DEVELOPING RENEWABLE ENERGY ROADMAPS FOR THE DECADE 2010-2020. AN EXAMPLE: THE COUNTRY OF ARMENIA

Kenell J. Touryan
American University of Armenia
PO Box 713
Indian Hills, CO 80454
kenell@comcast.net

Areg Gharabegian
Parsons
100 West Walnut Street
Pasadena, CA 91124
areg.gharabegian@parsons.com

Artak Hambarian
American University of Armenia
40 Marshal Bagramian Ave.
Yerevan, 0019, Armenia
arthambr@aua.am

ABSTRACT

In 2005, the European Commission requested that all EU countries prepare renewable energy roadmaps for the decade 2010-2020 and beyond, to increase the use of renewable energy in each country. Under sponsorship of the World Bank a team, led by Danish Energy Management, prepared such a ten-year strategic document for Armenia. The project was prepared along lines recommended by the EU Parliament. Armenia and Switzerland share the absence of fossil fuel resources and rely heavily on large hydropower. The main results of the analysis for Armenia showed that the contribution of renewable energy in Armenia can increase fivefold by 2020 compared to the present energy production from RE technologies. The findings have ranked small hydro power (less than 10MW) and solar water heaters as the most cost effective systems for Armenia in the short and medium terms, followed by grid connected wind farms and the use of heat pumps.

1. INTRODUCTION: THE FIVE CONVERGING FACTORS

Over the past decade, five converging trends have emerged that are beginning to shape the energy future of the USA and the world(1). These five trends are as follows:

- *World Energy Demand Growth*. The world energy demand rate shows a steady, average upward trend of 2%, with China and India leading the developing countries. If we continue exploiting our non-renewable resources, such as fossil fuels, this will inevitably lead to a global crisis in mid-century. The United States constitutes only 5.5% of the world's population but consumes 26.5% of the world's energy. What will happen if China and India, which together constitute 35% of the world's population, attain the same level of prosperity by mid-century?
- *Global Environmental Awareness.* Accidents such as the Chernobyl nuclear power plant disaster of 1986, the more recent catastrophe in Japan, the 2009 oil spill in the Gulf, and a factor of 3 increases in greenhouse gases in our atmosphere since the start of the Industrial Revolution, have all created something akin to an eco-shock. As responsible stewards of planet earth, it is high time for everyone, and most of all ASA members to start looking at renewable technologies to provide a sustainable future for our energy needs.
- *Energy Security*. Security risks associated with the unequal distribution of fossil fuel resources throughout the world pose major destabilization threats. Renewable energy resources on the other hand (solar, wind, biomass, mini-hydro, organic waste utilization and geothermal) are quite equitably distributed, with one or more of these resources available to every country in the world. In addition, the distributed nature of renewable technologies provides an inherent security against terrorist attacks. Large power stations operated by fossil fuels or nuclear power plants are vulnerable to sophisticated terrorist attacks
- *New Energy Technology Options*. The new emphasis placed on alternate energy resources and serious efforts at energy conservation in developed countries and even developing counties, has led to the development of new technologies such as efficient gas turbines, better insulation of buildings, energy efficient appliances and a number of renewable technologies (such as solar hot water, run-of-the river small hydro power plants, wind farms, etc.). All these are becoming economically viable and have begun to make a noticeable impact on the world's energy budget.
- *Increasing Business Interest*. Power production in the electricity sector, fuel production in the transportation sector

and thermal energy applications together have become a trillion dollar business throughout the world. All this has led to a competitive market and opened up potentially lucrative business opportunities in the world's energy sector, including developing renewable technologies.

The convergence of these trends has given renewable energy technologies a significant boost as an economically feasible alternative to fossil fuels and nuclear power. In fact, the European Council of March 20067 called for EU leadership on renewable energies and asked the Commission to produce an analysis on how further to promote renewable energies over the long term, for example by raising their share of gross inland consumption to 15% by 2015.

2. EUROPEAN COUNCIL DECISION

The European Parliament has by an overwhelming majority called for a 25% target for renewable energies in the EU's overall energy consumption by 2020. To this end the Commission in 2006 prepared the framework for renewable energy road map for all EU countries to employ, in preparing their 10-yr strategies for achieving these targets. Similar initiatives have been taken by Australia, Russia and the USA. For example, in the US, the Solar America Initiative (SAI) is part of the Federal Advanced Energy Initiative to accelerate the development of advanced photovoltaic materials with the goal of making it cost-competitive with other forms of renewable electricity by 20158. Other countries, such as Georgia, Turkey and even Azerbaijan and Iran have also started to pay attention to renewable energy seriously, even though they are major producers of oil and gas.

