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SREP Investment Plan for Armenia
(June 2014)

Republic of Armenia

Scaling Up Renewable Energy Program (SREP)




Investment Plan for Armenia

June 2014

Minister of Energy and Natural Resources of the Republic of Armenia

FOREWORD

"Armenia adopted a policy of sustainable economic development, which assumes concurrent development of the economy, in the context of which energy, as the most important sector, is called to ensure such a progress for the state that through coordination and balancing of environmental issues will create preconditions for sustainable development of future generations while reducing the loss of energy.

All energy resources, including renewable energy, need to be widely utilized, and included in the energy balance for the purpose of energy supply.

As Armenia lacks own resources of fossil fuel, raising the energy efficiency of the economy, development of nuclear energy and efficient use of renewable energy resources are a prerequisite for energy security."

"Energy Security Concept of Armenia" approved by the President of Armenia on October 23, 2013, Yerevan /NK-182-N/

On behalf of the Government of Armenia, I would like to express gratitude for including Armenia in the list of pilot countries for the Scaling-Up Renewable Energy Program of the Climate Investment Fund. This is unique opportunity to kick off development of the renewable energy technologies with strategic importance for Armenia that could not be done without such support.

Armenia started development of renewable energy starting from 2001, with incentives for private investments and so far we successfully developed small hydro power technology. During the last ten years Armenia made significant progress with development of small hydropower plants increasing their share in the generation mix from 0.5% in 2003 to 9% in 2013. Although the same regulatory framework is applied to the other RE technologies, however, high unit energy costs and absence of subsidization mechanisms did not allow the same success for solar and geothermal technologies.

We hope that presented Investment Plan, which was developed with support of SREP preparation grant and assisted by an experienced team of experts, as well as broad involvement of all stakeholders groups, will be endorsed to give a green light to the investments into the renewable energy technologies that are priority for Armenia. The selected priority technologies will help the country build the much needed additional generation capacity given that some fossil fuel plants are schedule for retirement due to dilapidation and inefficiency. Moreover, the identified priority technologies will have significant positive transformational impact on the overall economy, including, promotion of small and medium enterprises working in those fields, research and development, education and development of remote areas.

The Government of Armenia is committed to continue improvement of legal and regulatory framework necessary for the proposed projects. Armenia was very successful in reforming its energy sector in mid-90s and early 2000s, and turning it into one of the best performing sectors in the region, and we are committed to continuing this momentum.

Taking this opportunity I would like to mention the important role of the donor countries and international organizations that continuously support Armenia to reach adequate level of energy security.

Yervand Zakharyan,

Minister of Energy and Natural Resources

June 16, 2014

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1 Proposal Summary

This document contains the Investment Plan (IP) for the Republic of Armenia. The IP is the result of extensive analysis led by the Renewable Resources and Energy Efficiency Fund (R2E2) and a wide-reaching internal and public consultation process, led by government, to identify priorities in the development of renewable energy technologies for electricity and heating. The consultations included a wide range of government agencies, as well as representatives from the private sector, civil society, and academia. The IP serves as an update and further elaboration of the Renewable Energy Roadmap developed for Armenia in 2011.

1.1 The Role of Renewable Energy in Armenia

Armenia's energy sector has made significant progress in the last two decades. The sector has moved from severe crisis—characterized by crippling supply shortages, and near-financial bankruptcy of the sector—to stability more characteristic of developed countries than emerging markets. The use and development of renewable energy has been an important part of the transition from crisis to stability, and will remain important in the years to come as demand grows and ageing thermal plants are retired.

The historic importance of renewable energy in Armenia

Armenia has no proven oil or natural gas reserves and imports all of its fuel for thermal generation from Russia and Iran. The country relies on imported natural gas to generate roughly 30 percent of its power and most of its heat. Nuclear fuel, which is used to generate another 30 percent of electricity in Armenia, is also imported. The remaining electricity is generated by a series of hydropower plants in the Sevan-Hrazdan and Vorotan cascades, more than 130 small hydropower plants, and one small wind farm.

Armenia's dependence on imported fuels creates security of supply risks as well as affordability problems for customers. The sector is highly susceptible to fuel supply interruptions and price volatility. Between 1991 and 1996—because of disruptions in gas supply—customers suffered through several of Armenia's brutal winters with little more than two hours of electricity supply per day. Meanwhile, the import price of natural gas has continued to increase. The increases of the price of imported gas meant steady increases in end-user tariffs for natural gas and electricity. Between 2005 and 2013, the end-user natural gas tariff increased by 170 percent. End-user residential tariffs for electricity increased 52 percent during the same time period.

The Government of Armenia has worked for more than a decade to expand the use of renewable energy. A 2004 Law on Energy Savings and Renewable Energy in 2004 provided for, among other things, the establishment of the Renewable Resources and Energy Efficiency Fund (R2E2), a non-governmental agency dedicated to promoting and facilitating renewable energy and energy efficiency in Armenia. R2E2, with the support of the World Bank and GEF, implemented a Renewable Energy Program that helped to remove barriers to the development of renewable energy generation, and create an enabling environment for private investors. The project was co-financed by EBRD and local private financing institution.

In 2007, the Public Services Regulatory Commission (PSRC) set renewable energy feed-in tariffs for small hydropower plants (SHPPs), wind, and biomass to stimulate private investment. The feed-in tariff regime guarantees purchase all of the power generated by renewable energy plants for 15 years. Tariffs are adjusted annually in line with changes in inflation and exchange rates. The feed-in tariff has been successful in attracting private investment in more than 200 MW of small hydropower. More recently, Government took steps to streamline the process of developing renewable energy projects, including relaxing tax obligations for some investments.

The future of renewable energy in Armenia

The historic threats to supply security and affordability are expected to continue in Armenia. Therefore, the Government's commitment to developing renewable energy remains as strong as before and there is now more urgency, given a looming gap between supply and demand.

Demand grew at an average annual rate of roughly 4 percent between 2004 and 2013, and is expected to continue to grow at a rate of around 2 percent per year. New supply will be needed since 50 percent of available capacity is more than 40 years old, and one of the largest generating units in the system, the remaining nuclear unit at Metsamor, is in urgent need of investments. Metsamor's retirement has been postponed twice, most recently from 2021 until commissioning of the new nuclear power plant (expected in 2026) because of the difficulty in securing financing for it. If Metsamor is retired in 2026, Armenia can expect a supply gap of roughly 830 MW, considering the base-case forecast average annual peak demand growth of roughly 2 percent per year.

Natural gas prices, too, are expected to increase. Specifically, the import price of natural gas could increase by more than 50 percent over the next 12 years depending on the domestic gas price increase in Russia and the US inflation to which the Armenia border gas price is linked to. This will affect the cost of power generation. The current average cost of generation in Armenia is roughly US$ 0.035/kWh, but is set to increase to US$0.10-0.19/kWh as gas prices increase, and a new nuclear plant is brought online in 2026. The range reflects different assumptions about the size of the new plant, and whether concessional or commercial financing is used to finance it. The above estimated range of average generation cots suggest that geothermal power and utility-scale solar PV may become cost-competitive options (see Figure 1.1) for meeting forecast electricity demand in Armenia.

The Government's renewable energy strategy is driven by the overarching goals of improving energy security, ensuring tariff affordability, and maximizing the use of Armenia's indigenous energy resources. A 2013 Decree of the President of Armenia approved an "Energy Security Concept" for the country, which prioritizes the use of renewable energy resources. The Government's Development Strategy for 2012-2025 specifically calls for the development of indigenous renewable energy resources.

Table 1.1 shows Government's targets for various renewable energy technologies. Excluding output from the large hydroelectric plants, renewable energy generation represented roughly 6 percent of total generation in 2012. The Government's target is for such generation to represent 21 percent of total generation by 2020, and 26 percent by 2025.

Table 1.1: Renewable Energy Generation Capacity and Production Targets 2020-2030[1]

	Capacity installed (MW)		Generation (GWh)	
Electricity	**2020**	**2025**	**2020**	**2025**
Small Hydro	377	397	1,049	1,106
Wind	50	100	117	232
Geothermal	50	100	373	745
PV	40	80	88	176
Total	492	677	1,627	2,259
Heating	**2020**	**2025**	**2020**	**2025**
Geothermal heat pumps	12	25	16	33
Solar thermal	10	20	13	25

The targets shown in Table 1.1 update the 2011 Renewable Energy Roadmap for Armenia, developed in cooperation with R2E2, with the support of the Global Environmental Facility (GEF) and the World Bank. Targets have been updated in this IP because a number of factors, global and local to Armenia, have changed since the development of the Roadmap. There is, for example, more information now about the solar, geothermal, and wind resources in Armenia than there was when the Roadmap was produced. Wind resources, in particular, have shown to have lower capacity factors than previously thought, making them more expensive on a levelized energy cost (LEC) basis. Solar PV has, in contrast become more attractive. The capital costs of utility-scale solar PV projects have declined substantially over the past few years, shifting more of the technically viable solar potential toward financial viability. As a consequence, Government's priorities in the years to come are likely to shift away from wind and toward solar PV.

1.2 SREP's Role in Removing the Barriers to Renewable Energy in Armenia

Armenia faces a number of barriers to the further development of renewable energy. SREP funding can be instrumental in helping to remove or at least weaken a number of these barriers.

Barriers

One of the most significant barriers to renewable energy in Armenia is the high cost of investment relative to the currently low cost electricity generation mix in the country. Tariffs are low because many of the thermal plants generating electricity are fully depreciated and need only to recover variable costs. This will change as new

[1] Excludes generation from the large hydro cascades.

generation plants are brought online and tariffs are raised to reflect their capital costs. In the meantime, however, the low cost of generation makes it difficult for consumers to understand the need for higher-cost renewable energy generation which will satisfy –at least initially—only a small portion of demand. This is a barrier of perception which, as described below, Government can overcome with SREP's assistance.

There are also legitimate concerns about affordability. The global economic crisis increased the already high incidence of poverty in Armenia. Between 2008 and 2010, the poverty incidence increased from 27.6 percent to 35.8 percent of the population, and severe poverty grew from 12.6 percent to 21.3 percent of the total population.[2] Energy poverty—in which households spend more than 10 percent of their budgets on energy—affects nearly 30 percent of Armenian households. The poorest quintiles of the population allocate a relatively higher share of their budgets to electricity than rural households. These households are likely to experience more significant pressures on their budgets as a result of increased energy tariffs. A recent World Bank study has estimated that, when a new thermal plant is built, tariff increases could result in increases in poverty of 1-8 percent, depending on the sources of financing used, the gas price, and the technology (nuclear or gas) built first. Higher tariffs also have environmental consequences in Armenia. The historical experience in Armenia is that poorer, rural households have switched—at least temporarily—to traditional fuels (mostly firewood, collected illegally) when electricity and gas tariffs increase. Armenia's forests shrunk by roughly half during the years of energy crisis, and now the forests cover only roughly 10 percent of total area of the country.

Another important barrier is the lack of experience with many renewable energy technologies. There is no experience building and operating utility scale solar PV or geothermal in the country. The lack of experience creates, or reinforces several other barriers, namely:

- **The absence of regulatory incentives for certain technologies.** The Law on Energy guarantees cost recovery through tariffs, but feed-in tariffs were never set for some renewable energy technologies because of perceptions about cost and the absence of long-term financing opportunities. Solar PV, for example, was not initially thought to be commercially viable, and so was not, until recent years, a priority in Armenia.
- **Limited capacity for equipment acquisition and installation.** Limited experience with certain technologies limits the expansion of solar PV, large scale geothermal, and geothermal heat pumps. It also substantially raises the costs of doing first projects in these technologies.
- **A lack of technical capacity among local financiers.** The success of the SHPP program is owed, in part, to the good quality of technical assessments completed by local commercial banks in programs supported by the World

[2] The poor are defined as those with consumption per adult equivalent below the upper general poverty line; the severely poor are defined as those with consumption per adult equivalent below the lower general poverty line. The poverty line in 2010 was computed using the actual minimum food basket and the estimated share of non-food consumption in 2009.

Bank, European Bank for Reconstruction and Development (EBRD) and Germany's Kreditanstalt für Wiederaufbau (KfW). Local commercial banks do not, however, currently have capacity to assess other types of RE projects.

- **A lack of confidence in certain technologies.** The lack of experience with RE technologies makes potential developers, property owners and energy users skeptical of these technologies and uninclined to take the risk of being the first to use them.
- **Underdeveloped local markets for certain technologies.** The lack of experience in certain technologies also means that there are no markets for services or expertise required to develop projects using certain technologies. Whereas the technologies themselves are typically imported, project development requires local expertise in engineering design, procurement and installation. The market for such services is extremely thin in Armenia.

These barriers do not exist for all technologies, nor do all of the barriers listed above affect any single technology. There is some experience, for example, with small hydro, wind, and biomass.

SREP's Role in removing barriers

The Government is asking SREP for support in facilitating the scaling-up of a subset of renewable energy technologies identified in this Investment Plan. The technologies were selected because they met a number of criteria, identified through comprehensive analyses and stakeholder consultations, which aligned well with SREP's objectives. Of these criteria, the potential for scale-up of the technology, the cost-effectiveness of the technology and the immaturity of the market were of key importance. The Government is not asking for support in markets, which are already developed (such as small hydro), or technologies, which show limited scale-up potential (such as landfill gas). The Government may seek to promote development of many of these technologies on its own or through financing facilities already provided through the multilateral development banks (MDBs), but has not requested SREP support for them.

SREP support will be critical in reducing the cost of technologies that lie at the threshold of competing with the expected future cost of generation in Armenia. As noted above, the next large thermal (gas or nuclear) plants to be built in Armenia will be substantially higher cost than current generating costs. SREP funding can help overcome the perception that high-cost renewable energy technologies are an unnecessary expense, as well as concerns about affordability. For technologies, such as geothermal power and utility-scale solar PV, the initial projects will help to reduce resource and performance risks, develop local markets and expertise, and provide Government the impetus and opportunity to put in place reforms—in particular appropriate tariffs—to support their development. As experience with the new RE technologies increases in Armenia, project development costs can be expected to decline, and for some technologies, such as solar PV, local production may also emerge. The eventual development of service providers and, possibly, manufacturers of RE technologies will have obvious follow-on benefits for Armenia's economy as a whole.

Finally, SREP support will be critical in creating a demonstration effect for technologies that are relatively unknown in Armenia, and in funding directly—or by attracting other donor funding for—capacity building.

1.3 The Proposed Investment Program for Armenia

The Government of Armenia, led by the Ministry of Energy and Natural Resources (MENR) and supported by the MDBs, has identified three areas for strategic investment that would lead to scale-up. The areas were identified through comprehensive analysis of RE technologies and a participatory process involving a wide range of government agencies, non-governmental organizations, academic institutions, and the private sector. The participatory process included many one-on-one meetings, a workshop with the Government's SREP working group, as well as an open forum.

The technologies identified

Each of the potential renewable energy resources were evaluated against five criteria, and prioritized accordingly. The five criteria reflect the Government's strategic objectives, and the clear recognition that SREP funding should be used to overcome barriers to technologies that will have the potential to have a transformative impact on the energy sector. The criteria considered were: cost-effectiveness of the technology, the potential for scaling up the technology, the maturity of the market, the potential for job creation, and the effect of each technology on the stability of the grid. Three investment priorities emerged from the analyses and the discussions with stakeholders. These are as follows:

1. **Geothermal Power Development.** SREP resources would be used for further exploration of Armenia's most promising Karkar geothermal site (in the South-East), thereby, attempting to demonstrate the viability of geothermal energy in Armenia if the exploratory drilling at Karkar confirms availability and quality of resource for power generation. Of the known potential geothermal sites in Armenia, the Karkar site has been the most comprehensively assessed through surface studies and was assessed to be the highest-potential site to date, with possible output estimated at around 28.5 MW. Exploratory drilling is required to confirm the availability and quality of the resource for power generation. By using SREP grant funding for drilling, the Government can help reduce the risk of developing the site. If a geothermal resource exists at the site, this support can help make geothermal power a financially attractive investment for private investors and an affordable source of electricity.[3] This support will serve to demonstrate the feasibility of geothermal power in Armenia and can catalyze development of the other perspective geothermal sites.

[3] The exact commercial arrangement will need to be developed through further consultation within government, with donor partners, and with potential investors. However, the arrangement currently envisaged would involve a private operator having a BOT or BOO agreement under which they finance, build and operate the power plants and have a power purchase agreement with the transmission company, HVEN. Government would own the steam fields, thereby taking risk on the resource availability. The SREP funding would be used to hire a transaction advisor to help structure, tender, and negotiate the BOT/BOO.

2. **Development of Utility-Scale Solar PV.** SREP resources would be used to develop roughly 40-50 MW of utility-scale solar PV. The rapid decline in solar PV costs in recent years has made utility-scale solar PV more competitive with the other power generation options available to Armenia. Therefore, it is strategically beneficial for Armenia to develop its capacity to scale-up this technology. SREP support would help catalyze private investment in first new plants, and show the potential for deploying solar PV on a commercial basis. A utility-scale commercial project would not only enable the country to take advantage of this technology in the future when its costs decline even further, but reduce costs for future projects because of learning effects.

   Therefore, SREP support is sought to allow the Government to develop solar projects. The grant would be used for feasibility studies, including site measurements and monitoring, and to develop projects itself. Initial studies indicate that the areas in the vicinity of Lake Sevan have some of the highest solar irradiance in Armenia, and would be considered as a first potential area for development, but more site-specific analyses will be needed to identify specific projects.

   Additional donor financing will be sought to complement the SREP contribution, as well as private sector equity and commercial debt. SREP financing would be used in much the same way that MDB funds were used to successfully jump-start the small hydropower industry in Armenia nearly a decade ago. The expectation is that, as with small hydropower, once the domestic capacity to deploy solar PV is developed and the financial market is comfortable with the technology, the market will take off. The SREP contribution and donor financing will also be essential to softening the effect on tariffs of the first solar plants.

3. **Development of Distributed Geothermal Heat Pump and Solar-Thermal Projects.** Financial analysis of the cost of geothermal heating and solar thermal technologies suggests that they are currently cost-competitive with electric heating in Armenia, and may be competitive with natural gas heating. However, solar and geothermal heating technologies are not yet widespread. This is largely because financing for those technologies became available recently. The EBRD's ongoing Caucasus Energy Efficiency Program (CEEP) provides financing for those technologies (around $9 million project). Moreover, in 2016, the Government intends to start implementation of $20 million energy efficiency program to be supported by Eastern European Energy Efficiency and Environmental Partnership (E5P). Initially, the E5P project in Armenia was planned to start in 2014.

