RENEWABLE ENERGY PROJECT IN ARMENIA: MAIN RESULTS AND OUTPUTS

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1. Background

The Republic of Armenia is a small landlocked country with limited energy resources to satisfy its needs. Armenia has no proven oil and natural gas reserves, and imports nearly all of its all primary energy resources (oil and oil products, natural gas, nuclear fuel). Given the regional geopolitical instability and Armenia's closed borders with two of its neighbors, the high reliance of electricity generation on imported fuels (more than 70% is generated by imported natural gas and nuclear) makes the Armenian economy vulnerable to fuel price and supply fluctuations [1]. The severe consequences of fuel supply disruptions on the Armenian economy and people's lives surfaced during the energy crisis (1992-95) when the electricity supply declined to 2 to 4 hours a day and there was a massive collapse in industrial activity and national income. Armenia buys natural gas from Russia at subsidized prices, and if the geopolitical situation changes and the subsidies are removed, the gas price would increase significantly, especially in the light of rising international hydrocarbon prices.

Following the energy crisis Armenia has achieved remarkable results in reforming the power sector. It has restored round-the-clock supply of electricity, brought the tariffs to cost-recovery levels and successfully privatized most of the energy sector assets, including the electricity distribution network. A strong regulator (established in 1997[1]) played and continues to play an important role in

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[1] Presently the Public Services Regulatory Commission (PSRC); www.psrc.am

the sector. Reforms are steadily improving the sector's financial performance, including improved payment discipline, reduction of losses and related elimination of the quasi-fiscal subsidies, as well as sector efficiency and quality of the power supply. The key remaining challenge is to ensure sustainable and reliable power supply by increasing the energy diversification and achieving a higher degree of energy security through utilization of domestic renewable energy resources [2]. Presently, Armenia has sufficient electricity generating capacity to meet the electricity demand, but new capacities are a high priority, as the demand (expected to grow at 2-3% annually) is estimated to outstrip supply when the 400 MW nuclear power plant ends its operating life. Also, electricity supply is affected by aging and deteriorating thermal and hydropower plants; 70% of the country's hydroelectric plants are more than 35 years old and 50% are more than 50 years old; overall, 40% of the power plants are more than 30 years old.

Armenia has significant renewable energy resources, but they play a limited role in the country's energy mix. Approximately 740 MW of small hydropower, wind and geothermal resources have been identified, which, if implemented, would represent approximately 25%t of the present installed capacity. Hydropower and some of the wind resources are estimated to be most attractive. According to various estimates, over 250 MW of capacity could be added through small hydropower projects (SHPPs) that are competitive with other forms of new generation[1]. Overall, the existing legal and regulatory framework in Armenia appears to be supportive to the development of renewable resources. The Energy Law and the Law on Renewable Energy and Energy Efficiency articulate the importance of renewable resources and provide a framework for facilitating their development. Among other things, the legal framework guarantees purchase of electricity produced by small renewable power plants at the tariffs set by the PSRC and provides payment assurance. The PSRC resolution has set attractive tariffs for newly constructed run-of-the-river SHPPs (US¢ 4.5/ kWh), and wind and biomass plants (US¢ 7.0/kWh) for 15 years. These tariffs and the off-take obligation greatly enhance the predictability of revenue streams for the small renewables.

[1] See more information at the Renewable Energy Portal of Armenia. http://www.renewableenergyarmenia.am/

Despite the significant opportunities for renewable projects, private investment in such projects is impeded by a number of barriers and constraints:

- *High capital outlay and preparation costs for small renewable projects*: Renewable projects typically have high investment costs with long payback periods, and project preparation and development costs make up a significant share of overall project costs. For small renewable projects the preparation cost can be as much as 20% of the total cost. As a result, these projects are perceived to have high or marginally competitive costs compared to conventional projects;
- *Limited access to long-term finance and management capacity constraints*: While the projects are generally small and therefore not attractive for international investors, the access to local finance is also limited due to the underdeveloped local financial market, financial institutions (FI) with limited management capacity, lack of long-term funds, and prudential norms of the Central Bank of Armenia (CBA) that prevent financing of relatively large projects given the small size of the financial sector;
- *Unfamiliar risk profile of borrowers and related perception of high risk for renewable energy projects*. There is a considerable gap between the real and perceived risk by local FIs with respect to renewable energy projects. FIs do not have the necessary technical and commercial skills to properly assess and prepare renewable energy projects;
- *Lack of experience* of project sponsors, local FIs and engineering and consulting industry with renewable technologies and the appropriate project structures;
- *Legal and regulatory barriers* with gaps in regulations and procedures for resource allocation; long and often non-transparent process for obtaining the necessary permits, licenses and other required approvals; and tariffs for existing and newly constructed SHPPs operating on artificial water flows requiring further improvements to eliminate uncertainties and attract project financing;
- *Lack of reliable information* about the potential and perspective sites and technologies for renewable energy projects.

The Government of Armenia (GoA) has recognized the strategic necessity to diversify energy sector in general and the primary energy resource utilization in par-

ticular. The Energy Strategy Development Paper [3] declared Renewable Energy (RE) development as one of the 4 pillars of the energy strategy of the republic. Besides, The Poverty Reduction Strategy Paper (PRSP) adopted by the GoA in October 2003 emphasizes the need for policy reforms in five key areas, including promotion of private sector development and improvement of public infrastructures. More specifically, the PRSP states: "Maintaining and strengthening energy independence by developing indigenous and alternative energy sources and promoting energy efficiency. Regarding the development of indigenous resources, priority should be given to developing renewable energy production."

2. Renewable Energy Project in Armenia. Development Objectives, Main Components and Key Indicators

The objective of Renewable Energy Project (REP) implemented by Armenian Renewable Resources and Energy Efficiency Fund (R2E2 Fund) was to increase privately owned and operated power generation using renewable energy. The global objective of REP was to reduce greenhouse gas (carbon dioxide, CO_2) emissions by overcoming barriers to the development of renewable energy.

Key indicators of the projects were:

- Installed capacity (MW) of renewables added to the power grid;
- Renewable generation (GWh) added to the generation mix;
- Carbon dioxide emission reductions (ton CO_2).

It was expected that by the completion of the Project the installed capacity of the grid-connected renewable generation will be around 127 MW, the annual generation of renewable energy will be around 336 GWh, and the annual CO_2 emission reductions will reach 0.218 million tons.

The REP had two components; Credit and Technical Assistance.