Both eastern and western European countries have responded to this initiative and their road maps can be found on the Internet. It is beyond the scope of this article to allow us to give a comprehensive review of all these roadmaps. However, it will be instructive at this point to look at Armenia, and for comparison, briefly at Switzerland. Both are small countries and are looking ahead in the coming decades of how to meet their energy needs with minimum reliance on imported fuels. The reason for selecting these two countries is that both lack fossil fuel reserves and rely heavily on large hydropower for electricity generation.

3. THE SWISS PLAN (2010—2050)

Historically, Switzerland's longest serving and most important source of renewable energy has been hydropower, which has been the same for Armenia. But the new renewable resources including solar thermal, solar photovoltaic (PV), wood, biomass, wind and geothermal also play an increasingly important role in today's Swiss energy mix. For economical reasons, wood, biomass, solar thermal hot water, small hydropower, and wind to a modest extent are available now and in some cases are also economically attractive. The potential for PV and geothermal will be large only in the longer term (2030). One of the goals of Switzerland's energy policy for 2030 is to increase the proportion of electricity production from renewable energy by 10% of the country's present-day electricity consumption. As of 2007, approximately 55.6% of the Switzerland overall electricity production comes from renewable resources with hydropower providing 53.6% of this amount and the rest comes from other renewable resources, of which the largest portion is biomass (wood and biogas).

However, it is noteworthy that Switzerland is considering very seriously, to institute a drastic cut in energy consumption by 2050, down to 2000 watt per capita which represents a major cut from the 3000 watts per capita in the current level of energy consumption. Energy supply which would rely mainly on indigenous sources of renewable energy is thus only possible given a far lower level of energy consumption than today Thus a "2000watt society" is being promoted at the level of the Department of Environment, Transport, Energy and Communication(3).

4. THE ARMENIAN STRATEGY FOR THE NEXT DECADE (2010-2020 and beyond)

Unlike Switzerland, Armenia to date has not yet been ready to adopt renewable energy technologies (RET) for its energy budget. It has no fossil fuel resources in the country and relies on nuclear power for 35% of its electricity production and 30% in large hydro power, not unlike Switzerland. The balance comes from fossil fuel imports. In December 2010, the World Bank selected the Danish Energy Management Company to work with a team of Armenian engineers and scientists to prepare a 10-year strategy plan for bringing renewable technologies to Armenia(4). The roadmap was prepared along the same lines as the requirements set forth by the EU Parliament for their member countries. The team completed its plan in June 2011, and presented it to all branches of the government.

The plan showed that the country can group RETs into three categories, as in the Swiss case:

- Electricity production, from small hydropower plants (less than 10MW per river-run), wind power, photovoltaics (PV) and biomass.
- Thermal energy using heat pumps, solar thermal heat, geothermal, and biomass.
- Transportation from gas and liquid fuels, extracted form using non-food related biomass (such as corn Stover,

switch grass, algae) and eventually the use of hydrogen fuel cells.

Several factors were taken into consideration during the development of the roadmap, such as targets, technologies, legislative measures, and possible impact on the environment.

- The roadmap targets set the priorities in the development of the renewable energy (RE) and the energy systems such as energy independence, potential of lowering the energy costs, creation of high tech industries, environmental benefits, as well as responsiveness to the technological and business changes in the world.
- The types of technologies available determine the potential for energy generation, suitable management structures, pre-requisite infrastructure requirements, and how the use of the generated energy can be optimized. These technologies include: small hydro, wind, solar PV, solar hot water, biofuel, heat pumps and electric vehicles, pumped hydro storage, hydrogen economy, demand-side management tools for load leveling, and also energy efficiency technologies and measures. The global energy industry, technology, and business resemble a dynamic field that develops fast and relies on technological, scientific, and business knowledge.
- Preparedness for possible changes in the energy environment can be achieved through planning and developing the appropriate capacities in these areas. The changes to the energy environment may include technological developments, emerging export/import opportunities, as well as overall industry and economic developments in Armenia and in the rest of the world.
- RE legislation represents a package of legislative measures intended to encourage and to support the business as well as the implementation of renewable energy technologies (RET) by the population. Each RE option or technology requires a specific approach stemming from the Republic of Armenia targets. This set of variables serves as the catalyst for the RE development in Armenia. Managing these important factors through proper planning and regular updates would contribute to the achievement of the targets of the Armenian RE roadmap.