   Therefore, the Government will use some SREP resources to expand funding available under EBRD's existing CEEP until E5P project funds become available. Under this program, EBRD extends loans to local commercial banks for sub-lending to industrial and residential sectors for energy efficiency and rational energy utilization investments, which include geothermal heat pumps and solar water heaters. Loans will also be extended on a demand-driven basis. The EBRD program also includes grant funding to engage consultants in order to prepare energy audits, review investment proposals, support companies in securing funding from participating banks and implementation support. The SREP support coupled with the above donor financing will help to kick-start the market for those technologies in Armenia, and ensure that financing for geothermal heat pumps and solar thermal becomes standard financing product in Armenia.

Table 1.1 presents a plan for financing the projects described in Section 5. It shows the proposed contributions or grants from SREP as well as estimates of the amounts anticipated from MDBs and the private sector.

As the table shows, roughly US$40 million of SREP funding is expected to catalyze nearly five and a half times as much investment, most of it from the private sector (as equity or debt), and the commercial lending windows of the MDBs.

Table 1.2: Financing Plan

SREP Project	SREP	Responsible MDB	Government of Armenia	MDBs	Private Sector (Equity)	Commercial/ Private arms of MDBs	Total
Geothermal Development				(Million US$)			
Project Preparation	0.3	IBRD	0.1				**0.4**
Geothermal Resource Confirmation	8.1		2.3				**10.3**
Transaction Advisory Services (structuring of PPP for power plant)	0.6		0.2				**0.8**
Investments in 28 MW plant		TBD after drilling	6	30	35	35	**106**
Subtotal: Geothermal Development	**9.0**		**8.6**	**30**	**35**	**35**	**117.6**
Development of Utility-Scale Solar PV							
Grant for Project Preparation, Feasibility studies, site measurement and monitoring	1.5	ADB	0.5				**2.0**
Transaction Advisory Services	0.5		0.1				**0.6**
Investments in power plants (total of 40-50 MW)	17	ADB	4.4	20	36	27.5	**104.9**
	9	IBRD	2.5	10			**21.5**
Subtotal: Development of Utility-Scale Solar PV	**28.0**		**7.5**	**30**	**36**	**27.5**	**129.0**
Development of Geothermal Heat Pumps and Solar Thermal							
Investments in geothermal heat pumps and solar water heaters	3	EBRD	0	0	2	7	**12**
Subtotal: Geothermal heat pumps and solar thermal	**3**		**0**	**0**	**2**	**7**	**12**
Grand Total	**40**		**16.1**	**60**	**73**	**69.5**	**258.6**
SREP Leverage	**5.5**						

Scale-up potential

The scale-up potential of each RE technology in Armenia depends ultimately on how much of a resource is available, how much of that resource is commercially viable, and what the transmission grid can sustain. Table 1.3 shows the total estimated technical potential for renewable energy technologies in Armenia.

Table 1.3: Renewable Energy Resource Potential in Armenia by Technology

Technology	Capacity (MW)	Generation (GWh/yr)
Wind	300	650
Utility scale solar PV	830 – 1,200[a]	1,700 – 2,100[a]
Concentrating solar power (CSP)	1,200	2,400
Distributed solar PV	1,300	1,800
Geothermal power[b]	at least 150	at least 1,100
Landfill gas	2	20
Small hydropower	100	340
Biogas	5	30
Biomass	30	230
Total (electricity)[c]	**3,800 –4,300**	**7,400 – 8,700**
Solar thermal hot water	200	260
Geothermal heat pumps	3,500	4,430
Total (heat)	**3,700**	**4,690**

[a] The resource potential depends on which solar PV technology is deployed: Fixed PV, Single-Axis Tracking PV or Concentrating PV

[b] Assumes flash technology is used. The actual capacity cannot be known without exploratory drilling. The geothermal capacity estimates are based on results of estimates for three potential sites, for which some geo-technical information was available. The potential can be significantly larger given several other potential sites, which have not been explored at all.

[c] Solar PV and CSP were evaluated as options for development in the same areas. Therefore, the total resource potential includes only the generating potential for one of these technologies (Solar PV). For this reason, the total is not the same as the sum of the resource potential listed for each technology.

Not all of this technical potential will be ultimately commercially viable. As noted above, the cost of generation in Armenia is likely to increase substantially as new thermal or nuclear generation is brought on line and older thermal plants are retired. Figure 1.1 shows a supply curve of the cost of renewable power resources in Armenia assuming concessional, commercial and mixed financing assumptions. By way of reference, Armenia’s average cost of generation is expected to range from

USD$0.10/kWh – US$0.19/kWh when a new nuclear plant is put into service in 2026.[4]

Solar is not yet cost competitive under purely commercial financing assumptions, but the combination of several factors could make it more so in the near future. The factors include: (i) new, higher-cost thermal plants being built to serve demand in Armenia; (ii) lower solar installation costs that will result as a domestic industry develops around it; (iii) lower financing costs as lenders become more comfortable with the technology, and (iv) potential further reductions in the global costs of PV panels. SREP support can help Armenia nurture its solar industry so that, as these factors converge, Armenia can look to utility-scale solar as a commercially viable alternative to some thermal power generation.

Figure 1.1: Renewable Energy Resources Supply Curve for Armenia, Commercial, Mixed Commercial/SREP and Concessional Financing

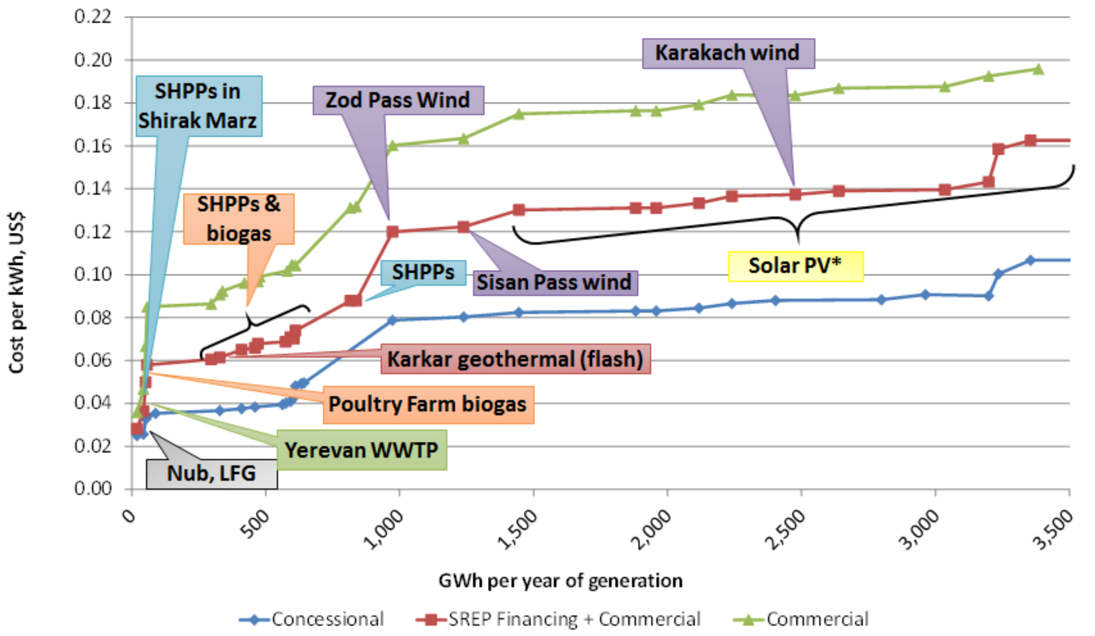
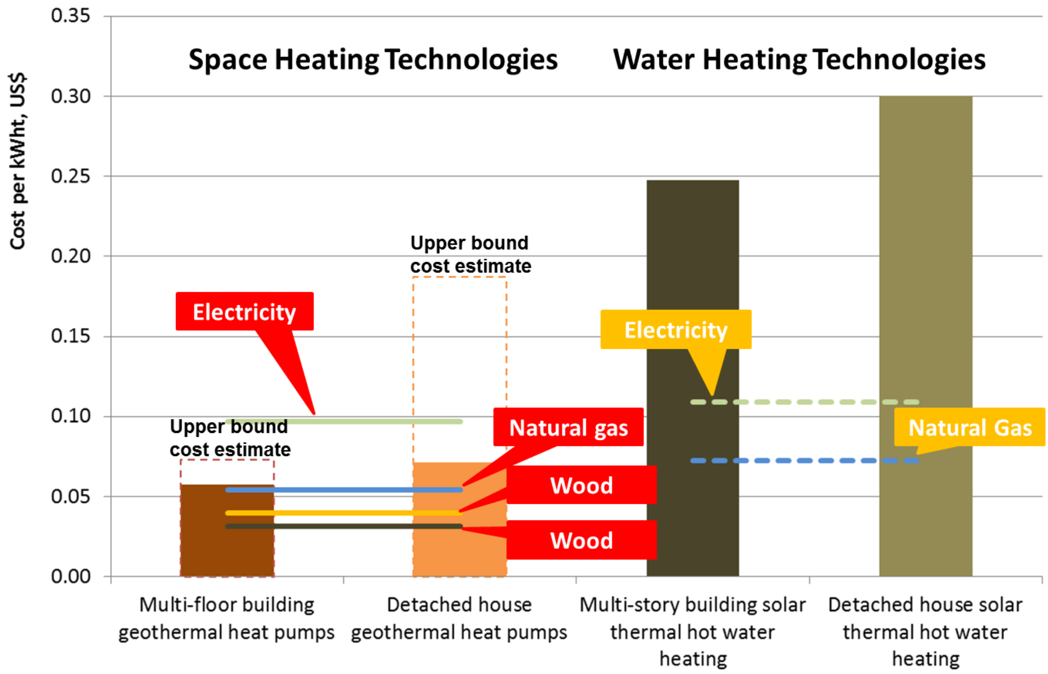


Figure 1.2 shows the cost of renewable heating technologies in Armenia compared with the cost of heating with electricity, natural gas, firewood and coal. As the figure shows, geothermal heat pumps are already cost-competitive with electrical heating in multi-floor buildings, and are nearly competitive with natural gas. Solar thermal heating is not yet cost competitive with alternatives, but as gas prices continue to rise, will increasingly become competitive.

4 As noted above, the cost depends on the size of the plant, and whether concessional or commercial financing is used to finance it.

Figure 1.2: Comparative Cost of Renewable and Non-Renewable Heating Technologies



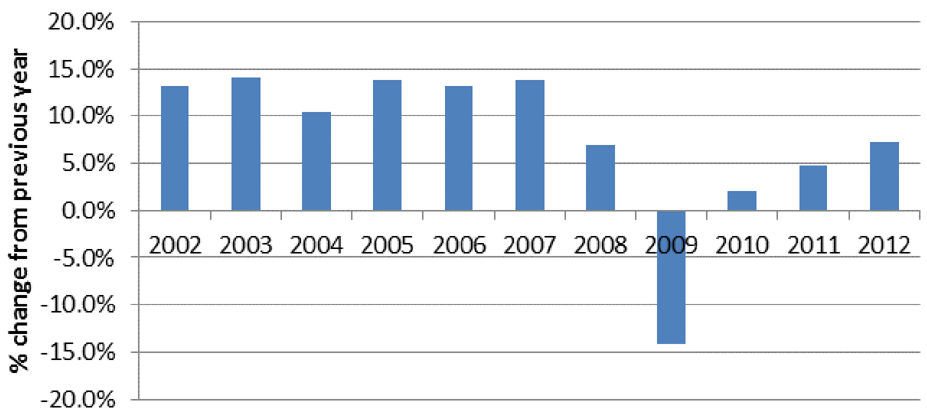
2 Country Context

The Republic of Armenia is a mountainous, landlocked country of 30 thousand km^2 located in the South Caucasus region of Eurasia.[5] Armenia borders Georgia in the North, Azerbaijan in the East, Turkey in the West, and Iran in the South. Prior to the fall of the USSR, Armenia was a Soviet Republic for 70 years. Armenia gained independence in 1991.

Armenia has a population of 3 million and a population density of 102 people per km^2. It is one of the most densely populated countries in the region.[6] The majority of the population lives in urban areas and approximately 38 percent of the population lives in the capital city, Yerevan.[7] From 2000 to 2010, the population of Armenia decreased by an average of 0.4 percent annually and increased by 2 percent from 2010 to 2012. Population growth is projected to remain flat in coming years, and the World Bank projects population increase of less than 1 percent by 2025.[8]

Armenia experienced strong economic growth in 2002-2008, but was severely affected by the global financial crisis. Real GDP grew, on average, 12.2 percent annually from 2002 to 2008, but declined 14.1 percent in 2009. Armenia has experienced moderate growth since 2009, but, despite annual increases, growth rates have not recovered to pre-crisis levels. Figure 2.1 shows the annual change in real GDP from 2002 to 2012.

Figure 2.1. Annual Change in Real GDP, 2002-2012



Source: The World Bank, "World Development Indicators," accessed 7 July 2013.

The main drivers of economic growth in Armenia include: construction, retail services, mining, manufacturing and agriculture. These sectors were some of the hardest hit by the financial crisis, with construction and agriculture remaining depressed in the post-crisis period. Poverty levels also increased as a result of the

[5] The Government of the Republic of Armenia, "Geography," http://www.gov.am/en/geography/

[6] The Government of the Republic of Armenia, "Demographics," http://www.gov.am/en/demographics/

[7] The World Bank, "World Development Indicators Database," Accessed August 2013.

[8] The World Bank, "Health Nutrition and Population Statistics: Population estimates and projections Database," Accessed August 2013.

crisis, with the percentage of the population living below the poverty line increasing from 27.6 percent in 2008 to 35 percent in 2011.[9] Urban areas other than Yerevan host the largest share of the approximately 1.2 million poor in Armenia. Targeted social assistance, such as the Poverty Family Benefit Program (PFBP), has helped mitigate the poverty impacts of the global crisis. Poverty among FB recipients increased by 7 percent in 2008 to 2010 compared to the 30 percent increase for the population as a whole.

Energy poverty affects almost 30 percent of Armenian households. Energy poverty refers to households spending more than 10 percent of their budgets on energy. Armenia's targeted social assistance program, known as the Poverty Family Benefit Program (PFBP), helps to reduce poverty among vulnerable households. Government has also used the PFBP in conjunction with other measures, to help alleviate energy poverty. Beginning in 2011, a lifeline tariff for natural gas consumption was introduced for PFBP beneficiaries.[10]

2.1 Energy Sector Legal, Regulatory and Institutional Framework

The energy sector is expected to play a critical role in achieving the strategic objectives of the Government of Armenia (GoA) in coming years. Section 2.1.1 describes the GoA's strategic objectives for the energy section and the importance of the energy sector in achieving national development objectives. Section 2.1.2 describes the institutional and legal framework of the energy sector of Armenia.

2.1.1 Strategic Objectives of the Government of Armenia

Energy security is a central concern of several strategic planning documents in Armenia. The 2013 National Energy Security Concept outlines the GoA's strategies for achieving energy security through fuel diversification, building up fuel reserves and reserve generation capacity. The Concept identifies the promotion, development and investment in renewable energy technologies as critical to Armenia diversifying its energy supply and achieving energy independence.

The Armenian Development Strategy (ADS) and National Security Strategy (NSS) also emphasize the importance of renewable energy and energy efficiency in addressing energy security. The ADS and the NSS outline the GoA strategic objectives for economic growth, poverty reduction, and national security. Both policies highlight the fundamental importance of the energy sector in achieving these objectives. Strategic objectives of the ADS and NSS for the energy sector in the 2012-2017 time period are:

- Increase of energy security;
- Development of renewable energy, including increased efficiency of existing hydropower potential and creation of alternative sources of energy supply;

[9] National Statistical Service of the Republic of Armenia, "Statistical Yearbook of Armenia, 2004-2012," www.armstat.am.

[10] The poor covered by PFBP were given discounts on their natural gas consumption. From April 1, 2011 to March 31, 2013, the discount applied to the first 300 cubic meters consumed. From April 1, 2013 till July 6, 2013, the discount applied to the first 75 cubic meters consumed. From July 7, 2013 to December 31, 2014 the discount applied to the first 450 cubic meters.

- Improvement of system reliability;
- Development of regional trade;
- Replacement of depreciated power plants;
- Promotion of energy efficiency;
- Further development of nuclear energy.

Several energy sector strategic documents identify concrete targets for achieving the GoA's stated objectives in the sector. These documents include: (i) Energy Sector Development Strategy within the Context of the Economic Development in Armenia, approved by the GoA in 2005, (ii) the National Program on Energy Saving and Renewable Energy, approved in 2007, and (iii) the Action Plan of the MENR of the Republic of Armenia in line with the National Security Strategy, approved in 2007.

2.1.2 The History of Sector Reforms

Armenia's energy sector has made significant progress in the last two decades. The sector has moved from severe crisis—characterized by crippling supply shortages, and near-financial bankruptcy of the sector—to stability more characteristic of developed countries than emerging markets.

In 1992, customers had only 2-4 hours of electricity supply per day; most households depended on firewood or electricity for heating. Fiscal and quasi-fiscal subsidies for the energy sector were a major drain on the state—about 11 percent of gross domestic product (GDP). Collections were around 50 percent, and nearly 25 percent of all power produced disappeared before the meters as commercial losses (mostly electricity theft).

Since 1996, 24-hour electricity service has been restored and gradually customers have switched to cheaper, more efficient gas heating. Meanwhile, tariff increases and operating efficiency improvements have helped create commercially viable service providers, technical and non-technical losses have decreased, and collections have increased. Now the energy sector is one of the largest taxpayers in Armenia. Supply security has also improved with new regional gas and electricity interconnections, thermal plant construction and rehabilitation, and growth in renewable energy generating capacity (primarily small hydro).

A series of ambitious reforms made this transition possible. The principal reforms were:

- **Unbundling and privatization of the power sector.** By March 1995, efforts began on unbundling the power system and privatizing the power sector; Armenergo, the state-owned vertically integrated utility, was separated into generation and distribution entities. In March 1997, a Presidential Order and new Energy Law formalized separate generation, distribution, transmission and dispatch. During 2002-03, ownership of several major generating plants was transferred from the Government in exchange for US$96 million in state debt forgiveness.
- **Establishment of a sector Regulator.** A Presidential Order and the Energy Law enacted in 1997 established an independent energy sector regulator, the Armenian Energy Regulatory Commission (AERC). The Law on the Regulatory

Body for Public Services, enacted in 2004, changed the name of the regulator to the Public Services Regulatory Commission (PSRC) and expanded its authority to other sectors, including water, drainage and sewage, telecommunications, and rail transport.