A. Credit Component of the REP. Financing investments for the development of renewable energy projects US$ 21.4 million, of which US$ 5 million from the IDA credit (or $3.5 mln in SDR[1]). Private investors were able to access

[1] *Special Drawing Rights* (SDR) are supplementary foreign exchange reserve assets defined and maintained by the International Monetary Fund

financing for the development of renewable energy projects, mainly targeted at SHPPs on natural (run-of-the-river) and artificial (drinking water, irrigation pipes and canals) water flows and WPPs. The sub-loans ranged from US$ 100 thousand to $ 2 million with an average project size of US$ 500 thousand. The demand for the financing was significant. IDA funds were channeled through the R2E2 Fund. The R2E2 Fund provided finance to project beneficiaries through on-lending to Cascade Credit (CC), later on through Ameria Bank. CC and Ameria Bank pooled IDA and EBRD funds with their own co-financing in pre-determined proportions and extended loans to the beneficiaries.

B. Technical Assistance (grant) component of the REP. Assistance to remove barriers and support RE project implementation, including improvement of legal and regulatory framework, capacity building, support in facilitating investments in renewable sub-projects, development of mechanisms to leverage additional financing, implementation and monitoring (indicative amount: US$3.65 million, of which US$3 million from the GEF). This component covered the following areas:

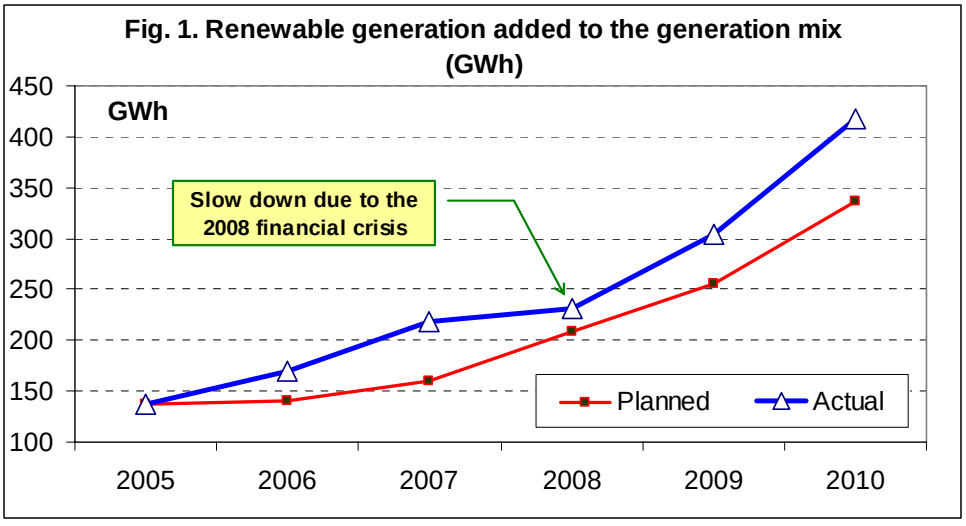
1. **TA Component 1**. Improvement of legal and regulatory framework and capacity building for state agencies: revising the existing legislation and regulations to improve and streamline procedures for transparent and fair allocation of resources (e.g. land rights, water permits, and licenses); developing sub-legislation to operationalize the law on renewable energy and energy efficiency; reviewing and amending the rules of acceptance for small renewable generation for the system operator.
2. **TA Component 2.** Capacity building and support to facilitate investments in renewable energy sub-projects: (a) TA and capacity building to local FIs, private investors, local engineering and consulting industry, including information and incentives about new renewable energy technologies and associated benefits; (b) developing a comprehensive database of renewable energy resources, with a related open source Geographic Information System (GIS), and a web portal for identification, assessment, and monitoring of potential renewable energy projects; (c) field survey of potential sites; (d)

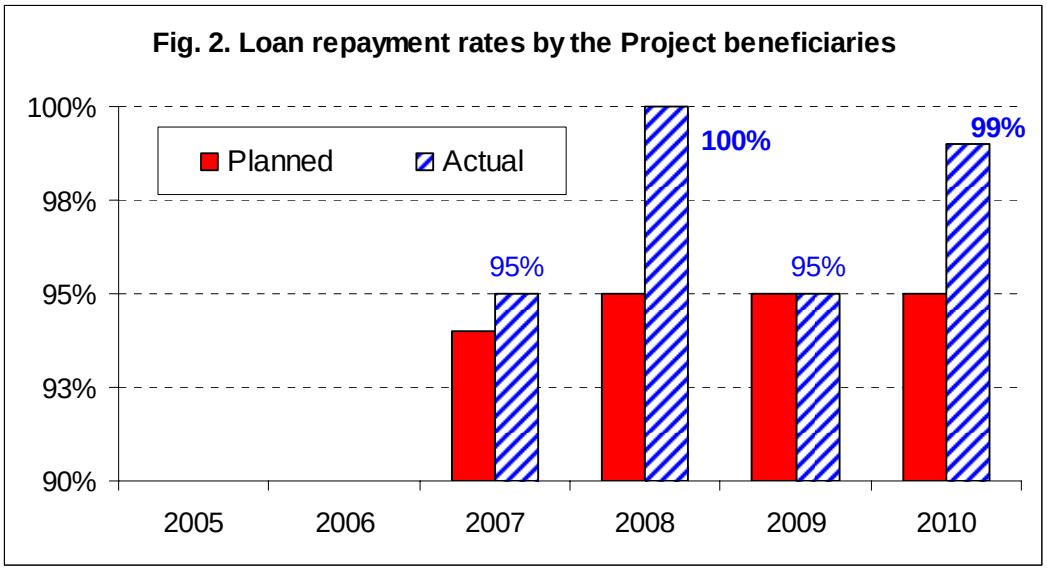
establishing a one-stop-shop for potential investors to facilitate the process of obtaining required permits, licenses, and other documents; (e) TA to potential investors for project preparation activities, such as business plans, feasibility studies, and preliminary designs.

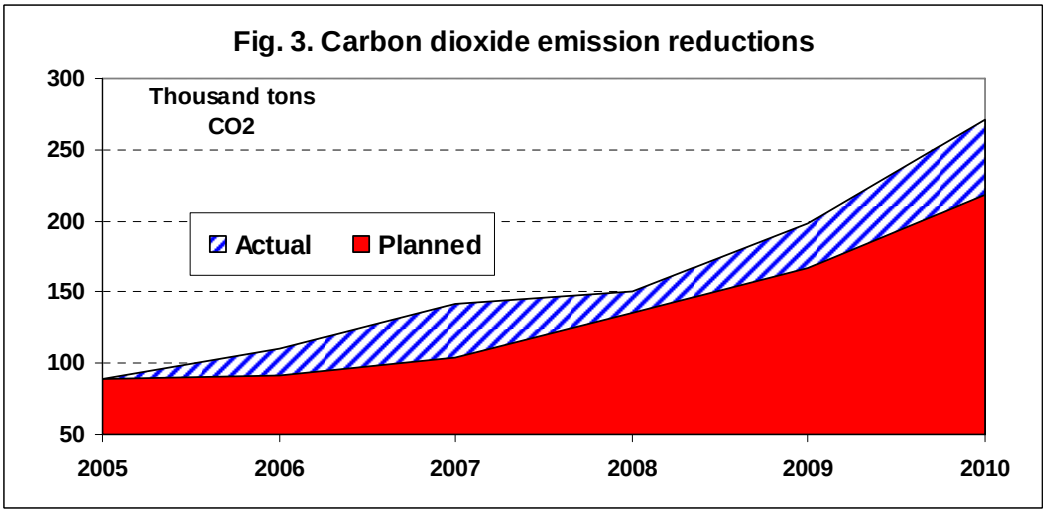
3. **TA Component 3.** Mechanisms to leverage additional financing: assistance provided to the R2E2 Fund and other implementing agencies to prepare a long-term strategy for the mobilization of additional financing for developing renewable energy.
4. **TA Component 4.** Project implementation and monitoring.