According to the main results of the Armenian RE roadmap project, the contribution of the renewable electricity in Armenia can increase by fivefold in 2020 in comparison to the present energy production from RE. In 2010 RE production generated 310 GWh, and it is forecasted to generate 740 GWh in 2015, and 1500 GWh in 2020. It is important to emphasize that the achievement of targets is much more dependent on politically implemented measures than on technical capabilities.

The findings of a comprehensive review of RE potential in Armenia have ranked small hydropower production (SHPP) (up to 10 MW) and solar hot water heaters as the most advanced RETs and the most economical for Armenia in the short to medium-term, followed by grid connected wind farms and the use of heat pumps.

Photovoltaics, geothermal power, and biofuels, especially bioethanol from cellulosic feedstocks, are ranked as more costly in today's prices and are not expected to be commercially viable in the short to medium-term, but may play a more important role in the longer term, and in the development of RE high-tech industry.
Biomass was also considered for both heat and electricity production for the short term, under several conditions, including re-planting of harvested trees and biofuels using fractionation process. In addition, hydrogen was considered as a possible fuel for transportation in the longer term. Finally, although not strictly a renewable resource, municipal solid waste in landfills was considered a practical source for generating methane for power production near municipalities. Table 1 presents the estimated RE technical potential in Armenia in accordance to the findings of the roadmap project.

TABLE 1. ESTIMATED RENEWABLE ENERGY TECHNICAL POTENTIAL IN ARMENIA

Technology Type	Capacity
PV	>1000 MW
Wind	300-500 MW
Geothermal	25 MW
Small Hydro	250-300 MW
Solar Thermal	>1000 MW
Heat Pumps	>1000 MW
Biofuel	100 thousand tons/year

One of the most important results of the renewable energy roadmap for Armenia project is the establishment of the national targets for renewable energy technologies in all three energy sectors. The targets are established using a special methodology, based on the consumption data of the last decade. To that end, energy demand for Armenia in electricity, thermal energy, and transportation sectors were developed for various scenarios including the base case, where the demand can be fulfilled by utilizing a variety of energy sources such as renewable energy, fossil fuels, and nuclear power. In order to provide ease of comparison of the calculated results, GWh units are used for all three sectors. Table 2 summarizes the demand forecast for the three energy sectors, using a base case scenario for each sector.

TABLE 2. BASE CASE DEMAND SCENARIO FORECAST

Sectors	Year, GWh		
	2010	2015	2020
Electricity	4500	5 700	6 600
Thermal Energy	11 270	11 900	12 600
Transportation Fuel	7 593	8 121	8 659

One of the most important outcomes of the roadmap related research indicate that for the base case the national targets for RE penetration could be 2.4%, 3.1%, and 4.9% for the years 2013, 2015, and 2020, respectively. If renewable energy is considered in its classical meaning, i.e. including large hydro and biomass (firewood), then the targets become 17%, 15%, and 16%, respectively.

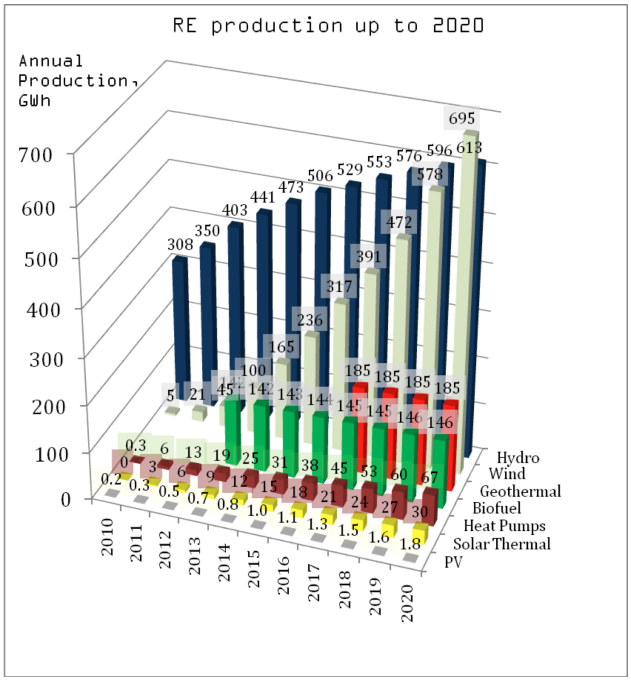

Fig. 1 Summary of Results of Base-Case Scenario

The base case calculations are performed based on the following two assumptions:

- The illegal cuttings of forests in Armenia that could amount in 2010 up to the equivalent of 2000 GWh, in 2015 they should decrease to the legally allowed (and naturally balanced) levels and result in 773 GWh.
- A new nuclear power plant (NPP) with 1000 MW installed capacity, planned to start its operation at the beginning of 2020.