- **Supporting financial sustainability.** Three steps were essential to increase collections, reduce commercial losses and improve the overall financial sustainability of the sector. These included:
  - Installing meters. Between 1997 and 1998, twelve thousand new tamper-proof meters were installed throughout the power system at a variety of voltage levels down to 0.4 kV. Residential customer meters were relocated to public areas. An Automated Metering and Data Acquisition System (AMDAS) was installed in 2001 and linked to a settlement center to facilitate accurate meter reading at the 110 kV and above.
  - Bringing tariffs to cost recovery levels. In 1994, Armenia began a gradual transition to cost-based tariffs by bring household tariffs to the average level of other retail tariffs. A schedule was established for further household tariff hikes. Since 1999, household tariffs have generally remained well above the overall average tariff.
  - Increasing transparency in collections and billing. The Electricity Distribution Company (EDC) installed a computerized customer information system to better track utilization and billing. In 1999, the EDC established a new collection scheme requiring bill payments at post offices instead of cash payments at local EDC offices, which reduced opportunities for collusion between customers and EDC inspectors.

The use and development of renewable energy has also been an important part of the transition from crisis to stability. In 2007, the PSRC set renewable energy feed-in tariffs to stimulate private investment in renewable energy. The feed-in tariff, and MDB financing through local banks, helped to jump-start a previously non-existent small hydropower industry. The framework for renewable energy feed-in tariffs is described in more detail in Section 2.3.

In 2004, Government passed the Law on Energy Saving and Renewable Energy. This is the main legal act on renewable energy in Armenia. Its main objectives were to:

- Strengthen the economic and energy independence and security of Armenia
- Increase the reliability of energy systems in Armenia
- Establish and develop industrial infrastructure and service organizations for promoting energy saving and RE
- Reduce adverse impacts on the environment and human health as a result of technological developments

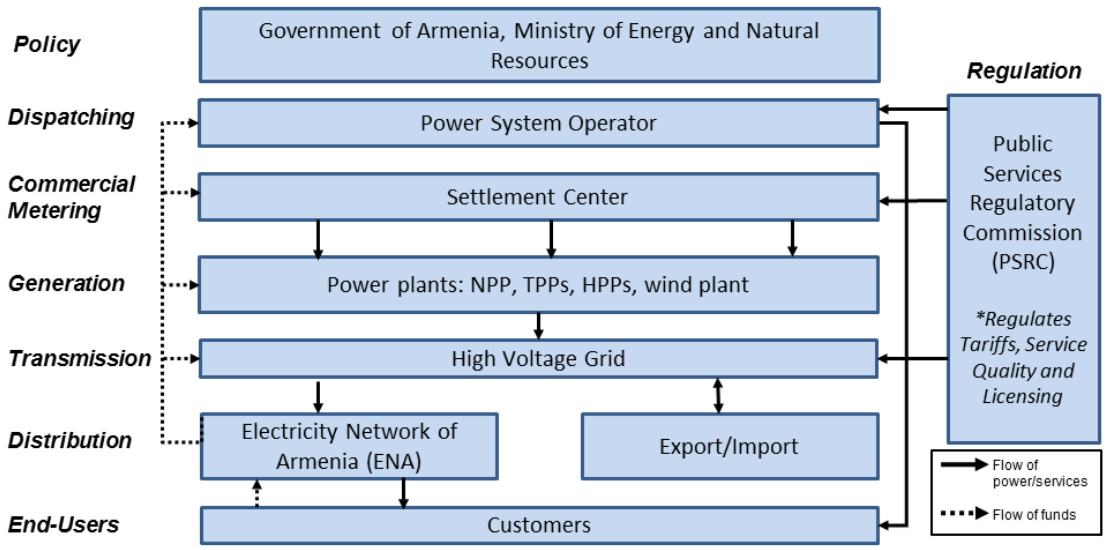
The Law also provided for the establishment of the R2E2 Fund. The R2E2 Fund was formed in 2006. The role of the R2E2 Fund is discussed in more detail in Section 2.1.3

2.1.3 Institutional Framework in the Energy Sector

The MENR and the PSRC are the key entities regulating the energy sector. The MENR is responsible for developing primary legislation and main policy documents guiding energy sector activities, including system planning and investment planning for state-owned entities. The Ministry of Finance approves allocation of financing for public and publicly-guaranteed energy sector investments recommended by the MENR. The PSRC regulates the water, electricity and natural gas sectors, and as part of its responsibilities, sets both end-user and supply-side power sector tariffs. The PSRC allows for recovery of power system investment costs through the tariff.

The electricity sector consists of nine publicly and privately-owned generation companies, one state-owned transmission company, one privately-owned distribution company, a state-owned system operator and a state-owned settlement center. The gas sector remains vertically integrated. ArmRusGazprom, the gas company fully owned by the Russia's Gazprom, imports gas from Russia and Iran, and owns and operates the gas transmission and distribution networks in Armenia. Figure 2.2 shows the structure of the electricity sector in Armenia.

Figure 2.2. Structure of the Electricity Sector of Armenia



Armenia's market framework is based on the "single buyer model" with regulated tariffs for generation, transmission, and distribution. Under this market framework, the Electricity Networks of Armenia (ENA) acts as the single buyer of electricity through contracts with generating companies at prices regulated by the PRSC. The Settlement Center monitors energy flows and ensures timely payment delivery between all sector entities. The System Operator dispatches generators taking into account the economic dispatch order of plants as well as plants' operational constraints.

In the renewable energy sector, the R2E2 Fund plays a critical role. The R2E2 Fund is an independent organization which facilitates investments in renewable energy by sponsoring renewable energy studies and projects, and supporting local renewable energy companies and stakeholders. Among numerous other projects, the R2E2 Fund implemented the project for development of SHPPs in Armenia, comprehensive surface exploration at the Karkar geothermal site, as well as the assessment of hydropower resource potential and the evaluation of the potential for solar PV manufacturing and bioethanol production in Armenia, and some other renewable energy related studies.

2.2 Energy Supply and Demand

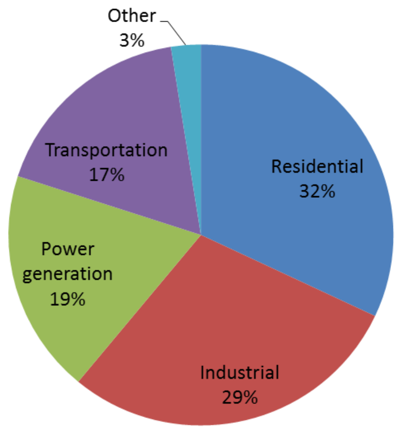
Armenia relies on electricity and gas to meet the majority of its energy consumption needs. The industrial, residential and transport sectors account for 85 percent of final energy consumption in Armenia.[11] Industry relies on a combination of electricity and gas to meet its energy needs. Residential households rely on a mix of electricity and gas for heating, cooking and hot water and electricity for lighting and other household appliance. The transport sector relies on oil and gas with 75 percent of the automobile and truck fleet using compressed natural gas (CNG).

The following subsections describe energy consumption in Armenia in further detail. Sections 2.2.1 and 2.2.2 describe the supply and demand characteristics of gas/heating and electricity, respectively.

2.2.1 Gas and Heating

Armenia has no proven oil or natural gas reserves and imports most of its fossil fuel resources from Russia and Iran. ArmRusGazprom, 100% owned by Gazprom, and the state-owned Yerevan TPP are the only companies licensed to import gas. ArmRusGazprom is the sole distributor of natural gas in Armenia. The company manages 10,483 km of gas pipelines and has approximately 640,000 consumers.[12] The residential sector is the largest consumer of natural gas in Armenia, followed by industry, electricity generating plants, and transportation. Figure 2.3 shows the breakdown of natural gas consumption in Armenia, by sector.[13]

Figure 2.3: Natural Gas Consumption by End-Use



Source: Public Services Regulatory Commission

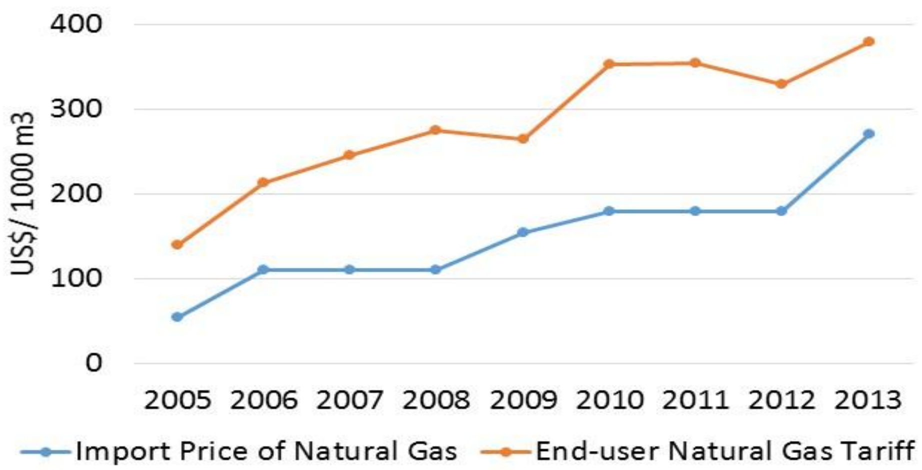
[11] Energy Institute of Armenia, Energy Consumption Data, 2013.

[12] PSRC. 2010. The Gas Sector of Armenia. http://www.naruc.org/international/Documents/13 Gas system in Armenia-ENGLISH.pdf.

[13] http://www.iea.org/stats/gasdata.asp?COUNTRY_CODE=AM

The import price of natural gas from Russia increased consistently in recent years, which has resulted in steady increases in domestic end-user tariffs for natural gas. From 2005 to 2013, the end-user natural gas tariff increased by 164 percent[14]. Figure 2.4 shows the import price of natural gas and the natural gas tariff for domestic end-users from 2005 to 2013.

Figure 2.4. Natural Gas Import Price and Domestic End-User Tariff, 2005-2013[15]



Note: End-user represents low use customer consuming less than 10,000 cm per month

Source: Public Services Regulatory Commission of the Republic of Armenia (PSRC), http://www.psrc.am/en

Armenian households heat primarily with natural gas and electricity Armenia's district heating network, which used to provide heat supply for roughly 55 percent of Armenia households, has fallen into disrepair. Many heat supply companies went bankrupt and closed following the economic and energy blockade that occurred during the early 1990s. As a result, many households switched to individual heating solutions using electricity and, more recently, natural gas. In 2005-2011, the share of natural gas in the heating fuel mix has increased from 10 percent to 70 percent, displacing firewood, electricity and other fuels, thanks to a rehabilitation and extension of the gas distribution network.

2.2.2 Electricity

Armenia's electricity system has 3,319 MW of installed capacity, and 2,530 MW of available generating capacity. Electricity is produced by three generation sources: nuclear (roughly 30 percent), thermal (roughly 30 percent), and hydropower (nearly 40 percent). Available capacity is low compared to installed capacity because due to the age and poor condition of many generating plants, significant share of installed generating capacity is non-operational. Roughly 50 percent of available capacity is more than 40 years old.[16] Many of the largest generating assets will need to be

[14] For end-user consuming less than 10,000 cm per month.

[15] Fluctuations in the end-user tariff in USD that are not correlated with fluctuations in the import price of natural gas are caused by annual AMD to USD exchange-rate fluctuations.

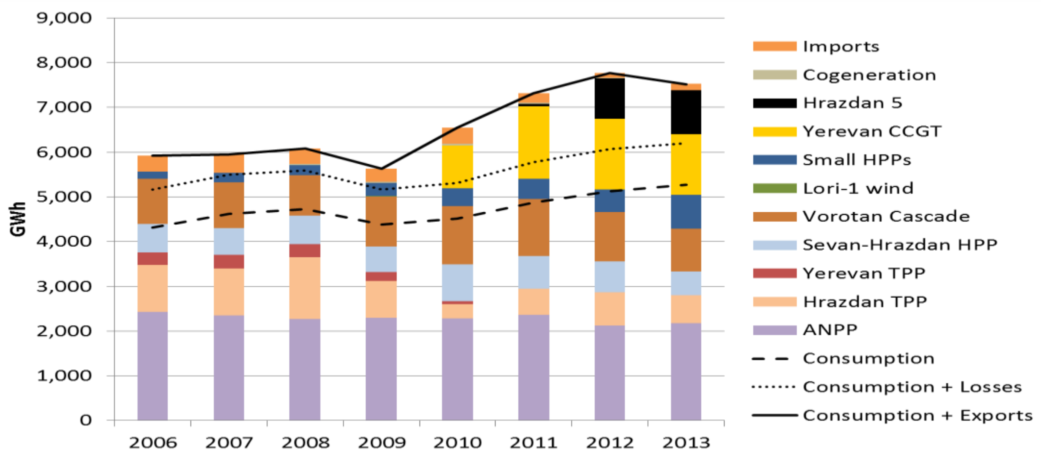
[16] Estimated based on available capacity of plants greater than 10 MW.

retired soon. The Government has already discontinued operation of old and inefficient units at Yerevan TPP and plans to retire the old units at the Hrazdan TPP by 2017. The nuclear plant is scheduled to remain online until 2026 because of a lack of alternatives, although it will require approximately US$300 million of investments to continue functioning. The share of thermal and hydropower plants in the capacity and production mix has increased in recent years because new plants have been built and Armenia has experienced good hydrological conditions over the past several years.

The NPP provides base load capacity. Other HPPs, including the Vorotan Cascade and several HPPs in the Sevan-Hrazdan Cascade, provide daily load regulation, while thermal plants operate to meet shoulder peak especially in the winter and to serve base load for several weeks in autumn when the NPP goes offline for maintenance. The Hrazdan-5 and Yerevan CCGT plants also generate electricity for export under the gas for electricity swap arrangement with Iran.

Demand grew steadily over the past decade, but dropped in 2008 as a result of the global financial crisis. Electricity consumption in Armenia grew 4.5 percent annually from 2004–2008, but consumption fell 7.4 percent in 2009 as a result of the financial crisis. Consumption has since increased, growing 5 percent and 3 percent in 2012 and 2013, respectively.[17] Figure 2.5 shows Armenia's electricity balance including net generation, consumption, exports, imports and transmission and distribution losses.

Figure 2.5: Net Generation and Consumption, 2006-2011



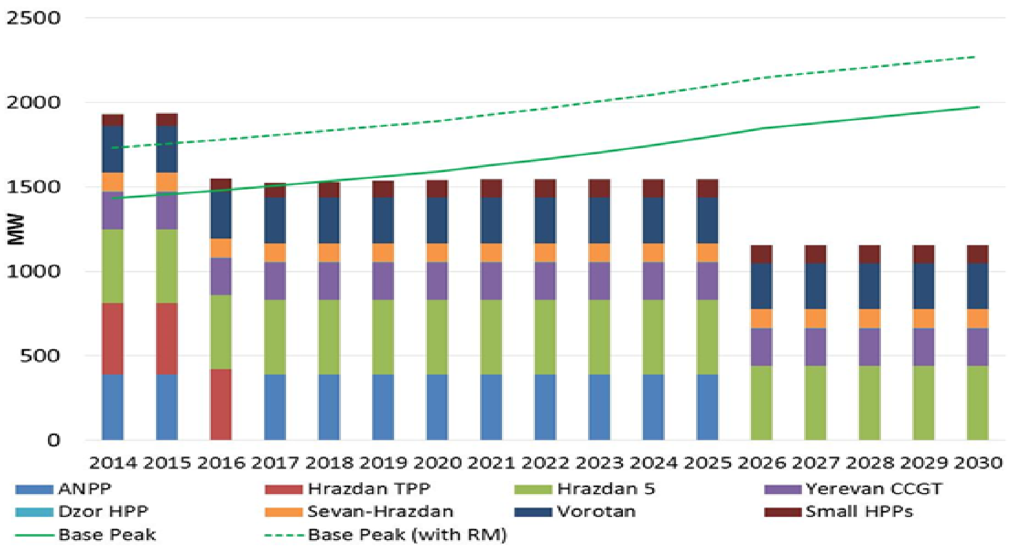
Source: Public Services Regulatory Commission

Given the growth in demand and the need to retire ageing generating assets, Armenia will potentially face a capacity gap to meet the peak. At least 230 MW of new capacity will be needed starting from 2016 to meet peak demand and maintain an adequate reserve margin if old (>47 years) and inefficient Hrazdan TPP is retired. To avoid such gap, Armenia will have to continue buying electricity from privately owned Hrazdan TPP that has the highest-cost energy in the system ($0.15 c/kWh) until a new large power plant (combined cycle gas turbine station) is in place by 2020. That means Armenia will incur significant economic costs during that period

[17] PSRC. Main Characteristics Indicators.

and will be prone to significant supply reliability risk given that Hrazdan TPP is old and under-maintained. The new for new capacity will increase to 1,100 MW by 2030. Figure 2.6 shows the expected gap between generation and consumption. Figure 2.6 shows the expected gap between available capacity and winter peak demand.

Figure 2.6: Forecast Gap between Installed Capacity and Winter Peak Demand



Source: World Bank

2.3 Electricity Cost and Pricing

The PSRC is responsible for setting and reviewing tariffs in the electricity sector, including tariffs for all companies in the sector as well as end-user tariffs. According to the Energy Law, a tariff should cover:

- Justified operation and maintenance costs
- Loan service costs
- Costs related to environmental standards
- Mothballing and preservation costs
- Technical and commercial losses
- Costs of the safe-keeping of the utilized nuclear fuel and requisite allocations to the Nuclear Plant Decommissioning Fund
- Reasonable profit
- Other justified costs as provided by Legislation.

The PSRC or the Licensee can request a tariff review every six months. Once requested, a tariff review request must be submitted within 90 days. The PSRC is authorized to set long-term tariffs for more than six-months if it is considered necessary to provide investment security. Once a tariff is set, licensees cannot appeal the size of a tariff. The only recourse for altering an assigned tariff is to petition the PSRC’s tariff methodology. Table 2.1 shows power company tariffs in Armenia from 2009 to 2013.

Table 2.1. Power Company Tariffs in Armenia, 2009-2012 (AMD/kWh) (excluding VAT)

	2009	2010	2011	2012	2013
Generation					
Hrazdan-5	N/A	N/A	N/A	21.65	33.4
Yerevan CCGT	N/A	N/A	11.657	5.328	20.07
Hrazdan TPP	22.559	38.851	43.997	41.219	59.47
Yerevan TPP	22.520	29.379	N/A	N/A	N/A
Sevan-Hrazdan	5.802	4.983	3.866	4.56	6.581
Vorotan	1.448	1.868	4.35	4.778	7.914
ANPP	7.525	7.963	8.428	9.658	10.830
Transmission					
HVEN	0.891	0.710	0.827	0.3322	1.0657
Distribution					
ENA	10.134	11.200	11.152	9.338	11.786

Source: Public Services Regulatory Commission of the Republic of Armenia (PSRC), "Calculation of Electricity Tariffs," 2009-2012.