3. Overall Results of REP in Armenia

The implementation of the project was sound and without any major delays. The project funds under all of the components were almost entirely (97%) disbursed by the end of 2011. The project meets all the targets specified under Project Appraisal Document (PAD). Moreover, in some of the main outcomes (Actual Installed RE capacity connected to grid (in MW), Actual RE generation added to the generation mix (in GWh), Actual Carbon dioxide emission reductions (in tons of CO_2), REP results exceeded the expected target outcome indicators even during the years 2008-09, a period marred with global financial crisis (see the Figures 1, 2 and 3).







Relevance of the project objective was rated high. The project objective, as stated in the Project Appraisal Document, was to increase privately owned and operated power generation utilizing renewable energy. The objective was relevant to and consistent with the development priorities of the Government as reflected in [3] and Sustainable Development Program (2008). The project made significant progress in meeting the development objective and exceeded all of the key performance indicators. The table below summarizes the achievements of the REP objectives under the REP Credit component according to the project indicators.

Outcome Indicators (credit component)	2006	2007	2008	2009	2010
Aggregate amount of investments financed by the PFI (R2E2 Fund), million US$					
Plan	2	6	11	16	21
Actual	0.0 (0.0)	5.4 (1.8)	11.8 (3.7)	28.32 (5.0)	28,6 (5.0)
Loan repayment rates by the Project beneficiaries (%)					
Plan	NA	94%	95%	95%	95%
Actual	NA	95%	100%	95%	99%

As of December 31, 2010 the total RE based electricity production (without large hydro) in Armenia was about 417 million kWh or about 7.6% of total electricity production in the republic (5,472 million kWh). This quantity comes from about 100 SHPPs with total installed power of 129 MW, one 2.64 MW wind farm and one 0.8 MW biomass plant. It should be stressed that the percentage of RE based electricity production in comparison to the total national production for Armenia is considerably higher than the same percentage in all neighboring countries – Georgia, Azerbaijan, Iran, Turkey or Russian Federation.

The project met the development objective through support to SHPP and RE projects developers along the whole chain of their activities – from idea to construction and commissioning of the power plant.

Support in Project identification, siting and design. Through different subprojects under the two separate components, REP focused on supporting the developers to identify and choose perspective sites for SHPPs, prepare adequate design documents, have access to affordable credit financing, etc. Specifically, over a decade old "SHPP development scheme in Armenia" was completely updated, corrected and modernized.

Provision of affordable credit financing to the developers. Under the credit component through IDA credit (SDR 3.5 million, or USD 5 million equivalent) different SHPPs projects were carried out with total installed capacity of about 44 MW and total annual production of 159 million kWh.

It should be stressed that REP achieved its objectives also in area of crediting and financial discipline of loan repayments. As presented in the Fig. 2 above,

actual loan repayment for REP credit component was never lower than the planned level of 95%. Actually, repayment level of 95 % was recorded only for 2007 – the starting year of the loan repayments, and in 2009 – in the aftermath of global financial crisis (see Fig.2).

Capacity building and knowledge transfer. Under the Technical Assistance (TA) component of the REP, 124 leading experts from Armenia and abroad (USA, Denmark, Sweden, Switzerland and Russia) were involved. About 24 separate project activities (services) were carried out in the various RE areas under the TA component.

The overall outcome of the project is rated Satisfactory due to high relevance of the project and achievement of the project development objective as measured by the key performance indicators. The project contributed to a substantial increase of privately owned and operated RE-based power generation in Armenia.

4. Main Outputs of REP by its Components

The main results and outcomes of REP by its components are presented below.

A. Credit Component of the REP. Financing of investments for the development of renewable energy projects.

Under the credit component of the REP, through an IDA credit, 23 different SHPPs projects were carried out with total installed capacity of about 44 MW and total annual production of 159 million kWh. Geographically these SHPP projects are located in eight out of the total 10 Armenian marzes (regions):

Lori marz, 6 SHPP projects	Kotayk marz, 2 SHPP projects
Tavush marz, 5 SHPP projects	Ararat marz, 1 SHPP project
Vayots Dzor marz, 4 SHPP projects	Shirak marz, 1 SHPP project
Syunik marz, 3 SHPP projects	Gegharkunik marz, 1 SHPP project

The installed power for these SHPPs ranged from 0.38 MW and up to 5.7 MW. Fourteen SHPPs out of the total 23 were located on natural water flows (derivational SHPPs), four were on irrigation canals, four were on irrigation pipes and one was on a potable water network. As of December 31, 2010, 12

SHPPs were in operation and the rest of the plants were in final stages of construction. The table below summarizes the technical information of the mentioned SHPPs.

NN	SHPP Name	Installed capacity, kW	Annual production, million kWh	Type
1	Bovadzor	380	2,23	canal
2	Aygezard	2000	6,42	canal
3	Apres	1500	11,34	natural water flow
4	Jradzor	5720	18,22	canal
5	Chanakhchi	1430	5,36	natural water flow
6	Kurtan	5700	16,12	natural water flow
7	Aghstev	3080	14,40	natural water flow
8	Ler-Ex 1,3,4,5,6	1830	13,04	water supply pipeline
9	Aygedzor-2	3200	4,01	irrigation pipeline
10	Ayri	1282	4,35	irrigation pipeline
11	Lernapat 1	560	2,87	natural water flow
12	Khachaghbyur 1	2190	8,07	natural water flow
13	Vahagni	953	7,18	canal
14	Aygedzor	400	1,56	irrigation pipeline
15	Spitak-1	725	3,72	run-of-the-river
16	Surb Aghbyur	737	2,49	natural water flow
17	Dzoragyugh-1, 2	680	4,08	irrigation pipeline
18	Artavan-1	2580	6,50	natural water flow
19	Khachaghbyur	1220	4,96	natural water flow
20	Yeghegnadzor	1430	7,85	natural water flow
21	Her-Her 1	1608	4,24	natural water flow
22	Goght 2	2316	5,19	natural water flow
23	Goght 1	1946	4,76	natural water flow
	TOTAL	**43 467**	**159**	

During the REP implementation $4.96 million of IDA credit was disbursed through R2E2 Fund for the mentioned SHPPs projects. It should be noted that total loan amount approved by banks for these projects amounted to $15.7million. The IDA credits ranged between minimum $12.5 thousand and maximum $433 thousand, with average amount of $170 thousand. Typical loan terms were

for 96 months with average interest rate of LIBOR plus 1% (during the implementation of REP, the rates varied from 2.5% to 6.4%). In addition, the lending bank added its interest rate, but the total rates did not exceed 12.5%. The loan repayment rates by the Project beneficiaries during the implementation were never below the planned level of 95% (Fig. 2).

