's wind potential is not on a high level, but there are some capabilities for development of wind energy. Wind energy development in Armenia is on initial phase. The future for wind power in Armenia is in large wind farms as Armenia inherited from USSR developed energy grid and it will be not economically effective to construct single windmills. Several prospective sites where wind farms could be erected are already defined. The part of wind energy in energetic balance in Armenia in future is estimated up to 10%.

2. Solar energy

Energy from the sun is typically more affordable than wind power for individual residences. Currently photo voltaic cells needed for solar power are far too costly to be used for the national electrical grid. Solar energy generation capacity in Armenia is currently around 650 MW, but estimates for future capacity are as high as 3,500 MW.

2.1. SUCCESSFUL EXPERIENCE

Limited practical applications of solar energy have proven cost-effective for American University of Armenia (AUA), however. This university is supplied with hot water and with heating and cooling by a project that its academic engineers from Engineering Research Center (ERC) are working on. At Engineering Research Center in American University of Armenia for years is being researched solar energy and its applications. For nearly a decade, ERC has been engaged in a variety of solar energy-related projects, such as Solar Monitoring Station (SMS) Project, "Design and Installation of a Solar Driven Desiccant Cooling Demonstration System" – (DESODEC) Project and "Solar Photovoltaic Power Station" Project.

SMS project has National significance. The station collects solar radiation data to assist with evaluating and developing solar energy devices. Based on SMS data, engineers have calculated that one square meter of land in Yerevan receives about 1,700 kWh of sun power annually (please see Table 2) [4, 5].

TABLE 2. Sun power on one square meter of land annually in different areas of Armenia

Stations	Sun power (kWh/sq.m)	Stations	Sun power (kWh/sq.m)
Yerevan	1674.2	Martuni	1740.0
Kalinino	1404.0	Jermuk	1682.0
Giumri	1624.0	Qochbeq	1786.4
Sevan	1670.0	Kapan	1647.2

Yerevan is sunny for 300 days each year. Additional solar data collectors are proposed for installation at several locations around the country to further research the applications of solar energy.

AUA is supplied with hot water and with heating and cooling by DESODEC project. The system provides the university with heat in the winter, and cooling in the summer. DESODEC is the first solar driven combined system in the former Soviet Union, and one of a handful in the world. Solar photovoltaic station installed on the roof, provides electricity to the system that makes the university building independent from the electricity grid, and which serves to back-up the university Internet servers.

Conclusions

Armenia has sufficient solar resources for development of solar energy. Particularly in Yerevan one square meter of land receives about 1,700 kWh of sun power annually, which is 70% more that in Europe, where weighable shifts for solar energy applications are going on. Installation of solar energy systems in American University of Armenia in is a successful case of solar energy application in former Soviet Union.

3. Hydrogen energy

Hydrogen could well become the major component of clean sustainable energy systems in the longer term. There are four major tracks in the development of use of hydrogen: production, transport, utilization, and storage. Hydrogen can provide storage options for intermittent renewable technologies such as solar and wind. Storage of hydrogen is an important area for international cooperative research and development, particularly when considering transportation as a major user and the need for efficient energy storage for intermittent renewable power systems. Armenia is in the stage of research in this field and these production technologies are being investigated, which have the potential to produce essentially unlimited quantities of hydrogen in a sustainable manner.

3.1. HYDROGEN FUEL CELLS: FIRST FIRM STEPS

Investigation of hydrogen energy applications in Armenia are being realized mainly by small companies, such as H_2 ECOnomy. Activities of this company mainly are focused on fuel cells. H_2 ECOnomy is a research and development company located in the Ararat valley, Armenia. Its expertise encompasses conductive composite materials, catalyst chemistry, polymer chemistry, electronic design, embedded systems and system integration [6]. Knowledge in these fields has led to the creation of fuel cells for the educational and demonstration markets, sold worldwide through distributors in the USA, Europe, and Asia. H_2 ECOnomy was set up in 2002. It currently employs about 30 experienced scientists. H_2 ECOnomy already manufactures several types of fuel cells and auxiliary products on a small scale, selling their samples to researchers around the world.

Activities of this company are under attention of international community. The US government provided a $500,000 scientific grant to this company for the development of fuel cells, a forward-looking technology to transform hydrogen and oxygen into electricity. The grant is part of the US Energy Department's ongoing Initiatives for Proliferation Prevention (IPP) program.

The funding is allocated through a major research center of the U.S. Department of Energy (DOE). The two-year US grant is aimed at improving technical parameters and cost-effectiveness. US government funding is not only an opportunity to advance research but also a recognition of companies achievements. Officials from the US National Renewable Energy Laboratory (NREL), the DOE's Colorado-based research arm also are supporting Armenian initiatives in hydrogen energy investigations.

The technological process of the environmentally friendly power generation is remarkably simple. But there is a catch. Extracting hydrogen from other substances such as hydrocarbons and water is itself a very costly and power-consuming chemical process. On the other hand, pressurized storage of the very light gas requires additional expenses.

Fuel cell experts believe that the search for a more cost-effective technology will intensify in the next few decades as the world gradually runs out of its oil and natural gas deposits. According to several estimations, transition to a hydrogen-based energy system can occur in the 20–40-years time frame if government will make a strong focused effort to bring it about. The problem is that none of the dozens of fuel cell companies around the world, many of them owned by multinational carmakers, is believed to be profitable yet. They still have a long way to go before making the technology, which can power anything.

For H_2 ECOnomy, a more realistic goal now is to become a big research center that would sell fuel cell know-how to foreign manufacturers. The company is already "well positioned" to achieve that. There are a number of markets today where H_2 ECOnomy's fuel cell products can compete with current technologies. These areas include reliable back-up power or UPS systems and remote applications in the telecommunications area. H_2 ECOnomy's latest product is a fuel cell-based UPS extender with a capacity of 1 kilowatt. It can simultaneously power three personal computers.

Conclusions

Hydrogen could become the major component of clean sustainable energy in Armenia. Armenia is in the stage of research in this field. Investigation of hydrogen energy applications in Armenia are being realized by small companies, based on outside financing and methodical support, as these activities could not be economically profitable. Particularly H_2 ECOnomy company worked out fuel cells and is planning to establish research center and to sell fuel cell know-how to foreign manufacturers. Government is not active yet in this field.

4. Concluding remarks

Alternative resources might not be exploitable today, but that it might become a better bargain when, or if, Armenia scraps nuclear power. Over time, hydrogen, wind and solar productions may attract more and more donor support from the government and from others.

In the case of sufficient financial and technical assistance it is quite realistic to develop capacity for generation of 1,595 million kWh hydro, wind, and solar energy annually in coming 10–20 years. This will substitute 518,000 ton of emissions. fossil fuel and, consequently, 802 ton of CO_2 emissions will be avoided (Table 3).

TABLE 3. Indicators of renewable energy utilization

Used energy type	Power production million kWh/year	Fuel substitute 1,000 ton	Prevention of CO_2 emission 1,000 ton
Hydropower	1,275	420.8	690
Wind energy	120	39.6	64.9
Solar energy	200	28.9	47.4
Total	1,595	489.3	802.3

With an appropriate and comprehensive strategy, Armenia has an opportunity to enter the international renewable energy market. In contrast to other established industrial markets, the renewable energy industry has not yet matured worldwide, which could provide an opportunity for Armenia's scientists, its manufacturing industry, and associated businesses.

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