In 2007, the PSRC set renewable energy feed-in tariffs to stimulate private investment in renewable energy. New generating plants sign 15-year power purchase agreement (PPA) under which ENA is obliged to pay the generator for all the power produced. According to the feed-in tariff methodology, the PSRC must adjust feed-in tariffs annually in line with changes in inflation and the USD to AMD exchange rate. Table 2.2 shows current feed-in-tariffs for all renewable energy systems in Armenia.

Table 2.2. Feed-in-Tariffs for Renewable Energy Systems, 2013 (excluding VAT)

RE Technology	**Feed-in Tariff**	
	AMD/kWh	US$/kWh
Wind	34.957	0.08
Biomass	38.856	0.09
Small hydro-power built on "natural water systems"	20.287	0.05
Small hydro-power built on irrigation systems	13.523	0.03
Small hydropower built on "drinking water supply systems"	9.017	0.02

Source: PSRC

The PSRC also sets tariffs for end-users. End-user tariffs are time-differentiated tariffs in which users pay different day-time and night-time rates. In July of 2013, the PSRC increased end-users tariffs for the first time since 2009. Table 2.3 shows current end-user tariffs in Armenia.

Table 2.3: End-User Tariffs, VAT inclusive

	Day	Night
	(AMD/kWh)	
Residential	38	28
0.4 kV	38	28
6 (10) kV	35	25
35+ kV	29	25

Source: Public Services Regulatory Commission of the Republic of Armenia (PSRC), "Electric Power Tariffs," accessed 3 July 2013. http://www.psrc.am/en/?nid=213

2.4 Energy Efficiency

Much has also been done, and is being done in the area of energy efficiency in Armenia. These activities complement the work being done on renewable energy.

Armenia can recoup sizable economic benefits through utilization of this potential. While Armenia is one of the less energy intensive economies in the region, largely due to the structural changes of the economy, there is potential for further efficiency improvements.

The Government recognizes that improvement of energy efficiency will contribute to addressing the challenges of supply adequacy and security. Specifically, higher energy efficiency will contribute to: (a) reduction of investment needs in new generation due to realization of energy efficiency potential; (b) improvement of the country's energy security due to reduced demand for gas used for heating purposes and as a fuel for electricity generation; and (c) improvement of affordability of energy for the poor given that improved energy efficiency will require less energy consumption to achieve the needed comfort level of heating, lighting or other use.

The Government has accordingly taken important steps to encourage realization of the energy efficiency potential. In 2005, the National Parliament passed the Law on Energy Savings and Renewable Energy, creating a legal basis for energy efficiency in Armenia. The Government also adopted the National Program on Energy Savings and Renewable Energy, which identifies the sectors with the largest energy efficiency potential and provides an outline of technical measures/solutions to be taken to realize the identified technically viable potential.

Currently, several donors are supporting the Government to realize the energy efficiency potential:

- The $20 million Armenia Sustainable Energy Financing Facility of EBRD supports private enterprises' access to energy efficiency investment funds through line of credit to local commercial banks.
- The $3 million UNDP/GEF project on Improvement of Energy Efficiency in Buildings supports development of building codes with energy efficiency requirements; control, testing and certification of energy efficiency of materials; awareness raising and piloting of integrated building design.

- The $10 million GEF/World Bank project supports energy efficiency improvements in public and social facilities (e.g. schools, kindergartens, hospitals, street lighting), and further improvement of the legal and regulatory environment for energy efficiency. The project aims to finance energy efficiency retrofits in 100 public and social facilities. The energy savings in facilities that have already been retrofitted are 45% on average.

There are also $20 million E5P program in the pipeline to scale up energy efficiency investments in the country.

3 Renewable Energy Sector Context

Armenia has significant indigenous renewable energy resources, and an educated workforce with extensive scientific and engineering expertise. Furthermore, the Government has taken proactive steps in recent years to craft laws and regulations designed to reform the power sector to enable private sector involvement in renewable energy technology development. However, Armenia's renewable energy sector faces a number of important barriers to renewable energy deployment, primarily related to the availability of financing, the regulatory framework for renewable energy, the high cost of renewable energy technologies and public awareness of the potential benefits of renewable energy technologies.

This section describes Armenia's renewable energy sector, and includes an assessment of the potential for different renewable energy options, a description of Armenia's business environment for renewable energy, as well as a description of the barriers facing renewable energy development in Armenia.

3.1 Analysis of Renewable Energy Options

An assessment of available data on renewable energy resources in Armenia was carried out to support the preparation of the IP. This section details the results of that assessment and describes progress to date on deploying renewable energy technologies in Armenia.

Table 3.1 shows the total estimated technical potential for renewable energy in Armenia.

Table 3.1: Renewable Energy Resource Potential in Armenia by Technology.

Technology	Capacity (MW)	Generation (GWh/yr)
Wind	300	650
Utility scale solar PV	830 – 1,200[a]	1,700 – 2,100[a]
Concentrating solar power (CSP)	1,200	2,400
Distributed solar PV	1,300	1,800
Geothermal power[b]	at least 150	at least 1,100
Landfill gas	2	20
Small hydropower	100	340
Biogas	5	30
Biomass	30	230
Total (electricity)[c]	**3,800 –4,300**	**7,400 – 8,700**
Solar thermal hot water	200	260
Geothermal heat pumps	3,500	4,430
Total (heat)		**4,690**

[a] The resource potential depends on which solar PV technology is deployed: Fixed PV, Single-Axis Tracking PV or Concentrating PV

[b] Assumes flash technology is used. The actual capacity cannot be known without exploratory drilling. The geothermal capacity estimates are based on results of estimates for three potential sites, for which some geo-technical information was available. The potential can be significantly larger given several other potential sites, which have not been explored at all.

[c] Solar PV and CSP were evaluated as options for development in the same areas. Therefore, the total resource potential includes only the generating potential for one of these technologies (Solar PV). For this reason, the total is not the same as the sum of the resource potential listed for each technology.

3.1.1 Small Hydropower

Small hydropower is the most widespread renewable energy technology deployed to date in Armenia except for large hydropower. Small hydropower contributes approximately 6 percent of Armenia's annual electricity generation. As of April 2013, Armenia had 136 small hydropower plants (small HPPs) with a total capacity of 221 MW and annual generation of 665 GWh. Roughly 60 percent of this capacity has been added since 2008. Additionally, the PSRC has licensed the construction of 77 new projects, which could potentially add approximately 168 MW of small HPP capacity and 592 GWh of annual generation.[18]

Over 90 MW of undeveloped small hydropower projects with a potential for generating almost 300 GWh have been identified throughout Armenia in addition to the operating and licensed projects.

3.1.2 Wind

Armenia has a number of areas with promising wind resources. The most promising areas that have been identified and characterized to date are Zod Pass, Karakach Pass, Pushkin Pass, Sisian Pass and the Fontan region. Together these sites are estimated to have 150 MW of developable resource potential, with estimated capacity factors ranging from 21 to 31 percent, depending on the site.[19]

The private companies Zodwind and Arenergy have completed feasibility studies for wind plants in Armenia. Two other private companies, SolarEn and MVV-Decon, have conducted wind measurement projects. However, to date no private companies has moved forward with wind plant development in Armenia.

Armenia's only operating wind project is the 2.64 MW Lori 1 plant. Lori-1 was built in in December 2005 under a grant from Iran. The plant has a capacity factor of approximately 11 percent and generates 2.5 GWh per year.[20]

3.1.3 Geothermal Power

Armenia has no installed geothermal power plants, but comprehensive geo-technical studies suggest that geothermal resources suitable for power production may exist at a number of sites, including the most promising Karkar, Jermaghbyur, and Grizor sites, as well as along the Armenian-Georgian border. In 2009-2011, comprehensive

[18] Public Services Regulatory Commission of Armenia, "Construction of small hydro companies operating indicators" and "Main Indicators of Producing small hydroelectric power companies operating" April 1, 2014

[19] R2E2, "Renewable Energy Roadmap for Armenia Task 4 Report," May 2011

[20] USAID, "Wind Energy In Armenia: Overview of Potential and Development Perspectives," March 2010

surface investigation works were conducted for Karkar site, including field scouting, magneto-telluric sounding (MT), independent interpretation of MT results, three-dimensional (3D) MT sounding, independent interpretation of the results of 3D MT sounding as well as early-stage economic and financial appraisal. The results of the above studies suggest that two different conceptual geothermal models or their combination might exist for the Karkar site:

Model A: Model A assumes that low resistance is not present in the geothermal zones of interest. In such a case, Model A would provide only for a diffuse source of heat and characterizes the field as a reservoir of moderately warm waters (around 150^{o}C).

Model B: Model B assumes that low resistance may be present in geothermal zones of interest. In such a case, Model B would provide for a localized high-temperature source of heat. Along with this, some of the layers could be characterized as a reservoir of high-temperature water (more than 250^{o}C).

Results of the above studies indicate that a geothermal resource exists at the site, and can only be confirmed through exploratory drilling. The key conclusions and recommendations of those studies were also reviewed by a third party – Iceland Geosurvey (ISOR), which confirmed the robustness of the methodology for the above studies and the key conclusion that exploratory drilling is needed to confirm the resource and its characteristics.[21] The World Bank/ESMAP Global Geothermal Development Plan TA Program supported the Government to prepare a drilling program for Karkar site, including test well options, drilling and associated consulting services required, contracting arrangements, and costs.

The total geothermal resource potential of three geothermal sites that were explored to some extend has been estimated to be at least 150 MW. However, it is important to note that because of the limited exploratory activities and information about Armenia's geothermal resources, this is a very rough estimate, which relates only to three potential sites for which information was available, and the actual geothermal resource potential could be much larger.

3.1.4 Solar PV

Armenia has good solar PV resources, with annual average global horizontal irradiation (GHI) ranging from 1,490 kWh/m^2 to over 2,100 kWh/m^2. By comparison, average annual GHI in Europe is 1,000 kWh/m.^{2} The total resource potential for utility-scale solar PV is over 6,500 MW.

Assuming polycrystalline solar PV modules mounted at a fixed angle to the sun are deployed in ground-mounted utility-scale plants, solar PV systems could achieve capacity factors of 20 to 24 in Armenia (dependent on location). If single-axis tracking solar PV technology is deployed, capacity factors could be as high as 30 percent.

In addition to utility-scale solar PV, distributed solar PV mounted on building rooftops could also be deployed throughout Armenia, although these plants would

[21] Memoranda from ISOR are contained in Annex H.

likely have higher costs and lower capacity factors than large-scale, ground-mounted plants.

Solar PV deployment in Armenia to date has been limited to relatively small-scale rooftop-based installations at schools, hospitals, office buildings and municipal sites throughout Armenia.[22] It is estimated that less than 100 kW of solar PV is currently operational.[23]

3.1.5 Concentrating Solar PV and Concentrating Solar Thermal Power

Although Armenia has good resources for solar PV, Armenia receives relatively low direct normal irradiation (DNI) compared to most of the locations where concentrating solar thermal power (CSP) is successfully deployed.[24] Armenia's annual DNI ranges from 1,410 kWh/m^2 to 2,453 kWh/m^2. The minimum DNI level threshold for viability for CSP plants that is generally accepted in the industry is 2,200 kWh/m^2. Only one area in the South-Eastern corner of Lake Sevan receives DNI above this threshold. However, overall Armenia has rather poor resources for CSP and for this reason this technology is not considered a viable option for development.

Concentrating solar PV (CPV) also does not appear to be a favorable technology option in Armenia compared with the other available solar PV technologies. Like CSP, CPV also takes advantage of DNI resources. An analysis of the theoretical performance of CPV plants deployed in Armenia revealed that CPV is expected to have lower capacity factors than flat-plate solar PV installations (fixed axis or single-axis tracking), and CPV is also expected to have higher capital costs than these technologies.

3.1.6 Biomass

Armenia's biomass resources that could potentially be used for power generation consist of forestry residues (fallen wood and sanitary cuttings) and crop residues from grain farming. Dedicated energy crops have also been considered as a potential biomass resource in Armenia, but preliminary estimates suggest that cultivating crops for fuel would be very high-cost.

The biomass resource assessment suggests that there are sufficient forestry residues to support a 4 MW power plant in Armenia and sufficient grain crop residues to support a 25 MW power plant. However, it would be necessary to transport forestry

[22] USAAA/US Embassy/EcoTeam/UNDP/GEF, "Use of Renewable Energy Sources in the World and Armenia Through Innovations to Clear Technologies," 2010

[23] Preparation of Renewable Energy Development Roadmap for the Republic of Armenia Task 2 Report," February 2011

[24] Direct Normal Insolation (DNI) is energy that travels directly from the sun without interruption. Rays of direct insolation are parallel, and concentrating solar collectors (both concentrating PV and concentrating solar power) collect the parallel rays onto a receiver. Solar energy which is not direct is called diffuse insolation, and it is carried by rays which have been scattered or reflected. Concentrating solar collectors are unable to collect these oblique rays of diffuse insolation, but flat plate collectors (solar PV) can absorb both DNI and diffuse insolation and convert them to usable energy. The DNI is relatively low in Armenia compared to other parts of the world where concentrating solar is being deployed. This means that in Armenia more of the energy of the sun is scattered by clouds or haze before it can hit a solar collector. Additionally, Armenia's latitude causes the sun to stay lower in the sky than in other parts of the world. The lower sun means that the direct insolation must pass through more atmosphere and so the energy is 'diluted' by striking the solar collector at an angle.

and crop from all around the country to central locations and there is currently no established infrastructure to do this. Therefore, it is expected that it would be logistically difficult to collect biomass resources for power generation, and that the collection costs from transporting the fuel would make fuel costs very high.

3.1.7 Biogas

Armenia has the potential for biogas-based power production at livestock farms, at the Nubarashen landfill (in the city of Yerevan) and at the Aeratsia wastewater treatment plant (in the city of Yerevan). In 2010, the GEF/UNDP identified three livestock farms as potential candidates for biogas-to-energy projects, with a combined resource potential of 3.3 MW. These plants would be similar to the Lusakert biogas plant, which is Armenia's only operating industrial-scale biogas-to-energy plant, located at the Lusakert poultry farm.

In 2001, a consortium of Japanese companies began studying the potential for a landfill gas-to-energy plant at the Nubarashen landfill. Although eventually the consortium installed a methane gas flare plant instead of an energy project, more recent assessments have identified the potential for building up to a 2.5 MW landfill gas-to-energy plant at the facility.

The other potential source of biogas energy in Armenia is the Aeratsia wastewater treatment plant. The plant is currently dilapidated and largely non-functioning, but if the plant were to undergo significant rehabilitation and anaerobic digesters are installed at the facility, it is expected that a 3 MW cogeneration plant could be constructed at the facility.

3.1.8 Geothermal Heating/Cooling Technologies

Armenia has significant potential for geothermal heating and cooling in residential buildings. If land is available, geothermal heat pumps could theoretically be deployed anywhere and could cover a large portion of Armenia's space heating and cooling load. Furthermore, Armenia is estimated to have high quality geothermal resources. The coefficient of performance (COP) for geothermal heating in Armenia is reportedly 5.0 to 6.0. By comparison, the average COP in Russia is around 3.5.[25]

Only one existing large-scale geothermal heating project has been implemented in Armenia. In 2009, an 860 kW geothermal heat pump was installed at a commercial building in Northern Avenue in Yerevan.

3.1.9 Solar Thermal Heating Technologies

There is significant potential for solar thermal hot water heating technologies in Armenia. This technology has been deployed in a number of demonstrations over the past decade, but the total penetration is small (less than 4 MW of total installed capacity) and the technology has yet to gain widespread commercial acceptance.[26]

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[25] The coefficient of performance is the ratio of the amount of energy recovered from a geothermal heating system to the amount of energy input to the system to operate it. A higher coefficient of performance means that a geothermal system more efficiently transfers heat from the ground to an indoor space.

[26] USAAA/US Embassy/EcoTeam/UNDP/GEF, "Use of Renewable Energy Sources in the World and Armenia Through Innovations to Clear Technologies," 2010

Recent solar thermal heating projects in Armenia include the implementation of GEF-funded systems at a housing development and a school in the Shirak region.[27]

3.2 Costs of Renewable Energy

The comparative cost of renewable energy technologies is an important factor when determining their viability and attractiveness for inclusion in Armenia's energy portfolio. This section presents supply curves that show the levelized energy costs (LECs) of the various renewable energy technologies assessed in Armenia for the preparation of the Investment Plan under different sets of financing assumptions. The financing assumptions used are shown in

Table **3.2**. Additional assumptions are shown in Annex F.

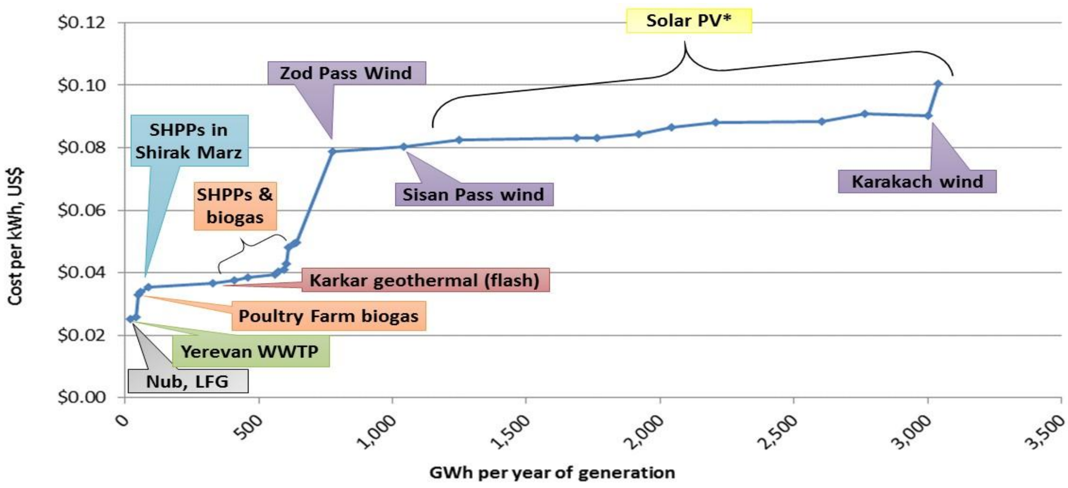
Table 3.2: Concessional, Commercial and SREP/Commercial Financing Assumptions

	Concessional	Commercial	SREP/Commercial Mixed
Debt/equity split (%)	100/0	70/30	70/30
Debt rate (%)	3.00	10.69	3.72*
Equity return (%)	N/A	18	18
Debt term (years)	20	20	40

* Synthetic debt rate used to model a financing structure in which 35 percent of project capital costs are financed with commercial debt at 10.69 percent interest (and a 15-year loan tenor), and 35 percent of project capital costs are financed with SREP capital contributions at 0.25 percent interest and with a 40-year loan tenor and a 10-year grace period.