B. Technical Assistance (TA) component of the REP.
Assistance to remove barriers and support RE project implementation, including improvement of legal and regulatory framework, capacity building, support in facilitating investments in renewable sub-projects, development of mechanisms to leverage additional financing, implementation and monitoring

Under the TA component 24 separate project activities (services) were carried out in various RE areas, such as: small and mid scale hydro power plants, pumped storage hydropower plant, modern solar photovoltaic, bio-ethanol production, high potential geothermal power and grid-connected wind power. Besides, special activities were dedicated to the elaboration of RE codes and standards for several RE technologies and applications, strengthening the capacity building and training projects, extensive information dissemination about new renewable energy technologies and the associated benefits, developing a comprehensive database of renewable energy resources, with a related open source Geographic Information System (GIS), support to the development of business plans, feasibility studies, and preliminary designs in RE areas, study and design of different financial instruments to accelerate lending to sub-borrowers, replenish funds and enhance the leveraging impact of the RE projects of broad informational campaigns for increasing of the public awareness, etc. One of the key activities under this component was the preparation of Renewable Energy Development Road Map for Armenia.

The Technical Assistance component supported the following key TA activities:

Improvement of legal and regulatory framework and capacity building for state agencies. Services carried out under this subcomponent can be grouped by the following main directions:

- Development of normative documents on the RE-based power generation technologies,
- Development of renewable energy in Armenia: lessons learned, determining the barriers and outlining the ways to overcome them,
- Assistance to the Ministry of Energy and Natural Resources (MOE) administration on the RE website.
- Strengthening the capacity of the Public Services Regulatory Commission (PSRC), the MOE, State Water Committee, and Meteorological Service and limited commodity support to the PSRC and MOE.

In particular, 26 norms and standards on Renewable Energy and Energy Efficiency were developed based on the US, European and Russian standards. These documents cover such areas as Solar Collectors and PV panels, Solar Heating and Hot Water Preparation, Wind Energy, Hydropower and Energy Efficiency and Conservation. Another important outcome under this subcomponent was the determination and analysis of the main barriers for development of market-ready renewable energy (small hydropower and wind power) in Armenia, based on the results obtained under the project "Development of renewable energy in Armenia: lessons learned, existing barriers, and measures for overcoming those barriers".

The short list of the determined barriers is presented below.

Barriers for development of small hydropower plants (SHPP)

1. Barriers in Legislation, Licensing, Permits: Signing the Power Purchase Agreement only after the construction of SHPP; limited validity period (only 3 years) of the Water Utilization Permit; vague requirements on ecological flows of rivers; license vs. ownership rights; no Governmental decree on water amount guarantees
2. Barriers in Land Ownership and Lease: inefficient occupation of land
3. Barriers in Financing: insufficient availability of financing sources; the VAT issue; artificially complicated and "not developer friendly" methodology and formula for tariffs

4. Barriers in Environmental Impact Assessment (EIA): ambiguity in duration of issuing the EIA
5. Barriers in Design, Hydrology, Construction: inaccuracy of design documents, which later result in problems when applying for funding; absence of the normative base; incorrect siting of SHPP; construction issues.

Barriers for development of wind power plants

1. Barriers in Legislation, Licensing, Permits: Power Purchase Agreement similar to SHPP; license vs. ownership rights
2. Barriers in Land Ownership and Lease: land allocation for wind power projects and "shadowing" effect for multi-owner sites
3. Barriers in Financing: Insufficient availability of financing sources
4. Barriers in Tariff Methodology: insufficiently attractive tariff for wind power projects; artificially complicated tariff formula and methodology
5. Barriers in EIA: ambiguity in duration of issuing the EIA
6. Barriers in Design, Construction: lack of professional experience; absence of the normative base.

The results of the mentioned investigation together with the outlines of methods to overcome these barriers were presented in a special seminar with participation of all decision makers and stakeholders in the RE area. Based on the achieved results and following the recommendations formulated in the study and by R2E2 Fund, special intergovernmental body was created by the decision of Prime Minister of Armenia in order to address all the raised issues and provide coordination to the works by overcoming barriers between different governmental and other entities.

Finally, the capacity of the PSRC and MOE were strengthened with limited commodity support (IT equipment) under this subcomponent.

Capacity building and support to facilitate investments in renewable energy sub-projects. Services carried out under this subcomponent can be grouped in the following main directions:

Assistance to local FIs, private investors, local engineering and consulting industry, including information and incentives about new renewable energy technologies and associated benefits

- Update of the existing Scheme of Armenian Small Hydro Power Development.
- Assessment of the hydropower potential for peak power production for Armenia and the region.
- Assistance to the modern Solar PV development in Armenia.
- Assistance to the bio-ethanol production development in Armenia.
- Determination of high potential geothermal sites in Armenia.
- Design of an emergency automation system for the Armenian power network with high penetration level of renewable energy.
- Assistance to dispatching and control aimed at increasing RE absorption capabilities of Armenian power network.
- *Development of a comprehensive database of RE resources, with a related GIS*
- Developing of the Geographic Information System (GIS) of Armenia, maintaining and editing the RE GIS (DB).
- *Assistance to potential investors for project preparation activities, such as business plans, feasibility studies, and preliminary designs*
- Support for preparation of RE business plans.
- *RE development strategy*
- Preparation of RE development roadmap for Armenia.

TA Component 3. Mechanisms to leverage additional financing: assistance provided to the R2E2 Fund and other implementing agencies to prepare a long-term strategy for the mobilization of additional financing for developing renewable energy. Services under this subcomponent targeted the following main directions:

Assistance for Development of RE Business Plans. The main outcome of this project was the publication of "Business Plan Manual for Renewable Energy Projects" in Armenian language, based on information about modern RE technologies (mainly hydropower and grid connected wind power), all procedures

and requirements of the Armenian legislation in the RE area, etc. The Manual also includes a trilingual (English, Armenia, Russian) dictionary of the main common RE terms. This manual was printed in 150 copies and disseminated during the public awareness campaign of the R2E2 Fund in June 2011.