The project suggests building a bioethanol capacity by 2013 that will provide 10% blend to all of the gasoline used in Armenia, which could decrease the imports of the latter by 18,000 tons annually. It is anticipated that gasoline consumption would not increase in the future but the growth of the demand for fuel would mainly be met by natural gas. Therefore, during midterm, additional production capacity of biofuel may not be needed to satisfy the 10% blending requirements. The creation of a fleet of cars operating on bioethanol after 2020, will allow the increase of bioethanol production up to 100 thousand tons/year. This will create a possibility to use up to 85% bioethanol blending.

In 2020, with the commissioning of the new NPP in 2017, there would be a power excess of more than 2000 GWh, which could be exported, representing the export potential for Armenia. The use of this potential may become an important basis for the regional cooperation, first of all in the directions of Armenia-Iran, Armenia-Georgia, Armenia-Turkey, and in other directions. In addition, introduction and exploitation of a fleet of electric vehicles (EV) and electric rail transportation means (in Yerevan and between the cities) will have a synergistic positive effect on the total power system, as well as on the improvement of the energy security of the republic, since:

a. The 100% dependency of the republic on the imported fuel would be eliminated.

b. Load leveling: since most of electric vehicles would be charging their batteries at night-time, they will be using the excess power of the new electric generation capacities most effectively, thus serving as a natural means of load leveling.

c. Environmental benefit by not releasing of approximately an equivalent of million tons of CO_2 every year. The air quality would significantly improve in the major cities, due to the substantial reduction of the emissions.

Development of various renewable energy sources and of industries associated with each of them is slow. Most of the time on a cost basis they cannot compete with traditional energy sources, with the exception of small hydropower plants (SHPP). Therefore, favorable laws and policies are necessary to stimulate the deployment of clean energy technologies. In general, laws and regulations of the Republic of Armenia are adequately addressing issues related to renewable energy. However, a more favorable regulatory environment is needed for the large-scale development of renewable energy resources in Armenia in order to achieve the targets listed in Table 2.

Governmental interventions would be necessary to achieve targeted goals for the development of RE in Armenia. These interventions were grouped into two main categories of legislation as well as institutional development and education, each with a number of sub-categories.

Business driven development and exploitation of the potential presented in the Table 1 is possible only through appropriate legislative support. In the electricity generation this is possible through adoption of the tariffs calculated in terms of the roadmap project. The break-even values of these tariffs that provide payback of expenses but without profit were also estimated. This system of supportive tariffs plays a central role for the achievement of the RE targets.

Several barriers that hinder the growth of RETs in Armenia are:
a. Obtaining the necessary permits and licenses for SHPP and wind power generation is cumbersome.
b. Coordination between different authorities in obtaining permits must be enhanced and the problems related to little transparency in procedures, long lead-times and high costs involved in obtaining permits or licenses must be solved
c. Turbines imported for small hydro power plants are free of VAT and customs duties; however, the law does not specifically mention that generators and other related control components are also exempt.

5. CONCLUDING REMARKS

Findings of a comprehensive review of the renewable energy potential in Armenia have ranked small hydro power using run-of the –river sources and solar hot water as the most advanced and economical for Armenia in the short and mid-term (by 2016), followed by grid connected wind farms and the use of heat pumps by 2020. The wind farms will be located in several mountain passes with the potential of supplying 20% of the electricity for the country. PV and cellulosic biomass from Jerusalem artichokes planted in arid regions will become economical after 2020.

The bottom line is that the use of RETs in Armenia can increase five-fold by 2020, forestalling the necessity for another nuclear power plant. However, Armenia is ranked very poorly in utilizing energy conservation and energy efficiency, compared to Switzerland (Japan is ranked the most efficient users of energy among developed countries). The roadmap prepared above made it clear that this option should come before Armenia invests large sums in RETs.

Two scenarios were presented to the government. One, scenario was with a new NPP, and the other without a new nuclear power plant. If the nuclear power plant becomes a reality after 2020 there will be excess electricity which then can be used to power electric cars in Armenia and/or generate hydrogen for cars to run on hydrogen fuel cells after 2020. Armenia has eliminated tramways, but still uses electricity-operated buses. Unlike in Switzerland, Armenia has very limited rail transport and is too poor to invest funds for an extensive rail system.

6. ACKNOWLEDGMENTS

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