Figure 3.1 shows a supply curve of renewable power resources in Armenia with LECs of less than US$0.10/kWh, assuming concessional financing assumptions.

Figure 3.1: Renewable Energy Supply Curve for Armenia, Concessional Financing Assumptions, LEC of Less Than US$0.10/kWh

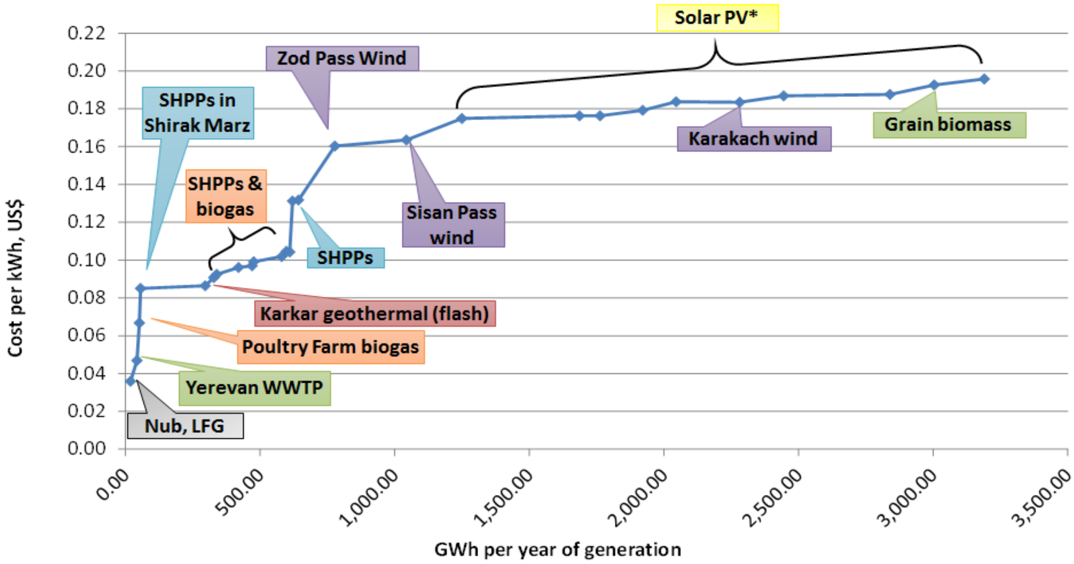


27 The GEF Small Grants Programme, "SGP Armenia Supports the Use of Renewable Energy and Energy Efficiency Practices," 2010; The GEF Small Grants Programme, "Transferring Experience on Practical Implementation of Low-Carbon Technologies in Basen Community of Shirak Region," 2013

*Assumes Fixed PV

Figure **3.2** shows a supply curve of renewable power resources with LECs of less than US$0.20/kWh, assuming commercial financing assumptions.

Figure 3.2: Renewable Energy Supply Curve for Armenia, Commercial Financing Assumptions, LEC of Less than US$0.20/kWh

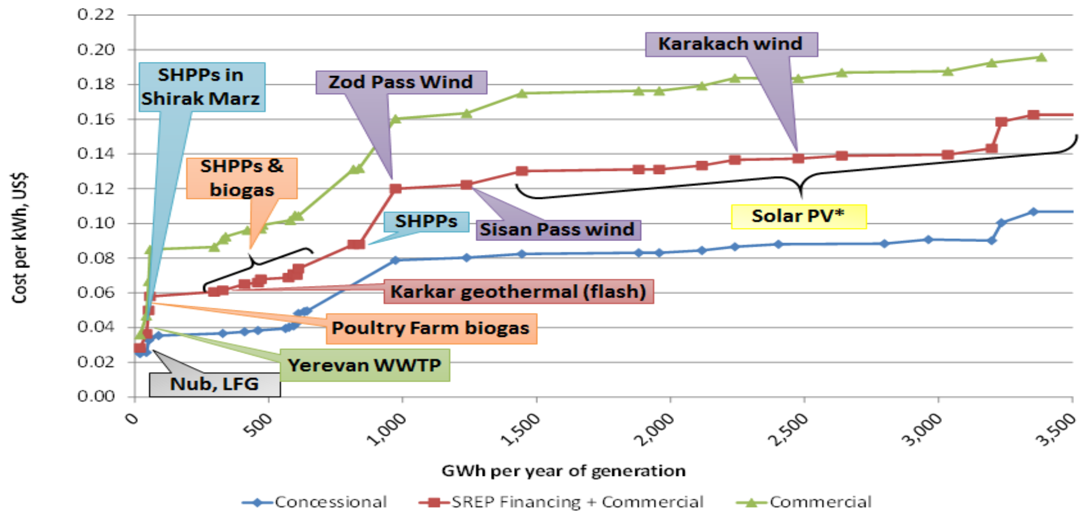


* Assumes Fixed PV

Figure 3.3 shows a supply curve of the cost of renewable power resources in Armenia assuming concessional, commercial and a combination of SREP and commercial financing assumptions.[28] This demonstrates the effect of different financing assumptions on the levelized energy cost of renewable energy resources, and the magnitude of the effect of SREP capital contributions on levelized energy costs.

[28] Note that the relative position of certain renewable energy options with respect to each other in the supply curve is different in the commercial and concessional supply curves. This is because the effect of changes to financing assumptions is different for different technologies, dependent on the proportion of each technology's LEC that comes from capital costs and the proportion that comes from operating costs. When the capital cost of a technology makes up a particularly large portion of that technology's LEC, increases in the cost of capital increases that technology's LECs more than it does the LECs of technologies for which operating costs are a higher proportion of their LECs.

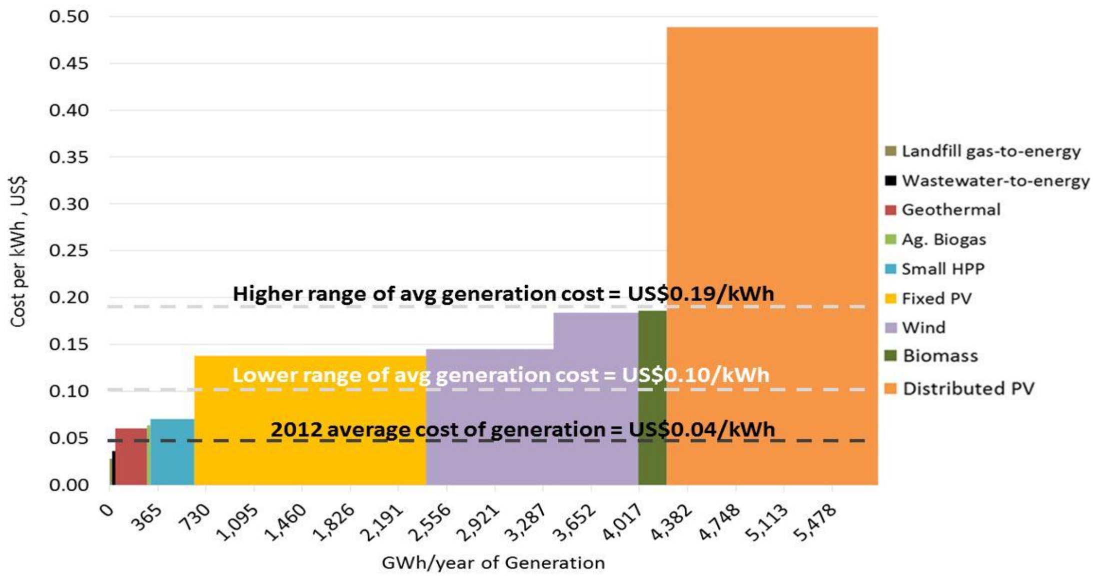
Figure 3.3: Renewable Energy Resources Supply Curve for Armenia, Commercial, Mixed Commercial/SREP and Concessional Financing



* Assumes fixed PV

Figure 3.4 show the average LEC of renewable energy resources in Armenia over the life of each energy project assuming mixed SREP/commercial financing assumptions, as well as the range of estimates of the cost of generation in 2026, when the a new nuclear plant would need to come on line to replace the Metsamor nuclear power plant.[29] This figure is intended to provide a more general picture of the comparative costs of different renewable power technologies in Armenia.

Figure 3.4: Renewable Energy Resources Average Supply Curve for Armenia (Mixed Commercial/Concessional Financing)



[29] The range reflects different assumptions about the size of the new nuclear plant, and whether concessional or commercial financing is used to finance it.

Note that there are several uncertainties associated with the data presented in the figures. The geothermal energy resource potential shown in this supply curve has not yet been proven to exist, and the size of the resource potential shown here is largely speculative. Furthermore, the potential for wastewater treatment plant (WWTP) energy is contingent on the completion of upgrades to the Aeratsia WWTP, the costs of which are not included here. Finally, the cost of transportation for biomass fuels is highly uncertain, and the costs provided above might not accurately reflect this.

It is also important to note that only the fixed-axis PV technology is shown in the supply curves above, but the potential for three other solar technologies was also assessed: single-axis tracking solar PV, concentrating solar PV and concentrating solar thermal power. These technologies were assumed to be deployable in the same areas—each solar technology was treated as a technology option that could be used to take advantage of a certain amount of solar resource. Fixed PV was the lowest cost of all these technologies, so it is the only technology included in the supply curves above. Table 3.3 shows the comparative minimum, average and maximum levelized energy costs for each of the utility-scale solar technologies assessed in Armenia.

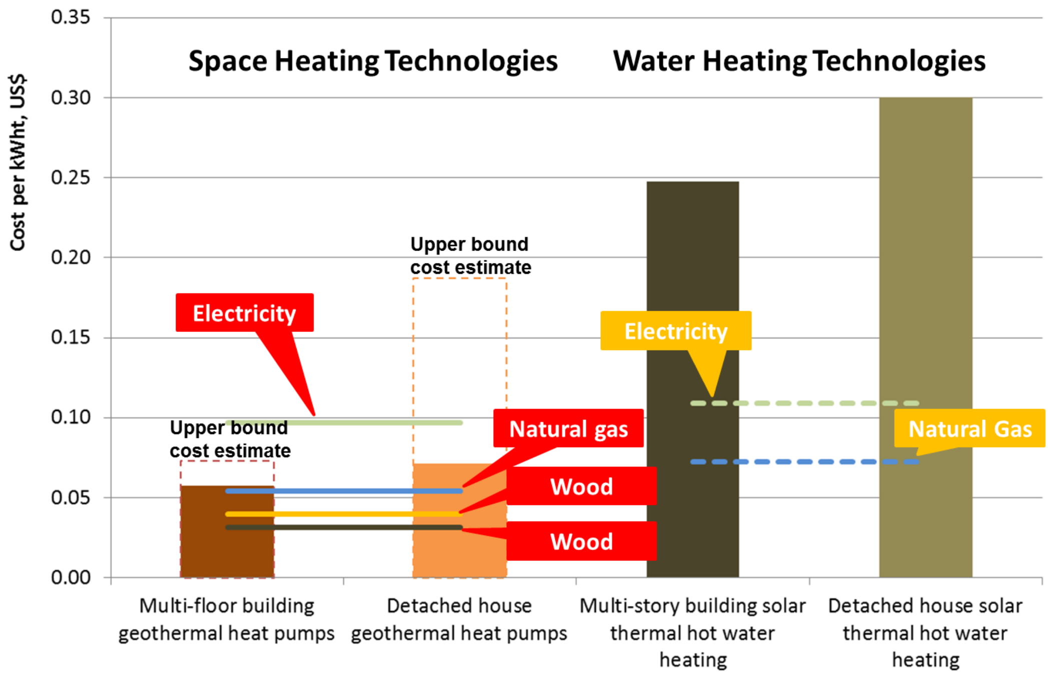
Table 3.3: Levelized Energy Cost Ranges of Various Solar Power Technologies in Armenia, Assuming Mixed SREP/Commercial Financing

Technology	Minimum	Average	Maximum
	Levelized Energy Cost, US$/kWh		
Fixed PV	0.13	0.14	0.16
Tracking PV	0.14	0.15	0.17
Concentrating PV	0.22	0.26	0.35
Concentrating solar thermal power	0.43	0.54	0.79

The LECs of each solar technology vary depending on the location where the technology would be deployed, which determines the solar resource and therefore each technology's theoretical capacity factor

Figure 3.5 shows the cost of renewable heating technologies in Armenia compared with the cost of heating with electricity, natural gas, firewood and coal.

Figure 3.5: Comparative Cost of Renewable and Non-Renewable Heating Technologies



3.3 Barriers to Renewable Energy Projects

Armenia faces numerous barriers to the further development of renewable energy systems despite the country's significant renewable energy resource potential and history of past success in the development of a robust domestic hydropower industry. Table 3.4 describes some of the most significant barriers hindering the development of renewable energy in Armenia. For each barrier, there is also a corresponding discussion of possible mitigation options.

Table 3.4. Barriers to Renewable Energy Development and Mitigation Options

Barrier	Mitigation Options	Solar PV	Geo-thermal Power	Wind	SHPPs	Others
Costs						
High costs of the first utility-scale solar and geothermal projects in the-country will likely not be cost-competitive with conventional energy generating technologies and Armenia's current power generation mix. Therefore, the implementation of renewable energy technologies can make energy unaffordable for consumers in this environment if the full cost of these technologies is passed on to consumers.	Support the Armenian renewable energy industry for a short period of time with funding and low-cost financing to help the domestic industry gain experience with these technologies and thereby drive their costs down in Armenia in the long-term	✓	✓			
Legal and Regulatory						
Poor coordination between authorities makes getting all necessary permits for RE technologies cumbersome and results in little transparency in procedures, long lead-times and high project costs.	▪ Streamline procedures for issuing permits ▪ Improve coordination between Government authorities (i.e. PSRC and Ministry of Natural Protection (MoNP))	✓	✓	✓	✓	✓
Environmental Regulation and Enforcement is not uniform for all RE technologies and responsibilities for enforcing regulations is not clearly defined within the Government	▪ PSRC and MoNP need to work out cooperative rules for uniform and effective monitoring and enforcement			✓	✓	

Barrier	Mitigation Options	Solar PV	Geo-thermal Power	Wind	SHPPs	Others
Some regulatory approvals are the same for all sizes of plants, in particular, for licensing, land use, EIAs, and water use. Therefore, the cost and time required to obtain approvals for a relatively small project can be large relative to that projects cost and construction timeframe and disincentivize the development of small projects	▪ Create a fast-track for smaller projects, which will be especially important if smaller solar plants are to be implemented			✓	✓	
Power Purchase Agreements (PPA) are not issued until construction of SHPPs and wind plants are complete	▪ Move issuance of PPAs to the time that the development permit is granted (this would require provisions in the PPA in case of major project delays, cancellations, etc.)			✓	✓	
PPA terms are limited to 15 years, leaving investors uncertain about the remaining 4-5 years of the plant life in the case of wind, 10 years in the case of solar, and 15 years in the case of geothermal	▪ Extend PPA terms to match the life of given RE technologies (25 years for solar and geothermal projects, 20 years for wind projects)			✓	✓	
VAT laws current legislation for wind plants allow payment of VAT to be postponed for 3 years, but having to pay back VAT 3 years later is a cash-flow burden for renewable energy projects, relatively early in the life of the project	▪ Extend the period by which the VAT must be paid back for all renewable energy technologies			✓		
There is currently no mechanism to guarantee remuneration for solar PV or geothermal projects	▪ Use data from SREP analysis of renewable energy resources in Armenia to implement a FiT or other financial support mechanism for solar	✓	✓			

Barrier	Mitigation Options	Solar PV	Geo-thermal Power	Wind	SHPPs	Others
	PV and geothermal power					
Inflation and exchange rate adjustments in FiTs only happen once a year, and based on previous year's data. Inflation based on CPI, which is not always same rate faced by investors in RE projects, where a producer price index (PPI) may be more appropriate.	▪ Make currency and FX adjustments more frequent, and based on more recent data or credible market forecasts ▪ Include "extraordinary adjustment" clauses in PPAs if rates go beyond agreed range			✓	✓	
Availability of Financing						
Local commercial banks do not have technical capacity to assess non-SHPP RE projects. The success of the SHPP program is owed, in part, to good quality of technical assessments by local commercial banks. They do not currently have experts to assess other types of RE projects	▪ Support domestic commercial banks with technical assistance to help educate them on appropriate underwriting criteria and due diligence assessments for solar PV, geothermal power and solar/geothermal heating technologies ▪ Project development facility/fund for RE projects to make it easier for local commercial banks to assess technical aspects of projects	✓	✓	✓		✓
Domestic Project Development Capacity						
Lack of experience with renewable energy technologies makes property owners and energy users skeptical of these technologies.	▪ Actively support demonstration projects and outreach campaigns to help market the benefits of renewable energy technologies to the public	✓	✓			✓

Barrier	Mitigation Options	Solar PV	Geo-thermal Power	Wind	SHPPs	Others
	▪ Support domestic commercial banks with technical assistance to help educate them on appropriate underwriting criteria and due diligence assessments for solar PV, geothermal power and solar/geothermal heating technologies ▪ Project development facility/fund for RE projects to make it easier for local commercial banks to assess technical aspects of projects					
Limited capacity for equipment acquisition and installation limits the expansion of solar PV or hot water, large scale geothermal, geothermal heat pumps, biomass or biogas. There is little experience with these technologies in Armenia.	▪ Finance pilots with the requirement that there be knowledge transfer to local partners ▪ Provide funding for training workshops for installers	✓	✓			✓
There is a lack of sufficient, good quality data on solar and geothermal resources. Additional studies will need to be done to accurately assess achievable potential.	▪ Fund the preparation of more comprehensive resource assessments for these technologies	✓	✓			

3.4 Government Strategy for the Renewable Energy Sector

The Government's renewable energy strategy is driven by the overarching goals of improving energy security, ensuring affordable energy supply, and maximizing the use of Armenia's indigenous energy resources. As described in Section 2.1, several key strategic documents—the 2013 National Energy Security Concept, the Armenian Development Strategy, and the National Security Strategy—specifically call for the development of indigenous renewable energy resources.