Organization of publications and information materials, workshops, road-shows, seminars and round tables on RE issues. During the implementation of REP several activities were carried out including: road-shows and conferences for potential investors in RE areas in Armenia, promoting the advantages of RE development and facilitating information exchange between the interested parties.

World Economic Forum in Davos 2009. In order to present Armenian energy sector during the World Economic Forum in Davos in January, 2009, the R2E2 Fund prepared a special presentation about current status and perspectives of RE development in Armenia based on progress achieved during implementation of REP. The presentation contained brief information about Armenian economy, investment climate and legislation ("Country in Brief"), as well as short description of the potential in hydropower, wind power and solar energy in Armenia with details about investment opportunities and specific projects in RE area and energy sector in general.

The **International Renewable Energy Agency** (IRENA) came into being on January 26, 2009 at the Founding Conference of IRENA in Bonn. More than 120 government delegations from across the world attended the conference and a total of 75 nations, a broad cross-section of developing and industrialized countries, signed the Agency's statute. In order to present the current status of RE sources utilization and the potential of development, as well as to attract some interest, financing and technology transfer possibilities for Armenia from EU and the world, the R2E2 Fund prepared a special presentation on REP results for the Armenian Delegation for IRENA founding conference. During the founding conference Armenia signed the statute of International Renewable Energy Agency. Thus, Armenia became one of the 75 Signatory States of the Conference on the Establishment of the IRENA and the first republic from South Caucasus to do so.

On behalf of the Government of the Republic of Armenia, the Minister of Energy and Natural Resources of the Republic of Armenia, A. Movsisyan, stated: "I am glad to announce that I intend to sign the founding documents of the International Renewable Energy Agency. Armenia plans to establish active collaboration with the Agency for better, cleaner and more affordable energy for our countries, for us and for our children!

"ArmTech" International Pan-Armenian Conference on High Tech and Technological Development. Given the limited possibilities and funds of the REP, it was decided to use the already established platforms for promotion of RE investment opportunities in Armenia and organization of international road-shows. One of them was the International Pan-Armenian Conferences on High Tech and Technological Development, regularly held since 2005 in the USA and Armenia. The first presentation of REP and RE opportunities took place at "ArmTech 2007" conference (July 2007, San Francisco, USA). A presentation titled "Renewable Energy and Technology Development in Armenia" was delivered at the plenary session. During the "ArmTech 2008" conference (October 2008, Yerevan, Armenia) an article titled "Renewable Energy & High-Tech: What can be done in ARMENIA?" was presented.

The final document of the conference it stated that:

- Both Hi-Tech & RE areas have high priority in the National Development Strategy papers in Armenia.
- Both Hi-Tech & RE areas have high productivity and growth potential. One should expect and make use of the cumulative effect from the synergy between these two important areas.
- Thus, it is an urgent task to elaborate, discuss, approve and implement a "Hi-Tech & RE Integrated Development Road Map" (The RE Development Road Map was elaborated later under REP TA Component 2, see above).
- Key areas to focus on:
- Technology and Knowledge Transfer, Prototyping
- Commercialization of technological solutions (new RE materials, processing etc.), support for international patenting

- Private sector and Interagency collaboration (e.g. WB/GEF Renewable Energy project + UNIDO, technology transfer + ArmTech, knowledge transfer + private companies)

During "ArmTech 2009" conference (5-8 November 2009, San Jose, USA) the Republic of Armenia deputy minister energy presented up-to-date results of REP at the plenary session of the conference. Such areas as bio-ethanol production and geothermal energy created great interest and led to follow-up meetings and negotiations on technology transfer issues in these areas of RE.

A special presentation "Energy Sector in Armenia: Progress and Potential for Investments" was carried out during **World Future Energy Summit-2010** in Abu Dhabi, UAE (18 – 21 January 2010).

5. Short summary of the main results obtained under the Technical Assistance subcomponent of REP

Updating the existing Scheme of Armenian Small Hydro Power Development

For more than a decade the only document to describe and support the development of SHPPs[1] in Armenia was the 1997 document "SHPP Development Scheme". Very quickly it become obsolete due to some not very well justified assumptions (e.g. "availability and affordability of only Russian manufactured hydropower turbines, designed for relatively small head up to 50-60m etc.) and rapid changes on the ground. Besides, only run-of-the-river derivational type SHPP was considered. Under Technical Assistance subcomponent a special project was carried out aimed at updating, correcting and modernizing the 1997 *Scheme*.

During the activities a wide range of modern hydro turbines was considered and designs of SHPPs was not limited only to the derivational type SHPPs, but hydropower plants on irrigation pipelines and canals as well as on potable water network were also considered. Field investigations were carried out in all 14 river basins of Armenia, geological, hydrological and other data were extensively collected and analyzed. All technical, economic and financial parameters were updated. Based on the obtained results a new document titled "Updated

[1] According to the rules and regulations of PSRC RA, the hydropower plant is considered small if its total installed power capacity is less than 10 MW.

Scheme of SHPP Development in Armenia" was prepared. The table below summarizes the obtained results of the Updated Scheme.

River Basins of RA	Number of SHPPs in the basin	Installed Capacity	Average annual production	Plant factor	
		MW	mln. kWh	h/year	%
Debed	33	24.8	90.8	3670	41.9
Aghstev	23	33.7	129.8	3843	43.9
Akhuryan	4	11.0	27.7	2521	28.8
Kasakh	4	3.5	12.5	3570	40.8
Hrazdan	4	4.3	13.2	3089	35.3
Lake Sevan	11	9.7	43.3	4466	51.0
Azat and Vedi	5	5.0	18.7	3728	42.6
Arpa	4	12.2	35.5	2908	33.2
Vorotan	5	10.3	42.7	4131	47.2
Voghgy	14	19.0	76.2	4009	45.8
Meghri	8	13.3	49.7	3724	42.5
TOTAL	**115**	**146.9**	**540.1**	**3677**	**42.0**

As it could be seen from the table above, the Updated Scheme presents 115 new SHPPs with 147 MW of total installed power capacity and 540 million kWh of total annual generation. The highest hydropower potential is recorded for Aghstev (34 MW) and Debed (25MW) river basins. It should be noted, that the efficiency of new SHPPs presented in the Updated Scheme is essentially higher than that of the old SHPPs in the 1997 Scheme. Indeed, the 1997 Scheme presented 206 SHPPs with total 111 MW of power, total 325 million kWh of annual generation and with average plant factor of only 32%. The Updated Scheme presented fewer number of SHPPs (115), but they are 24% larger (147 MW compare with 111MW) and 40% more efficient (540 MW compared to 325 MW), with average plant factor of 42%.

"Updated Scheme of SHPP Development in Armenia" was adopted by the Government of Armenia according to its Resolution No.3 dated 22 January 2009. As of June 2011, about 65-70 of SHPPs indicated in Updated Scheme are currently in operation or at the final stage of construction.

The Updated Scheme of SHPPs (500 page report, available both in Armenian and English) was widely disseminated among all interested parties starting

from 2009. It presents all the technical details (design head, discharge, derivation length, installed capacity and annual production, etc) and main economic parameters (capital cost, internal rate of return, net present value, simple payback period) under 4 different values of discount rate (8%, 10%, 12%, 14%) and two different scenarios of equity/debt participation (100% equity; 30% equity and 70% debt) for each of the 115 considered SHPPs.

Assessment of the hydropower potential for peak-power production for Armenia and the region

Under this investigation the potential of peak power demand in Armenia and South Caucasus region (Georgia, Azerbaijan, Turkey, Iran) was assessed and typical load curves were analyzed. It was concluded that the region experienced strong "hunger" in peak power, and the regional power exchange of peak power could be one of the most efficient areas of regional cooperation in the energy area.

Pumped Storage Hydropower Plant (PSHP) was considered as a renewable energy option for peak power production in Armenia. Eleven possible PSHP location sites were analyzed and three most promising sites were chosen. All of them are based on existing reservoirs (Aghbyurak, Tolors and Shamb) to act as lower reservoirs for the proposed PSHPs. The table below summarizes some of the main parameters of proposed PSHPs.

Main parameters of proposed Armenian PSHP	Aghbyurak PSHP	Tolors PSHP	Shamb PSHP
Lower reservoir	existed		
Normal elevation (m a.s.l.)	1695	1651.5	1335
Normal volume (mln cub.m)	4.0	80.0	1.8
Upper reservoir	not existed		
Normal elevation (m a.s.l.)	2050	2015	1730
Normal volume (mln cub.m)	1.2	1.2	1.1
Static Head, m	355	383.5	416.6
Design Head, m			
Generation	334.2	374.5	406.5
Pumping	369.5	390.0	423.5
Design Discharge, m³/s			
Generation	54	48	40
Pumping	45	43	45
Rated Power, MW			
Generation	150	150	150
Pumping	200	200	200

It was concluded that optimal parameters for Armenian PSHP should be 150 MW of rated power in generation mode with 440 million kWh of annual average production and in pumped mode – 200 MW of rated power with average power consumption of 580 million kWh. The obtained results indicated that although PSHP is a net consumer of electricity, it will allow to increase by 350 MW the technical control margin of the Armenian Power Network in general, will boost the main base power station limit by 100 MW helping to increase the annual production of these plants by additional 700 million kWh annually, as well as will essentially improve the power network's efficiency of operation in general. Finally, PSHP will reduce the night losses in Armenian thermal plants and increase the limits of electricity export (and power swap) to (and with) neighboring countries.

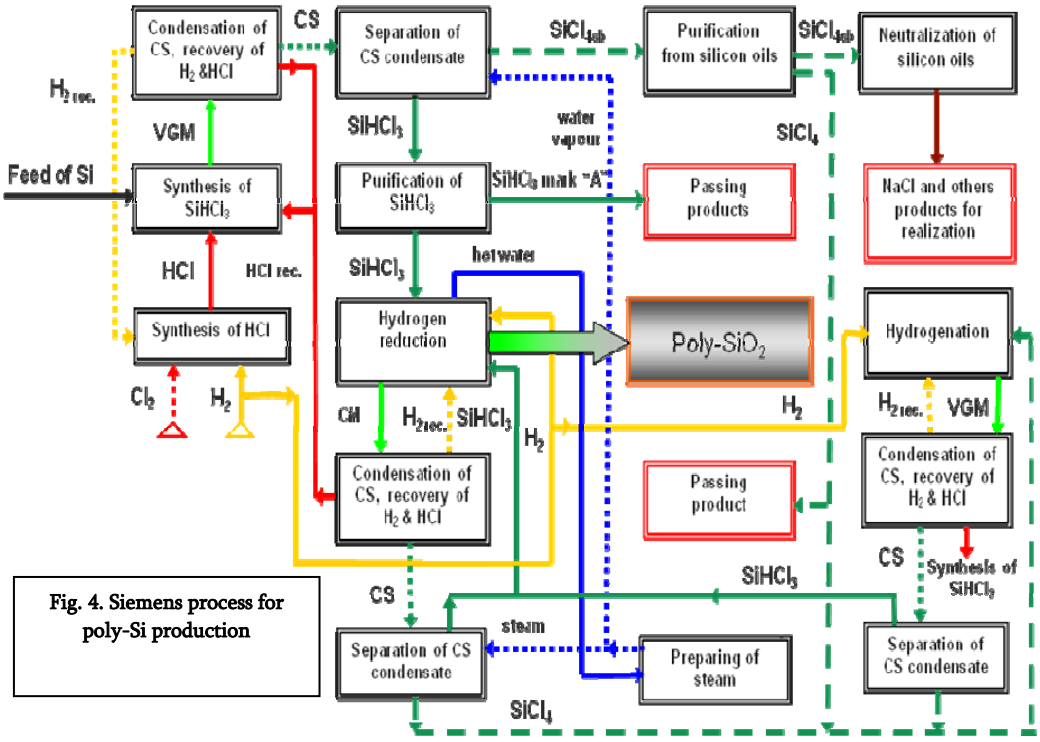


Fig. 4. Siemens process for poly-Si production

Assistance to the modern Solar PV development in Armenia

The main objective of this study was to assess modern PV production (raw materials, cells, elements, components, units) development potential in Armenia, in terms of a comparative advantage for Armenia, creating marketable end-products and/or maximum value added for all the value chain of modern PV based on "from mines of raw material to the markets" approach.

The obtained results indicate presence of strong motivation for development of an Armenian PV industry.

- Strong growth in worldwide electricity demand. Global power consumption is expected to increase by 58% between 2010 and 2030. Strong demand for renewable energy, with solar energy capacity growing 43% annually from 2008 to 2012.
- High quality quartzite deposits, overall political stability and predictability in the country.
- Significant solar radiation rates – 2500 hrs of sunshine per year and 1720 kWh/m^2 (the average in Europe is 1000 kWh/m^2);
- Local experience in PV technologies as well as the highly competitive R&D potential.
- Sustainable economic development, export oriented industry, and creation of new jobs and associated industries.