In the past few years the Government has acted on its commitment to deploy renewable energy technologies by implementing the Feed-In Tariff for certain technologies: wind, biomass, and hydropower. The Government has also undertaken regulatory reforms and amendments to tax laws that have streamlined the renewable energy project development process. For instance, in recognition of the fact that Water Use Permits and PSRC operating licenses had different durations and this was causing uncertainty among developers, a process has been created to obtain a Water Use Permit with the same duration as the PSRC permit.[30] The Government also enables wind energy developers to postpone VAT payments for imported equipment for three years.[31]

Table 3.5 shows Government's targets for various renewable energy technologies. Excluding output from the large hydroelectric plants, renewable energy generation represented roughly 6 percent of total generation in 2012. Government's target is for such generation to represent 21 percent of total generation by 2020, and 26 percent by 2025. The Government also plans to significantly increase the penetration of geothermal heat pumps and solar thermal. Currently, output of installed geothermal heating and solar thermal capacity is around 2 GWht/year.

Table 3.5: Renewable Energy Generation Capacity and Production Targets 2020-2025[32]

	Capacity installed (MW)		Generation (GWh)	
Electricity	**2020**	**2025**	**2020**	**2025**
Small Hydro	377	397	1,049	1,106
Wind	50	100	117	232
Geothermal	50	100	373	745
PV	40	80	88	176
Total	492	677	1,627	2,259
Heating	**2020**	**2025**	**2020**	**2025**
Geothermal heat pumps	12	25	16	33
Solar thermal	10	20	13	25

[30] USAID, "Small Hydropower Sector Framework, Status, Development Barriers and Future Development 2012 Update," March 2012

[31] USAID, "Wind Energy Development in Armenia: Legal, Regulatory, Tax and Customs Regulations," April 2010

[32] Excludes generation from the large hydro cascades.

The targets shown in Table 3.5 update the 2011 Renewable Energy Roadmap for Armenia, developed in cooperation with R2E2, with the support of the Global Environmental Facility (GEF) and the World Bank. Targets have been updated in this IP because a number of factors, global and local to Armenia, have changed since the development of the Roadmap. There is, for example, more information now about the solar, geothermal, and wind resources in Armenia than there was when the Roadmap was produced. Wind resources, in particular, have shown to have lower capacity factors the previously thought, making them more expensive on a levelized energy cost (LEC) basis. Solar PV has, in contrast become more attractive. The capital costs of utility-scale solar PV projects have declined substantially over the past few years, shifting more of the technically viable solar potential toward financial viability. As a consequence, Government's priorities in the years to come are likely to shift away from wind and toward solar PV.

3.5 Role of the Private Sector

Armenia has been successful in attracting substantial private sector participation in the renewable energy sector. For renewable energy projects, this participation has primarily been through small hydropower projects. However, there are also a number of private companies that manufacture and install solar thermal heaters, geothermal heating and cooling equipment and distributed solar PV in Armenia.

There are also several examples of successful private sector participation in non-hydropower renewable energy projects. The Lusakert biogas plant was developed by a consortium of organizations, some of which were private Armenian companies. The methane capture and flare gas plant at the Nubarashen landfill was funded by foreign donors, but it is currently operated by an Armenian company. A number of small solar thermal hot water and solar PV projects have been developed by private companies in Armenia over the years. Recently, a private company developed an 860 kW geothermal heat pump system in a large commercial building on Northern Avenue in Yerevan.

A number of commercial banks support renewable energy projects in Armenia by providing loans to project developers. As mentioned above, the lack of long-term financing at attractive interest rates is one major barrier to the development of privately-owned renewable energy projects in Armenia and the expansion of existing financing programs for renewable energy would encourage growth in the sector.

3.6 On-going and Planned Investments by Development Partners

Several multilateral and bilateral donors are actively involved in promoting renewable energy in Armenia. The following subsections describe these donors and their areas of involvement.

European Bank for Reconstruction and Development (EBRD)

EBRD is actively involved in Armenia's energy sector promoting energy efficiency and renewable energy. Current and recent activities include:

- **Rehabilitation of Sevan-Hrazdan HPP**. EBRD is co-financing the rehabilitation of the Sevan-Hrazdan cascade with ADB's PSOD.
- **Development of small hydropower plants (HPPs)**. EBRD provided US$7 million to Cascade Bank (now Ameria Bank) for on-lending to Armenian companies

developing SHPPs under the Renewable Energy Project. These funds, combined with a World Bank loan of US$5 million, US$3 million equity investment from a private investor, and US$13 million co-financing from project developers, which enabled to develop 25 SHPPs with total installed capacity of 45 MW.[33] The Renewable Energy Project included also US$3 million GEF grant to help create a better enabling environment for development of renewable energy. Specifically, the GEF grant helped to: (a) improve the regulatory environment for renewables; (b) develop and adopt technical standards for renewable energy and regulations for dispatching and load-regulation of grid-connected renewable energy plants; and (c) remove information barriers to investments in renewable energy, including creation of GIS database of RE resources, SHPP scheme, feasibility studies and resource assessments (e.g. competitive advantage of Armenia in solar PV value chain, assessment of technical and economic viability of biofuels, etc.).

- **Caucasus Energy Efficiency Program (CEEP).** The CEEP seeks to increase financial intermediation and financing for rational energy utilization, provide benefits in terms of energy resource utilization and assist in mitigating increasing energy prices and high energy intensity in Armenia. EBRD extends loans to local commercial banks for sub-lending to industrial companies for energy efficiency and rational energy utilization investments which include geothermal heat pumps and solar water heaters. Loans will be extended to residential customers on a demand-driven basis. The Project also includes grant funding to engage consultants in order to prepare energy audits, review investment proposals, support companies in securing funding from PBs and implementation support.
- **Eastern Europe Energy Efficiency and Environment Partnership (E5P).** Armenia recently joined E5P, a multi-donor fund managed by EBRD to improve energy efficiency and environmental protection in the Eastern Partnership region. Armenia plans to scale up ongoing energy efficiency program to invest additional $20 million (from E5P) in energy efficiency EBRD. The E5P funding is expected to become available to Armenia in 2016.
- **Regulatory support to promote renewable energy.** EBRD provided technical support to the PSRC on feed-in tariffs (FiT) and third party access (TPA) regulations.

KfW

KfW's engagement in Armenia's energy sector currently focuses on developing and maintaining renewable energy resources and financing transmission investments to support regional cooperation. Specific areas of recent and potential investment in the field of renewable energy include:

- **Construction and rehabilitation of SHPPs**. KfW provides financing and advisory support for construction and rehabilitation of privately-owned SHPPs. Under Phase 1, KfW supported 14 SHPPs through several commercial banks. Phase 2, currently under implementation, is expected to finance up to 20 SHPPs with a total capacity of 45 MW. Phase 3, currently in the planning stage, will include up to EUR 40 million in financing and may be expanded to cover financing for wind projects.

World Bank/International Finance Corporation (IFC)

- The World Bank Group has two decades of engagement in supporting power sector reforms and clean energy development in Armenia. The World Bank's and IFC's recent engagements in Armenia's energy sector have focused on development of renewable energy resources and promoting energy efficiency through rehabilitation of transmission infrastructure and, more recently, demand-side efficiency measures. As mentioned above, IFC provided US$15 million to Ameriabank CJSC, resulting in the development of 12 SHPPs with over 40 MW capacity. More recently, the World Bank provided a US$ 1.5 million to fund technical field investigation studies for potential geothermal sites in Armenia.

Global Environment Facility (GEF)

The GEF's Small Grants Program (SGP) provided grants for two solar thermal heating projects in the Shirak region of Armenia.

- **Solar Thermal Heating System in a Housing Development.** In 2010, the GEF provided a grant for US$30,970 to complete energy efficiency upgrades and the installation of a solar thermal heating system at a housing development. In the first winter of its implementation the project reduced natural gas consumption by 40 percent.
- **Solar Thermal Heating System in a Kindergarten.** Starting in 2013, the GEF provided a grant for US$33,920 to develop a multi-purpose solar thermal hot water system to provide heated water to a kindergarten. As part of the project a solar thermal heating system will be installed at a greenhouse next to the building. The intention is that this project will serve as a demonstration of the potential for using solar thermal technologies to heat greenhouses.

4 Prioritization of Renewable Energy Technologies

The Government of Armenia, led by the MENR and supported by the MDBs, has identified four areas for strategic investment that would lead to scale-up.

The areas were identified through a participatory process involving a wide range of government agencies, non-governmental organizations, academic institutions, and the private sector. The participatory process included many one-on-one meetings, a workshop with the Government's SREP working group, as well as an open forum.

The subset of "technically viable" resources was selected from those described in Section 3. These were geothermal and solar thermal heating, utility-scale solar PV, geothermal power, small HPPs, agricultural biogas, landfill gas, wind and distributed PV. These resources were evaluated against five criteria on a scale of 1 to 4, with 1 indicating that the resource met the criteria best of all resources and 4 indicating that it met the criteria worst of all resources. The five criteria reflect the Government's strategic objectives, and the clear recognition that SREP funding should be used to have a transformative impact on the renewable energy sub-sector.

The criteria considered were:

- **Potential for scale-up of the technology.** The amount of developable resource potential relative to the other technologies, as measured by production potential (GWh). Resources with higher production potential were given higher priority.
- **Market maturity/immaturity.** The extent to which the technology is used or the resource is already exploited in Armenia, or there is financing already available from other donor programs. Resources or technologies which are already well-known and well-developed in Armenia (such as small hydropower generation), were given lower priority because they already had sufficient support or private sector interest. Resources or technologies which already have financing available through other donor programs (such as geothermal heat pumps, solar thermal heating and rooftop solar PV) were also given lower priority because there is already financing available through other MDB programs (such as financing available through local banks from EBRD and IFC).
- **Cost-effectiveness.** The cost of the electricity or heat generated by the technology, as measured by the levelized energy cost (LEC).[34]
- **Potential for job-creation.** The extent to which use of a technology or exploitation of a resource creates jobs.
- **Effect on power grid stability.** The extent to which certain technologies had a negative or positive impact on system operation and dispatch. Technologies with no impact, or a positive impact on grid stability were prioritized over those with a negative impact.

Table 4.1 shows the quantitative rankings assigned to each technology under each criterion. The rankings were used as a rough guide for discussion only, using the assumption that each criterion had an equal weight. Ultimately, some of the highest-

[34] The LEC is the present value of capital and operating costs for each technology, on a kWh basis.

ranking resources (geothermal heat pumps and solar thermal, for example) were rejected because stakeholders recognized that substantial financing for such technologies already existed under MDB-financed programs or because (as is the case for SHPPs) substantial private sector activity already exists).

Table 4.1: Ranking of Renewable Technologies Against Selection Criteria

Technology	**Selection Criteria***					
	Power grid stability	Cost-effectiveness	Potential for job creation	Scale-up potential**	Market immaturity	Average score
Geothermal heat pumps	2	1	1	1	2	**1.4**
Utility-scale solar PV	3	2	2	2	1	**2.0**
Geothermal power	2	2	2	3	1	**2.0**
Solar thermal heating	2	3	1	2	2	**2.0**
Small HPPs	1	1	2	3	3	**2.0**
Ag. biogas	2	1	3	4	1	**2.2**
Landfill biogas	2	1	3	4	1	**2.2**
Wind	2	2	3	3	1	**2.2**
Distributed solar PV	3	4	1	2	1	**2.2**

* A lower score indicates that a technology is determined to be *more* suitable for SREP funding according to the chosen selection criteria. A score of 1 indicates that a technology meets the criteria very well, and a score of 4 indicates that a technology meets the criteria worst of all technologies.

** Technologies were put scored on scale-up potential as follows: 10,000+ GWh/yr = 1, 1,000-10,000 GWh/yr = 2, less than 1,000 GWh/yr = 3, less than 100 GWh/yr = 4

Three investment priorities emerged from the analyses and discussions with stakeholders. These were: (1) geothermal power, 2) utility-scale PV and 3) geothermal heat pumps and solar heating. Table 4.2 provides brief explanations for why each technology received a particular ranking on each criterion.

Table 4.2: Ranking of Renewable Technologies Against Selection Criteria

Technology	Selection Criteria				
	Power grid stability	Cost-effectiveness	Potential for job creation	Scale-up potential	Market immaturity
Geothermal heat pumps	Can consume energy at peak times with pumps	One of the lowest cost of those assessed	Potential for creation of an entire industry	Very large	Somewhat mature. Only one commercial-scale geothermal heating facility exists in Armenia, but financing for such projects has become available through local banks under existing EBRD CEEP
Solar thermal heating	Can consume energy at peak times with pumps	Relatively high-cost	Potential for creation of an entire industry	Large	Somewhat mature. There are a few operating STH facilities in Armenia, and some financing is available through local banks under existing EBRD CEEP
Utility-scale solar PV	Can be used during daytime hours to preserve stored hydropower for evening and morning peaks	Moderate cost	Potential for creation of an entire industry	Large	Very immature. No utility-scale solar PV plants operate in Armenia
Geothermal power	Provides stable, base-load power	Very low cost if resource is high-temperature	Not labor intensive, low potential	Currently small; however several sites warrantee further exploration	Very immature. No geothermal power plants operate in Armenia
Small HPPs	Provides diurnally stable, but seasonally variable power	Very low cost	Labor intensive, but low potential	Many of the best sites have already been developed, so	Very mature. Most widespread renewable energy technology deployed to date

Technology	Selection Criteria				
	Power grid stability	Cost-effectiveness	Potential for job creation	Scale-up potential	Market immaturity
				potential is small	
Ag. biogas	Provides stable, base-load power	Very low cost	Labor intensive, but low potential	Very small	Immature. Only one commercial-scale facility exists.
Landfill biogas	Provides stable, base-load power	Lowest cost technology assessed	Labor intensive, but low potential	Very small	Very immature. No LFG power plants operate in Armenia
Wind	A variable generation resource, therefore, it must be managed	Moderate cost	Not labor intensive, moderate potential	Moderate	Immature. Only one commercial-scale facility exists
Distributed solar PV	A variable generation resource, therefore it must be managed	Very high cost	Potential for creation of an entire industry	Large	Somewhat mature. Just a few small installations, but financing is available through local banks under existing EBRD and IFC-financed programs.

5 Program Description

The prioritization exercise described in Section 4 has led to the selection of three focus areas: geothermal power, utility-scale solar PV, and geothermal and solar thermal heating. In order to overcome existing barriers to renewable energy deployment and to catalyze future investment and scale-up of the selected technologies in Armenia, the SREP investment program is built around the following five objectives:

1. Provide the Armenian renewable energy industry with a "window of opportunity" during which renewable energy project costs can be reduced through first-projects without significantly affecting the affordability of energy to consumers. This will enable future projects to be developed at lower cost without donor support.
2. Build capacity among local banks to finance renewable energy technologies and develop their abilities to do this in the future.
3. Build capacity among local industry to procure, deploy and make equity investments in renewable energy technologies.
4. Build public confidence in renewable energy technologies to create market demand
5. Encourage further reforms among regulatory agencies to support renewable energy scale-up after SREP funding/donor financing is gone.

This section describes the proposed projects, the transformational impact of each project, the activities envisioned for each, and the expected co-benefits and environmental and social risks associated with each technology.

Program Objective

The objective of the SREP Armenia IP is to catalyze private investment in technologies which, for lack of experience, high capital costs and a variety of other reasons, have not previously been considered as options in the country. SREP funds will be used to do first-projects in utility-scale geothermal power and utility-scale solar PV, and foster more widespread investment in geothermal heat pumps and solar thermal heating. In the process of developing these projects, local capacity will be built in the financial and project development communities that will be crucial for the scale-up of these technologies after SREP and donor funding is expended. Furthermore, the demonstration effect of these projects will serve to educate consumers on the benefits of renewable energy technologies.

SREP support can help gradually introduce solar PV, geothermal power and renewable heating technologies to Armenia as follows:

- By absorbing some of the project development risk on geothermal power, by subsidizing exploratory wells.
- By helping the country's first utility-scale solar PV project or set of projects to attract private investors while minimizing the tariff-impact.

- Increasing existing financing for industrial, commercial and residential customers to invest in geothermal heat pump and solar thermal heating until E5P funds become available in 2016.

Expected Outcomes

The main results expected from the SREP Armenia IP are as follows:

- Better security of supply and reliability by increasing the proportion of domestic renewable energy in the energy mix
- The creation of a utility-scale solar sector and geothermal power sector attractive to private investors.
- Develop the first utility-scale solar PV projects, which through gradual tariff increases (as the tariff levels in the country gradually increase to reflect long-run supply costs) will eventually become commercially viable without SREP/MDB support. These first projects will be so small as to have only a very minor impact on the overall cost of generation in Armenia, but could have a catalytic effect on the market for solar PV through:
  - Lower solar installation costs that will result as a domestic industry develops around it;
  - Lower financing costs as lenders become more comfortable with the technology; and
  - Potential further reductions in the global costs of PV panels.

  The foreseen increase in thermal generation costs in Armenia will move solar toward financial viability. Armenia's new thermal plants will require substantially higher tariffs than many of the existing plants, because they are fully (or near fully) depreciated and no longer recover depreciation charges. Moreover, existing plants do not require debt service through their generation tariffs, whereas new plants will require such provision.
- Contribution to reduction of impending supply capacity gap to meet forecast demand. As noted above, Armenia will need roughly 1,100 MW of new capacity by 2030.
- Improvement to the enabling environment for renewable energy technologies. The first utility-scale solar PV and geothermal projects will provide an opportunity for PSRC to streamline administrative procedures and fiscal policies to encourage investment in a wider range of renewable energy technologies.
- Empower Armenian energy users to realize the economic benefits of switching from electricity and natural gas to geothermal heat pumps and solar thermal heating technologies for heating and cooling.
- Creation of jobs related to the construction/installation, operation and maintenance of renewable technologies. Education of the workforce in the deployment of these technologies. An indication of possible job creation in Armenia is provided in Annex D.

- Promotion of local R&D in a technology which has traditionally been a focus of researchers and academicians in Armenia
- Reduced greenhouse gas (GHG) emissions as compared to the business-as-usual scenario, under which Armenia will likely continue to expand the use of natural gas for power generation and heating.

The details of the three projects to be carried out are described in more detail below.

5.1 Geothermal Power Exploration and Development

SREP resources would be used for further exploration of Armenia's most promising geothermal site - Karkar. Prior studies suggest the existence of a geothermal resource at the site, but it is necessary to carry out exploratory drilling to confirm the availability and quality of the potential geothermal resource for power generation. The typical signs of a high temperature geothermal area are not present on the surface, however, the very low resistivity anomaly in the layer between 500-1,000 meters is an indication of a possible high temperature hydrothermal alteration. The real nature of the resource, whether high, low or intermediate temperature and its potential for power generation can only be confirmed through exploratory drillings.

By using SREP support for this activity, the Government can help reduce the risk of developing the site for the private sector. If a geothermal resource exists at the site, this support can help make geothermal power a financially attractive investment for private investors and an affordable source of electricity for Armenia's grid.

The support can also serve to demonstrate the feasibility of geothermal power in Armenia. A first successful project can build domestic capacity in the development of additional geothermal resources in Armenia at Armenia's other prospective geothermal sites. It will also build investor confidence that geothermal is a viable and profitable investment opportunity in Armenia.

5.1.1 Priority activities

The geothermal power project would include the following activities:

- **Exploratory Drilling at Karkar Geothermal Site.** This step requires carrying out exploratory drilling at the site to determine whether or not power could be produced from the resource.
- **Feasibility Study for Karkar site.** If the presence of a resource is confirmed, a full feasibility study will need to be prepared to recommend the type of geothermal technology/plant to be constructed, reassess the economic and financial viability, compliance with environmental and social safeguards, and to complete legal and regulatory due diligence. The legal and regulatory due diligence will include recommendations on the need for a feed-in tariff specific to geothermal or a recommended structure and method for procuring as a public private partnership in a way that determines the tariff through bidding (for example, a reverse auction). It will also be necessary to evaluate the potential for grid interconnection at the chosen site, and whether or not grid upgrades will be necessary for the potential geothermal power plant to be connected to the grid.

- **Transaction Advisory Services.** The Government would procure the project as a Public Private Partnership (PPP). Therefore, advisory services will be needed to help structure the PPP (for example, as a Build-Operate-Transfer or Build-Own-Operate contract) and procure a private investor and operator. The exact commercial arrangement will need to be developed through further consultation within government, with donor partners, and with potential investors. However, the arrangement currently envisaged would involve a private operator having a BOT or BOO agreement under which they finance, build and operate the power plant and have a power purchase agreement with the distribution company. The Government would own the steam fields, thereby taking risk on the resource availability.
- **Development of Geothermal Power Plant.** As noted above, it is expected that the private sector will make the capital investment required for generation of electricity (the power plant itself). This investment plan assumes a plant with installed capacity of 28.5 MW, based on the average size of geothermal plants elsewhere. The actual size of the plant will depend on the resource potential identified in earlier activities.

5.1.2 Parallel activities to be funded by other parties

It is expected that the World Bank (IBRD), ADB or the commercial lenders within the MDBs (IFC in the World Bank Group, PSOD at ADB, or EBRD) as well as other commercial financial institutions may be able to finance some of the capital costs of the project as a way of making it more attractive to private investors.

The Government contributions may include, for example, land or co-financing of taxes. The MDB support may also include concessional lending to the Government for the transmission lines, or other infrastructure required at the site.

5.1.3 Environmental, social and gender co-benefits

The development of a geothermal power project at the Karkar site in Armenia would have a number of environmental, social and gender co-benefits. These are likely to be somewhat similar to the co-benefits of most of other renewable power generation technologies, with some important exceptions. For instance, geothermal power provides base load generation, which does not require as much “back up” generation as variable renewable energy sources.

The geothermal project is expected to create the following environmental, social and gender co-benefits:

- **Minimized land-use for energy generation.** Compared with other renewable energy generating technologies, such as solar and wind, geothermal power uses a relatively small land area.
- **Reduction of pollutant emissions.** A geothermal power plant has the potential to reduce greenhouse gas as well as local particulate matter emissions from gas-fired power generation in Armenia. Although the majority of Armenia’s energy generation is from nuclear and hydropower sources, there is still the potential to reduce greenhouse gas emissions from Armenia’s operating natural gas-fired power plants by offsetting their generation with energy from a geothermal power plant.

- **Job creation.** Potential short-term job creation during exploration of the geothermal site. Potential for both short and long-term job creation during the development and operations of a geothermal plant. Given the remote location of the Karkar site, the project could help reduce rural unemployment in the surrounding areas.
- **Targeted job creation for women.** Potential for operational agreements for the renewable energy projects to target the encouragement of jobs for women. For example, the concession contract with the private operator could include set-asides for women to make up a certain percentage of local staff.
- **Energy security.** By replacing existing electricity generation resources, a large portion of which relies on imported fuel that is subject to price fluctuation, geothermal power could act as a hedge against future natural gas and uranium price increases. This could help minimize the effect of these price fluctuations on domestic electricity tariffs and, thereby, help keep electricity service affordable for all consumers.

5.1.4 Environmental and social risks

The development of a utility-scale geothermal project at the Karkar site in Armenia is expected to have relatively limited environmental and social risks, especially compared with conventional and even other renewable energy technologies. However, significant gaps exist in the environmental and social risk analyses that have been conducted to date and the site should be studied in greater detail before the project implementation. Having said that, a preliminary review of available data related to the potential site and an analysis of the generic risks that face this type of project development suggest that the project will have relatively limited negative environmental and social risks. The impacts of this project are expected to be akin to those from any other large infrastructure project that takes place in a rural area, although with some notable exceptions. Specifically, the geothermal project is expected to face the following environmental and social risks:

- **Environmental risks**
  - Land subsidence (compaction of rock due to the withdrawal of groundwater).
  - Increased micro-seismic activity near the local area, including increased risk of landslides though excavations for geothermal well and laying of associated infrastructure and transmission networks.
  - Altered groundwater recharge/extraction regime if groundwater is used for energy generation (such as for steam generation or emissions cleaning) and is not later returned to the aquifer.
  - Water use during operations, which causes surface water abstraction, run-off and discharge leading to localized changes in river flows and morphology.
  - The potential for localized geological damage though excavations for geothermal well and laying of associated infrastructure and transmission networks.

– During the construction stage, the project is expected to produce emissions due to material transportation and on-site plant movements (e.g. vehicle emissions, particulate matter and dust).

– Construction activities have the potential for causing soil erosion and compaction. Localized erosion, compaction, salinization, sealing and/or contamination from site alteration and project activities could wash away fines and change the soil's properties. Furthermore, excavations for land-grading and foundations could mobilize previously contaminated soils.

– Localized land-take from footprint of energy generation infrastructure. This could have footprint impacts upon species due to construction of power plant and related infrastructure.

– Transformation of landscape.

- **Social risks**

  – Lack of a local workforce with the knowledge and skills capable to operate and maintain the plants. This might mean that it is necessary to import labor to the region to develop and operate the plant.

  – Impacts to traffic patterns during construction and operation (not expected near the site, as there is limited road infrastructure, but rather expected on the way to the site).

5.2 Utility-Scale Solar PV Project Development

SREP resources would be used to finance the development of 40-50 MW of utility-scale solar PV. The rapid decline in solar PV costs in recent years has made utility-scale solar PV more affordable and more competitive with the other power generation options available to Armenia. SREP support would help catalyze private investment in a first new plant (or plants), and show the potential for deploying solar PV on a commercial basis. Given recent trends in solar PV costs, solar PV is expected to become even more cost-competitive in Armenia and a demonstration project would enable the country to take advantage of this technology in the future when it becomes more cost-competitive with other technologies. SREP funds would be used in much the same way that MDB funds were used to successfully jump-start the small hydropower industry in Armenia nearly a decade ago.

5.2.1 Priority activities

The utility-scale solar PV project would include the following activities:

- **Project preparation, feasibility studies, site measurement and monitoring.** SREP grant funds would first be used to fund more detailed resource assessments, and identification of possible sites and possible projects. As described in Section 3.3, relatively coarse resolution solar data are publicly available for Armenia. Given the nature of solar energy resources, these coarse data are generally acceptable for understanding the nature of the resource and conducting a high-level financial analysis. However, a feasibility study will be needed to characterize the solar resource potential in the areas targeted for solar development in more detail. Furthermore, it will be necessary to evaluate the potential for grid interconnection at the chosen site, and whether or not grid upgrades will be necessary before the project is interconnected. As for the geothermal power project, the feasibility study will also reaffirm the economic and financial viability, compliance with environmental and social safeguards, and to complete legal and regulatory due diligence.

- **Transaction advisory.** Transaction advisors would be hired to help government tender for the projects identified in the feasibility studies. Private operators would be procured through competitive tender. Bidders would be selected based on technical and financial criteria, the financial criteria being the level of tariff required or, alternatively, the level of concessional support required.[35] Developers offering lower tariffs or requiring less concessional support would receive higher scores.
- **Investment in 40-50 MW project or projects.** Government would on-lend SREP funds at concessional rates to private operators bidding on the projects being tendered. The private operators would contribute equity and also source loans from commercial banks and from the commercial lending arms of the MDBs. Government estimates that, given current capital costs for utility-scale solar PV, SREP funds could be used with these other sources of financing to support roughly 40-50 MW of solar. As noted in Section 3, initial studies indicate that Gegharkunik Marz has some of the highest solar PV potential in Armenia, and would be considered as a first potential area for development. This could be a single plant, or several plants with a total capacity of 40-50 MW, as development of solar is often more effective if there are multiple sites, in areas with different solar profiles (to provide more stability by diversifying generation profiles).

5.2.2 Parallel activities to be funded by other donors

As noted above, it is foreseen that, in addition to SREP support, the commercial lending arms of the MDBs will be willing to provide co-financing for the solar projects.

As for the geothermal power project, Government can also be expected to contribute in ways that reduce the overall capital expenditure required for the project (by providing land, for example or waivers of taxes).

5.2.3 Environmental, social and gender co-benefits

The development of a utility-scale solar PV project could have a number of environmental, social and gender co-benefits. These are likely to be somewhat similar to the co-benefits of other renewable power generation technologies. The solar PV project is expected to create the following social, environmental and gender co-benefits:

- **Reduction of pollutant emissions.** A solar PV plant has the potential to reduce greenhouse gas as well as local particulate matter emissions from gas-fired power generation in Armenia. Although the majority of Armenia's energy generation is from nuclear and hydropower sources, there is still the potential

[35] Bidders will be offered, as part of the conditions of tender, access to SREP capital contributions.

to reduce greenhouse gas emissions from Armenia's operating natural gas-fired power plants by offsetting their generation with energy from a solar PV power plant. Solar PV plants generate most of their energy during the middle of the day, during some of the higher hours of energy consumption in Armenia. Solar PV could be used to offset the need to dispatch hydropower, saving hydropower generation to serve peaks in the mornings and evenings when otherwise more expensive thermal plants would be needed.

- **Job creation.** Potential short-term job creation during the development and operations of the plant. More importantly, there is considerably research and development (R&D) and interest in solar PV within Armenia's academic institutions. A solar PV project could catalyze further research and development and facilitate the transfer of capacity for manufacturing, installation and operation to the local market.
- **Targeted job creation for women.** Potential for operational agreements for the renewable energy projects to target the encouragement of jobs for women.
- **Energy security.** By replacing existing electricity generation resources, much of which relies on imported fuel that is subject to uncontrollable price fluctuation, solar power could act as a hedge against future natural gas and uranium price increases. This could help minimize the effect of these price fluctuations on energy tariffs and thereby help keep electricity service affordable for all consumers.
- **Reduced water resource use.** Solar PV does not require cooling water, which is required for most combustion-based energy sources including thermal plants. Unlike hydropower resources, solar PV does not divert or interrupt the flow of natural water courses. In general, development of solar PV will result in less disturbance and consumption of Armenia's water resources than most other energy technologies currently used in Armenia, and some other renewable energy technologies.

5.2.4 Environmental and social risks

The development of a utility-scale solar PV plant in Armenia is expected to have relatively limited environmental and social risks, especially compared to conventional power generation technologies. For instance, the utility-scale solar PV projects are expected to have negligible emissions compared with fossil-fuel-based generation. However, there are no site-specific feasibility studies or other documents that could have been drawn up on to provide a more detailed description of environmental and social impacts of potential solar PV project. A detailed environmental and social impact assessment, including mitigation measures, will be conducted as part of the preparation of each site-specific project.

Many of the environmental and social risks expected to arise from this project are site-specific. But, unlike the geothermal project, the site for this project has not yet been chosen. The fact that large swaths of Armenia's land have reasonably high-quality solar energy resources suggests that there are many locations where this project could be implemented, and therefore it is expected that at least some of the environmental and social risks detailed here could be avoided by choosing a site where these risks would be minimized. Based on an analysis of the generic risks that are typically related to this type of projects, the solar PV project is expected to face the following environmental and social risks:

- **Environmental risks**
  - Construction-stage air emissions due to material transportation and on-site plant movements (e.g. vehicle emissions, particulate matter and dust).
  - Vegetation clearance during construction and placement of generating equipment and ancillary facilities in floodplains could increase catchment flooding potential.
  - Impacts from construction of power transmission lines to evacuate electricity generated by solar PV plants.
  - Footprint/land-take for solar generation infrastructure. Limited habitat re-growth potential due to presence of PVs. Fragmentation of ecosystems from footprint, access roads and transmission networks.
  - Disturbance of habitat during construction. Land-take footprint impacts upon terrestrial species.
  - Disposal of obsolete solar PV modules upon their decommissioning is a significant environmental issue, largely due to the presence of toxic chemicals in the discarded modules. Recycling methods for PV panels are in place within the industry and further developments are planned for future PV panels. However, if the used PV panels are not appropriately handled or recycled, then their disposal could cause environmental pollution with toxic waste and become a considerable risk in Armenia.
- **Social risks**
  - Given that solar PV is a new technology in Armenia, it is possible that there will be a lack of local labor supply to deploy the technology, and workers and supplies might need to be imported to the project site from outside Armenia. If this happens, this would minimize the economic and employment benefits of deploying this technology.
  - Solar PV plants have a large footprint relative to the amount of energy they generate. Thus, the deployment of a large-scale solar plant will impact landscapes over large areas. Local impacts on landscape character and visual amenity might also be associated with ancillary development (buildings and pylons). This might affect property values if the plant is built near populated areas, or might have visual and land access impact on recreational activities such as hiking, eco-tourism, fishing and hunting. Impacts to landscape character might also lead to the loss of aesthetic value for areas with tourism potential and cause associated impacts on local tourism services.
  - Potential disruption due to noise and dust during construction, such as operational noise and vibration.

- If the plant is built in an area where there is the potential for other land uses such as mineral extraction, agriculture, or industry, then these alternative land uses will not be able to occur or will need to be delayed because of the presence of the solar facility.
- Transportation of people and equipment might impact traffic patterns during construction near the project site.

5.3 Development of Geothermal Heat Pump and Solar-Thermal Projects

Substantial solar thermal and geothermal heat resource potential exists in Armenia, but the use of these technologies is not yet widespread. The financing to deploy these capital-intensive technologies has just become available. Absence of long-term and low-cost capital for such projects is cited by Armenian geothermal heating companies as one of the main barriers to the technology's deployment. Existing facilities that are currently lending for geothermal heat pumps and solar water heaters through commercial banks can be expanded to ensure sufficient financing for investments until E5P funds become available in 2016.

5.3.1 Priority activities

The geothermal heat pump and solar thermal project will be folded into the existing EBRD CEEP program. Under this program, EBRD extends loans to local commercial banks for sub-lending to industrial companies and residential users for energy efficiency and rational energy utilization, which include geothermal heat pumps and solar water heaters. Loans will also be extended on demand-drive basis:

Examples of renewable energy projects under CEEP include:

- Wind farms
- Run-of-river hydro or small hydro power Sub-projects
- Solar water systems generating hot water for processes and/or heating
- Biomass systems generating heat only or heat and electricity
- Gas engines using biogas
- Diesel engines using biodiesel
- Geothermal heat pumps

The EBRD program also includes grant funding to engage consultants in order to prepare energy audits, review investment proposals, support companies in securing funding from PBs and implementation support.

5.3.2 Parallel activities to be funded by other donors

Use of $3 million of SREP funds will help to increase the size of CEEP, while ensuring sufficient financing for geothermal heat pumps and solar water heaters until the $20 million of E5P funds become available by 2016. Use of credit lines through local banks will create an effective financing mechanism with good technical support. The technical assistance component, financed by EBRD, will ensure the pursuit of good lending opportunities that are well assessed.

5.3.3 Environmental, social and gender co-benefits

The development of geothermal heat pump and solar thermal heating projects in Armenia would have a number of environmental, social and gender co-benefits. If deployed on a large-scale, these technologies could have very significant co-benefits. For instance, because geothermal and solar thermal technologies tend to be deployed in smaller and more distributed implementations than utility-scale power generation technologies, these technologies tend to be more labor-intensive per unit of installed capacity. Therefore, these technologies could have a greater potential for job creation. Specifically, geothermal heat pump and solar thermal heating projects are expected to create the following social, environmental and gender co-benefits:

- **Potential for improvements in domestic air quality.** The deployment of renewable energy alternatives may offset the need to use wood for heating.
- **Stabilization of energy prices for consumers.** By providing a new source of heat energy for domestic consumption, these technologies can help stabilize energy prices for consumers. This can reduce energy poverty for households, which currently cannot afford sufficient heating and it can reduce poverty for households who spend a large portion of their income on heating.
- **Job creation and industrial development**. These technologies will create short-term and potentially long-term jobs in project installation and operations (jobs for operations are only expected for larger systems). Given the size of the resource potential and the relative labor-intensity of these technologies, it is possible that an entire industry will be developed around the installation of these technologies and create many jobs. Also, some components of geothermal heating and solar thermal systems can be manufactured in Armenia. A large domestic market for these technologies could encourage the development of a domestic manufacturing industry for renewable heating technologies.

5.3.4 Environmental and social risks

Distributed renewable energy technologies are anticipated to have inherently smaller-scale environmental and social risks and opportunities than utility-scale technologies, as individual installations of these technologies are relatively small-scale. However, the cumulative environmental and social risks and opportunities of deploying these technologies as part of a strategy can still be significant due to the large number of units constructed. The environmental and social risks facing these technologies are as follows:

- **Environmental risks**
  - Construction-stage emissions due to material transportation and on-site plant movements (e.g. vehicle emissions, particulate matter and dust).
  - Localized geological damage though excavations for geothermal infrastructure (geothermal heat pumps only).
  - Excavations for geothermal infrastructure could mobilize previously contaminated soils (geothermal heat pumps only).

- Risk of groundwater contamination during drilling for geothermal energy generation (geothermal heat pumps only).
- Risks posed by new land-take for multiple well-sites – including, for example, the loss of existing land uses and risks to flora and fauna. (geothermal heat pumps only).