International experience on ten modern PV cell production technologies (including Wafer-Silicon PV, Thin-Film PV, CdTe PV, CIGS PV, Organic PV, Nano-Architecture PV etc.) was analyzed during the work. Based on the technological characteristics two most perspective ones were chosen for Armenia. Correspondingly, two scenarios of Solar PV industry development were prepared.[1]

Scenario 1: Siemens technology based poly-Si PV cells production up to 150 MW of total peak power annually. The technological chain is based on Ar-

[1] In the light of the recent Solyndra scandal in the USA, related to the PV technologies, it should be stressed that choosing the poly-Si based PV as the most perspective option for Armenia in short- to mid-term perspective should be considered a well justified and adequate decision (for more information: http://www.c-spanvideo.org/program/Solyn).

menian quartzite (Si dioxide) deposits, Metallurgical Grade Si production, PV cells production based on trichlorosilane and rectification to the highest purity level with further decomposition by hydrogen leading to the production of poly-silicon wafers (Fig. 4). The total needed investment cost of this scenario was assessed about $230 million (in 2009 USD).

Scenario 2: Poly-Si and Upgraded Metallurgical Grade (UMG) silicon blend PV cells production up to 150 MW of total peak power annually and with total investment cost of about $200 million (in 2009 USD). According to the obtained results the Net Present Value for both of these technologies is positive and the IRR rate is over 15% after taxes. This makes them economically feasible. On the other hand, the most critical components for the economic sustainability for selected technologies are: expected market price of PV cells, production costs in 5-10 year perspective and the issue of Solar PV electricity tariff (currently absent in Armenia, which should be considered one of the main obstacles for PV industry development in Armenia).

Assistance to the bio-ethanol production development in Armenia

The following facts are the rationale behind this project. As a land-locked country without any significant deposits of crude oil, Armenia is 100% dependent upon motor fuel imports. Dramatic volatility in world crude oil trading prices over the past year are already being passed onto and reflected on retail petrol prices in Armenia. Bio-ethanol for blending as a motor fuel has the potential to reduce imports of petrol through displacement, reduce foreign exchange drains, increase security of energy supplies in a traditionally unstable region of the world, create value from domestically grown bio-ethanol feedstock on surplus lands, create jobs in depressed, high altitude rural areas, and improve local air quality particularly in congested urban areas.

Findings of the project were as follows:

- The prospect for creating a new and sustainable bio-ethanol fuel industry utilizing marginal or surplus lands that presently are not cultivated for production of food (143 thousand hectares in total) is quite promising in Armenia in the

short- to mid-term, especially in rural areas that currently experience extremely high rates of unemployment and low economic growth rates.

- The most promising bio-ethanol feedstocks (from the 20 considered) in the short- to mid- term include: Jerusalem artichokes, feed corn, sweet sorghum, and chicory while the most promising feedstocks in the mid- to longer-term include grain straws and possibly fast growing hybrid trees such as poplar, willow, and mulberry.
- The results of the preliminary sectoral environmental review indicate that the overall environmental impacts of bio-fuel production and use in Armenia would be considered positive including the reduction of greenhouse gas emissions over time.

A forecast of bio-ethanol production market size required to achieve selected blending levels by volume is presented in the table below (10% Growth in Demand for Petrol, in thousand tons per annum).

Indicator	Year											
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
5% Level of Blending (E5 Fuel)												
Petrol	172	189	208	229	252	277	305	335	369	406	446	468
Bio-Ethanol	8.6	9.5	10.4	11.4	12.6	13.9	15.2	16.8	18.4	20.3	22.3	24.5
10% Level of Blending (E10 Fuel)												
Petrol	172	189	208	229	252	277	305	335	369	406	446	468
Bio-Ethanol	17.2	18.9	20.8	22.9	25.2	27.7	30.5	33.5	36.9	40.6	44.6	49.1

The key technical findings and recommendations were as follows:

- The preferred scenario for developing a new bio-ethanol industry in Armenia involves two processing plants with capacity of 7,000 tons per annum each at separate locations in the short- to mid-term (14,000 tons in total, 5% penetration level by 2014);
- The most promising bio-ethanol feedstocks that can be produced in large quantities on surplus lands by 2014 include Jerusalem artichoke (JA), feed corn, sweet sorghum, and possibly chicory.

A summary of costs and financing requirements for JA Bio-ethanol Plant with annual production of 7,000 tons of bio-ethanol (97 thousand tons of JA per annum) is presented in the table below, assuming a limited resource project financing with a 60/40 debt to equity ratio (*in 2008 U.S. Dollars).* The major variables for the financial analysis of a biofuels project are bio-ethanol price, feedstock price, co-product price, and energy costs.

Major Cost Components	JA Plant
EPC Cost to Construct	11,867,000
Owners Costs	2,148,000
Total Installed Bio-Ethanol Project Cost	**14,015,000**
Implementation Planning Costs	311,000
Project Development Fee	560,000
Commitment and Disbursement Fees	126,000
Financial Advisory and Arrangement Fees	268,000
Working Capital	1,000,000
Interest During Construction	720,000
Total Soft Costs	**2,985,000**
Total Project Financing	**17,000,000**

Determination of high potential geothermal sites in Armenia

The geothermal power – production of electricity based on the heat drawn from high potential geothermal sites – probably is the only branch of renewable energy that can provide continuous electricity production capacity to the system. Unlike wind or solar power plants, geothermal power plant can be part of the mid- and long-term plans to cover the expected load – much like hydro power plants with large reservoirs or nuclear power plants. This rationale, in parallel with strong indications (hot springs, young volcanic activity, etc.) of the possible presence of high potential geothermal sites in Armenia led to implementation of a special study for determination of prospective high potential geothermal sites in Armenia.

Based on a deep analysis of the collected geological, geochemical, seismological and other information, the obtained results indicate four perspective areas with high occurrence probability of high potential geothermal mines. Inside

these areas, two perspective sites were chosen for further on-site field investigations. A detailed plan of these investigations was prepared. Currently these investigations are in progress under another WB/GeoFund on-going project (GEF TF-092563). In the first phase that has been already completed; geological field works and several magneto-telluric sounding studies of the mentioned two sites were carried out. During the second phase of investigations it is planned to produce 2D/3D seismic sounding of the most promising site in order to determine the possible location of a high potential geothermal mine.

Other Projects

Under the REP special projects were carried out aimed at supporting the penetration and absorption of RE based electricity production into the power network of Armenia. The first one – "Assistance to the dispatching and control aimed to increase RE absorption capabilities of Armenian power network" was intended to help deal with modern microprocessor based relay protection devices, installed at most of the modern RE based power plants (SHPPs, wind farms etc). The main outcome of this project, its final report, was a manual titled "Design Requirements, Norms and Methodology of Calculation of Main Parameters of Microprocessor Based Relay Protection for the Armenian Power Network". This manual will help to correctly set up the relay protection devices seeking not only to increase the absorption level of Armenian electric grid to feed in electricity produced by more than 100 small hydropower plants, but also to improve the efficiency of operation of the high voltage network in general. This manual created a significant interest among the professional institutions and organizations. In response to this interest, the final report of this project was disseminated to all utility companies, dispatching center of Armenian Electric Network, Armenian Institute of Energy, Electric Power Network Design Institution, technical universities and institutions, technical libraries, and other interested organizations.

The second project – "Design of emergency automation system for Armenian power network with high penetration level of renewable energy" helped to develop the basis of emergency automation system for 2010-2016 timeframe, tak-

ing into account the schedule for launching new generation capacities, including those based on RE (SHPPs, Karakhach wind farm, etc). As in the previous case, the final report of the project generated great interest among the power network related institutions. In response to this interest, the report "Design of emergency automation system for Armenian power network with high penetration level of renewable energy" was disseminated to all interested organizations in Armenia.

The next project was "Developing the GIS of Armenia". The developed GIS is a flexible, multidiscipline and comprehensive computer tool, in Open Geographical Consortium format and in UTM WGS 84 system. The GIS is based on Digital Elevation Model of all marzes of Armenia, and incorporates the main hydrology layer for the major rivers (more than 5 km long) codified according to the official National River Codification of RA. The RE GIS has the following thematic layers:

- hydrology layer: all rivers, canals, conduits and water pipes, lakes, water reservoirs as well as the existing and planned hydrologic observation stations; water collection basins of the main rivers;
- ground transportation infrastructure based on existing topographic maps, including: separate layers for rail-road and ground transportation (type and class of road cover, down to the local, earth-covered roads);
- RA residential areas with the boundaries of republic, marzes and community territories;
- special purpose territories, reserves, national parks;
- energy infrastructure layer including the main substations, transmission lines (330, 220, 110 and 35 kV) and all power plants of all types,
- General climate data.

The RE GIS of Armenia was prepared in ArcGIS compatible format with the help of special software packages for DEM preparation and GIS, purchased by R2E2 Fund.

Renewable Energy Development Road Map of Armenia

In a sense, this project sums up many of the studies carried out under the REP. The main objective of this study was to develop renewable energy development roadmap for Armenia till 2020. The RE roadmap, first ever prepared in Armenia, identified economically and financially sustainable potential of RE in Armenia, established short-, mid- and long-term targets for development and outlined specific steps of achieving these targets. First time in Armenia, the penetration level of RE in energy sector was considered in its entirety – including not only the electricity sector, but also transportation (motor fuel consumption) and heat production and delivery.

The following principal tasks were carried out. Existing policies, legal and regulatory framework, institutions and practices for RE were reviewed. Technical, financial and economic potential for development of RE in Armenia was assessed. In particular, the following RE technologies were considered: small and medium scale hydropower plants and pumped storage HPP, grid connected wind farms, biomass energy (including production of bio-ethanol), solar thermal and photovoltaic, high potential geothermal (electricity production) and low potential geothermal (thermal pumps, heating), and hydrogen energy.

Three scenarios (low cost case, base case, and high cost case) of the economically viable RE potential were considered, reflecting different levelized marginal costs of imported primary energy resources (natural gas, petrol, diesel, nuclear fuel). Besides, energy system development (RE penetration level) scenarios were developed. Finally, short-, medium- and long-term national targets for RE development, policy recommendations for achievement of these targets and time-bound action plan were prepared.

One of the most important outcomes of the Roadmap are suggestions of national targets for RE penetration in base case at **2.4%, 3.1%** and **4.9%** for the years 2013, 2015 and 2020, respectively. If one includes the large hydro and biomass, then the targets become **17%, 15%** and **16%**, respectively. The table below presents some results of the Roadmap in short-term (2011-13), mid-term (2014-15)

and long-term (2016-20) periods, as well as for the whole decade of 2011-2020. The data in all 4 columns are cumulative values for the particular time periods.

Parameters	2011-2013	2014-2015	2016-2020	2011-2020
Electricity				
Generation, GWh	18,000	12,800	44,900	75,800
Renewable without large hydro, GWh	1,360	1,380	6,070	8,800
Percent of RE as of total generation*	2%	2.8%	4%	3.3%
Investment in RE, US$ million	$ 130	$140	$ 450	$ 720
Thermal				
Generation, GWh	31,600	23,300	61,700	116,500
Renewable without biomass, GWh	56	83	380	520
Percent of RE as of total generation*	0.08%	0.17%	0.26%	0.20%
Investment in RE, US$ million	$32	$ 21	$ 54	$108
Transportation				
Generation, GWh	26 000	20 100	61 200	107 300
Renewable, GWh	140	290	730	1 150
Percent of RE as of total generation*	0.21%	0.57%	0.49%	0.43%
Investment in RE, US$ million	$74	$ -	$ -	$74
Total Generation, GWh	**67 900**	**49 700**	**149 600**	**267 200**
Subtotal of RE generation, GWh	**1 560**	**1 750**	**7 170**	**10 500**
RE percent of total generation*	**2.3%**	**3.5%**	**4.8%**	**3.9%**
Total RE with large hydro and biomass, GWh	**12 150**	**7 580**	**23 700**	**43 400**
Total RE with large hydro and biomass percent of total generation*	**18%**	**15%**	**16%**	**16%**
Total Investment, mln. $	**$238**	**$161**	**$504**	**$903**
** Total percentages are cumulative for the particular period*				

All reports produced under Technical Assistance component of the Renewable Energy Project in Armenia are available in public domain. They can be accessed via Renewable Energy Portal of Armenia[1], as well as on the websites of R2E2 Fund[2] and Ministry of Energy and Natural Resources of the Republic of Armenia[3].

In conclusion it has to be stressed, that implementation of such a complex and multidisciplinary project in Armenia would have been impossible without

[1] www.renewableenergyarmenia.am
[2] http://r2e2.am/
[3] http://www.minenergy.am/

committed work of the World Bank team of the Renewable Energy Project (Al. Astvatsatryan, Ani Balabanyan, Ar. Kochnakyan) led by Gevorg Sargsyan. On the other hand, support of all members of the Board of Trusties of the REP led by Mr. Armen Movsisyan, Minister of Energy and Natural Resources of Armenia and Mr. Areg Galstyan, Deputy Minister, was essential and very instrumental in achieving the main objectives of the project. The everyday organizational support of the R2E2 Fund staff under leadership of Ms. Tamara Babayan secured the successful implementation of REP in Armenia. The most important contribution to the success of the project was the dedicated work of all 124 experts involved. They brought their knowledge and vigor to the implementation of the Renewable Energy Project in Armenia.

October, 2011

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