▪ **Social risks**

- The risk of nuisance during construction/installation (such as noise, dust and impacts on traffic flows) resulting in temporary disturbance to the local community and visitors.
- The risk of adverse visual impacts resulting from the presence of the solar thermal systems on buildings – this is likely to be minor and may only be of particular significance when on historic buildings or in areas of historic landscape importance (solar thermal hot water heating only).

6 Financing Plan and Instruments

Table 6.1 presents a plan for financing the projects described in Section 5. It shows the proposed credits and grants from SREP as well as estimates of the amounts anticipated from MDBs and the private sector.

As the table shows, roughly US$40 million of SREP funding is expected to catalyze roughly 5.5 times as much investment, most of it from the private sector (as equity or debt), and the commercial lending windows of the MDBs.

The financing modalities will be determined at the time of appraisal, but it is expected that:

- The geothermal exploratory drilling project will be funded through: (i) an SREP grant to government, or (ii) a guarantee to private sector entities, which might want to undertake the drilling as part of early site development. If suitable resource potential is found, the site would be financed by a private sector developer whose remuneration would be based on a feed-in-tariff or on the terms of a power purchase agreement. It is assumed that the private sector would use a mix of debt and equity for the investment.
- For the utility-scale solar project, it is foreseen that Government would on-lend SREP funds at concessional rates to private operators bidding on the projects being tendered. A reverse auction would be used to tender for bidders.[36] The private operators would contribute equity and also source loans from commercial banks and from the commercial lending arms of the MDBs. Government estimates that, given current capital costs for utility-scale solar PV, SREP funds could be used with these other sources of financing to support roughly 40-50 MW of solar.
- The geothermal heat pump and solar thermal heating project will be included under EBRD's existing Caucasus Energy Efficiency Program (CEEP), which extends loans to local commercial banks for sub-lending to industrial and residential sectors for energy efficiency and rational energy utilization investments. Loans will also be extended on demand-driven basis. The Program includes grant funding to engage consultants in order to prepare energy audits, review investment proposals, support companies in securing funding from PBs and implementation support.

[36] In a reverse auction, the lowest tariff bid or lowest required subsidy bid (if the tariff does not recover the full cost of service) is the principal deciding factor in selecting the winning bidder.

Table 6.1: Financing Plan

SREP Project	SREP	Responsible MDB	Government of Armenia	MDBs	Private Sector (Equity)	Commercial/ Private arms of MDBs	Total
Geothermal Development	(Million US$)						
Project Preparation	0.3	IBRD	0.1				**0.4**
Geothermal Resource Confirmation	8.1		2.3				**10.3**
Transaction Advisory Services (structuring of PPP for power plant)	0.6		0.2				**0.8**
Investments in 28 MW plant		TBD after drilling	6	30	35	35	**106**
Subtotal: Geothermal Development	**9.0**		**8.6**	**30**	**35**	**35**	**117.6**
Development of Utility-Scale Solar PV							
Grant for Project Preparation, Feasibility studies, site measurement and monitoring	1.5	ADB	0.5				**2.0**
Transaction Advisory Services	0.5		0.1				**0.6**
Investments in power plants (total of 40-50 MW)	17	ADB	4.4	20	36	27.5	**104.9**
	9	IBRD	2.5	10			**21.5**
Subtotal: Development of Utility-Scale Solar PV	**28.0**		**7.5**	**30**	**36**	**27.5**	**129.0**
Development of Geothermal Heat Pumps and Solar Thermal							
Investments in geothermal heat pumps and solar water heaters	3	EBRD	0	0	2	7	**12**
Subtotal: Geothermal heat pumps and solar thermal	**3**		**0**	**0**	**2**	**7**	**12**
Grand Total	**40**		**16.1**	**60**	**73**	**69.5**	**258.6**
SREP Leverage	**5.5**						

7 Responsiveness to SREP Criteria

The Investment Plan developed for Armenia is responsive to most of the SREP criteria. One of the SREP criteria, related to energy access, is not relevant to Armenia as nearly all Armenians have access to energy supply (electricity and gas). Table 7.1 summarizes how each of the projects responds to SREP Criteria.

Table 7.1: Summary of Projects' Responsiveness to SREP Criteria

Criteria	Geothermal Power Development	Utility-Scale Solar PV Development	Geothermal heat pump and solar thermal project
Increased installed capacity from renewable energy sources	Armenia plans to increase installed geothermal capacity from 0 to (pending resource availability) 100 MW by 2025. SREP-funded investments represent the first 28 MW.	Armenia plans to increase installed solar capacity from 0 to 80 MW by 2025. SREP-funded investments will represent the first 40-50 MW.	Armenia plans to increase geothermal heat pump output from 1 GWht/year to 33 GWht/year by 2025 and increase solar thermal output from 1 GWht/year to 25 GWht/year.
Increased access to energy through renewable energy sources	Armenia is unique among other SREP applicants in that it has nearly 100 percent access to electricity. Therefore, Armenia's IP is not about access to modern energy services, but about using renewables to improve energy security and reliability, and reduce the future cost of supply. In particular, Armenia has impending power supply capacity gap. Thus, all of the projects will help to reduce it meanwhile improving energy security.		
Low Emission Development	Geothermal plants produce negligible carbon dioxide emissions and will displace some of the gas-fired electricity generation.	Solar PV produces no carbon dioxide emissions and will displace some of the gas-fired electricity generation.	Geothermal heat pumps and solar thermal displace the need to burn natural gas for heating or to generate electricity (roughly 1/3 of which is generated by gas in Armenia)
Affordability and competitiveness of renewable	The supply curves shown in Section 3.2 confirm that geothermal power	The supply curves shown in Section 3.2 show that utility scale solar	The supply curves shown in Section 3.2 confirm that geothermal heat

Criteria	Geothermal Power Development	Utility-Scale Solar PV Development	Geothermal heat pump and solar thermal project
resources	is competitive with Armenia's thermal generation alternatives (gas and nuclear).	PV is not yet cost competitive with existing thermal generation options in Armenia.[37] SREP financing will help kick-start the industry, while limiting the impact on tariffs of the first plants since reverse auction mechanism for tariff will be used to select the winning bidder	pumps are cost-competitive with natural gas and electric heating (in multi-story buildings) Solar thermal is not yet cost competitive but may be a better option in some rural areas.
Productive use of energy	Geothermal provides base-load supply and will, therefore, enhance supply adequacy and reliability, helping to reduce the risk of lost load with significant economic costs.	Solar PV generates electricity during high-demand daytime periods and will similarly enhance supply adequacy and reliability during the hours of the day in which the value of lost load is typically the highest.	Geothermal heat pumps and solar thermal heating will help reduce natural gas consumption which has tremendous benefits to Armenia in terms of savings of reserves required to import gas.
Economic, social and environmental development impact	The development of these projects have a number of economic, social and environmental benefits, which are described in detail for each technology in Section 5.		

[37] As noted earlier in the paper, however, the combination of several factors could make solar more cost-competitive in the near future. The factors include: (i) new, higher-cost thermal plants being built to serve demand in Armenia; (ii) lower solar installation costs that will result as a domestic industry develops around it; (iii) lower financing costs as lenders become more comfortable with the technology, and (iv) potential further reductions in the global costs of PV panels. SREP support can help Armenia nurture its solar industry so that, as these factors converge, Armenia can look to utility-scale solar as a commercially viable alternative to some thermal power generation.

Criteria	Geothermal Power Development	Utility-Scale Solar PV Development	Geothermal heat pump and solar thermal project
Economic and financial viability	The supply curves shown in Section 3.2 confirm that geothermal power is economically and financially viable, provided the resource is confirmed.	The supply curves shown in Section 3.2 confirm that solar may be economically and financially viable over time with the support of low-cost SREP financing, and given the future increase in the long-run generation cost in Armenia.	The supply curves shown in Section 3.2 confirm that geothermal heat pumps are economically and financially viable. Solar thermal may be economically and financially viable in some circumstances and may become more so given expected increase of natural gas prices.
Leveraging of additional resources	Investments from the private sector, MDBs, and government are estimated to leverage 5.5 times the amount contributed by SREP.		
Gender	Women will equally benefit from better security and reliability of supply. Each project also offers possible opportunities for targeted job creation for women (for example, requirements that the geothermal or solar plant operators provide earmarked jobs for women.		
Co-benefits of renewable energy scale-up	There are a number of co-benefits associated with each plant. These are described in more detail in Section 5 and Annex D.		

8 Additional Development Activities

The Government has carefully designed an IP that is complementary to the other activities of the MDBs, private sector, financial institutions and other donors. The IP builds on Armenia's successful commitment to introducing a high level of private sector participation in the energy sector, and uses SREP resources to leverage further participation.

The geothermal power project builds on the extensive preparatory work done by the Armenian government and the R2E2 Fund, much of it funded by the GEF/World Bank. More specifically, the GEF/World Bank provided a US$1.5 million to finance technical field investigation studies for two potential geothermal sites in Armenia.

The utility-scale solar PV project recognizes the extensive research and development activities of Armenian academics in the field of solar, and the move in the generation sector to private financing and operation, rather than government ownership.

The modality of financing the utility-scale solar project leaves open the possibility for EBRD, IFC or ADB's Private Sector Operations Department (PSOD) as well as other financial institutions to provide commercial debt financing that can be blended with the private operator's equity and other commercial financing. Government can rely on the R2E2 Fund to help manage the additional work required to identify and prepare viable solar projects, and attract possible investors.

The modality of procuring the geothermal and solar projects can further benefit from additional technical advisory services, potentially financed by MDBs, to help structure, tender, and negotiate the contracts with private investors and operators.

The modality of lending to geothermal heat pump and solar thermal projects builds on, and can be integrated directly into the successful experience of EBRD (as well as other donors) in on-lending through Armenian commercial banks. Financing for energy efficiency investments as well as geothermal heat pumps and solar thermal are also expected under the potential E5P program ($20 million) expected to be effective in 2016. Lending under EBRD's CEEP will help bridge the gap in time before the E5P funding becomes available.

Phase 3 of KfW's support to small HPPs, currently in the planning stage, will also include up to EUR 40 million in financing and may be expanded to cover financing for wind or other renewables.

Lastly, but not least important, the IP builds on the successful sector reforms supported by donors over the past two decades. It recognizes the importance of scaling up renewable energy using commercial principles, and with transparent regulation that ensures accountability of service providers.

9 Implementation Potential with Risk Assessment

The implementation risk of the IP in Armenia is low to moderate. The most serious risks are related to the fact that the priority RE technologies in the IP are relatively new to Armenia, and had not, until recently, been considered as options. For example, utility-scale solar PV only recently became an option because of the rapid decline in capital costs (driven by changes in prices of raw materials as well as the dynamics of supply and demand for the technology itself).

Because the technologies had not previously been seriously considered, there is some risk related to the legal and regulatory environment, and the resource potential, as the data on geothermal and solar resource potential are still being collected.

Table 9.1 lists and describes the principal risks associated with Armenia's IP, describes how to mitigate those risks, and evaluates the residual level of risk after the proposed mitigation measures are implemented.

Table 9.1: Risk Assessment of the SREP Program in Armenia

Risk	Description	Mitigation	Residual Risk
Legal and regulatory risks	The regulatory framework in Armenia is robust relative to many other countries in the region and other SREP countries. There is, however, a risk that the current or future Governments will feel pressure to keep end-user tariffs low. This could jeopardize efforts to establish generation tariffs (either through FiTs or PPAs) for solar or geothermal that are attractive to private investors.	The Government clearly committed through formalized policy statements and strategies (Energy Security Concept of 2013) to integrating into its long-term energy strategy the technologies in the SREP program, namely: Utility-scale solar PV and geothermal power. MDB technical assistance will be used to support the Government efforts to set generation tariffs at levels attractive to private investors while protecting vulnerable customers through Armenia's well-established and social support mechanism, the Poverty Family Benefit Program (PFBP).	Moderate
Institutional capacity risks	Armenia's energy sector institutions (MENR, R2E2 Fund, PSRC, the Energy Institute, and commercial bank partners, for example) have a long history of successful experience working effectively with donors to implement technical assistance and capital works projects.	The institutional capacity of specific implementing agencies will be assessed before appraisal of identified specific projects and, where necessary, SREP will contribute to capacity building. Such capacity building may include support in procurement, financial management, safeguards and technical aspects of utility-scale solar PV and geothermal projects.	Low

Risk	Description	Mitigation	Residual Risk
Technology risks	Utility-scale solar PV, geothermal exploratory drilling and generation, geothermal heat pump, and solar thermal technologies are relatively well-established and well-known globally. There is, however some technical risk associated with the technologies in Armenia because they are not yet used in the country. In particular, exploratory geothermal drilling is novel to Armenia.	The technology risks will be partially mitigated through the targeted technical assistance and capacity building planned under the SREP program. Moreover, the World Bank is currently supporting the Government with preparation of geothermal drilling project, including recommendations on types of exploratory wells to be drilled, determination of the precise location of test wells, procurement and contracting structure, preparatory civil works required for geothermal exploratory drilling project at Karkar. There is also considerable academic research in solar PV, solar thermal heating and geothermal heating technologies in Armenia. Institutions with experience in the technologies covered by the SREP program will, therefore, be involved at an early stage.	Low
Environmental risks	Any industrial-scale development assumes environmental risks. For example, the selected projects might have construction-related air emissions, limit alternative land use, cause alteration of land drainage characteristics, require the clearance of vegetation and compaction of soil, cause vibrations and downwash during construction.	Site-specific environmental impact assessments will be carried out for all projects implemented under SREP. These assessments will ensure that the projects comply with Government of Armenia requirements as well as donor safeguards policies. Furthermore, by ensuring that projects are sited away from particularly environmentally sensitive areas, environmental risks can be minimized. This is especially relevant for utility-scale solar PV projects, which provide more flexibility in terms of siting.	Low
Social risks	The social impacts of the SREP program in Armenia are limited. There are some risks associated with limiting alternative land use, impacts to traffic patterns during construction, There is also the risk that,	Site-specific social impact assessments will be carried out for all projects implemented under SREP. These assessments will ensure that the projects comply with Government of Armenia requirements as well as donor safeguards policies	Low

Risk	Description	Mitigation	Residual Risk
	given their cost relative to current generation tariffs in Armenia, the new RE plants will raise the cost of generation and ultimately, the end-user tariff.	The end-user tariff is not likely to increase substantially as a result of the new projects given that estimated average generation cost for Armenia is estimated to significantly increase as new larger generation plants are built to meet the forecast demand.	
Financial risks	As described earlier in this document, Armenia's energy sector is largely privatized and therefore must operate on a full-cost recovery basis.	Please refer to mitigation measures for legal and regulatory, and resource risk.	Moderate
Renewable resource uncertainty	There is some risk that Karkar geothermal site may not be suitable for power generation despite comprehensive field investigation works conducted considering the advanced international experience in comprehensive surface studies for potential geothermal fields. The assessment of potential for utility-scale solar PV is based on fairly coarse resource data and very limited site monitoring.	The exploratory drilling at Karkar geothermal site is the final step required to determine the existence and quality of a resource. If the drilling shows no resource, or an insufficient or low quality resource, remaining funds can be reallocated to other areas of the SREP program. If the exploratory drilling does show a resource worth exploiting, then a tender will be launched to construct and operate a geothermal plant. The site-specific higher-resolution solar insolation measurements will be conducted to confirm the solar resources before launching any tender.	Moderate

10 Monitoring and Evaluation

A monitoring and evaluation (M&E) system will be established by the Government, in cooperation with the MDBs and other donor partners, for the purpose of tracking and reporting on progress in reaching SREP impacts and outcomes.

The M&E framework will be coordinated by the R2E2 Fund and involve the participation of MENR, PSRC, the National Statistical Service (Armstat), and commercial lenders with RE projects.

Government will allocate US$ 100,000 of SREP resources to further strengthen the monitoring and evaluation system in the energy sector and therefore enhance the catalytic impact of SREP finance in the country. In addition to facilitating the scale up of deployment locally, the lessons learned would help other countries also embark into the development of renewable energies, especially geothermal and solar technologies. In particular, the proposed funding will support the implementation of evidence-based learning approaches (e.g., impact evaluation, rapid-stakeholder consultation, real-time learning, etc.) that would enhance learning throughout the lifecycle of investments. The objective is to generate knowledge and share best practices which may be incorporated in the further design and implementation of projects, therefore improving their capacity to deliver results on the ground and facilitating the scaling-up of geothermal and solar energies in Armenia and other countries. The concept proposals for evidence-based learning activities will be elaborated during preparation of SREP-funded geothermal and utility-scale solar projects based on specific context and needs.

Table 10.1 summarizes the proposed monitoring and evaluation (M&E) framework for Armenia's SREP IP.[38] Armenia is unique among other SREP applicants in that it has nearly 100 percent access to electricity. Armenia's IP is therefore not about access to modern energy services but about using renewables to improve energy security and reliability, and reduce the future cost of supply.

Whereas Armenia may not benefit from substantially expanded access to modern energy services, it will however benefit from the reduced use of hydrocarbons for electricity production.

[38] The indicators in the results framework are based on the SREP Revised Results Framework from June 1, 2012.

Table 10.1: Results Framework for the SREP Program in Armenia

Result	Indicators	Baseline	Targets	Means of Verification
SREP Transformative Impacts				
Support low-carbon development pathways by increasing energy security.	Electricity output from (non-large hydro) RE in GWh per year	No output	1,600 GWh by 2020; 2,300 by 2025	MENR, PSRC
	Increased annual public and private investments (USD) in targeted subsector(s) per year	Less than US$1 million in annual investments	US$45 million in annual investments	R2E2 Fund, MENR, PSRC
SREP Program Outcomes				
Increased supply of renewable energy	Increased annual electricity output (GWh) as a result of SREP interventions	Geothermal electricity output: 0 GWh Utility-scale solar PV output: 0 GWh Solar thermal heating output: 1 GWh Geothermal heat pump output: 1 GWh	Geothermal electricity output: 373 GWh by 2020; 745 GWh by 2025; Utility-scale solar PV output: 88 GWh by 2020; 176 GWh by 2025 Solar thermal heating output: 25 GWh by 2025 Geothermal heat pump output: 33 GWh by 2025	SREP Project's M&E system
New and additional resources for renewable energy projects (US$220 million)	Leverage factor: USD financing from other sources compared to SREP funding	0	5.5	SREP Project's M&E system

Annex A: Project Concept Briefs

A.1 Geothermal Power Project

Problem Statement

Armenia has no proven oil or natural gas reserves and imports all of its fuel for thermal generation from Russia and Iran. The country relies on imported natural gas to generate roughly 30 percent of its power and most of its heat. Nuclear fuel, which is used to generate another 30 percent of electricity in Armenia, is also imported. The remaining electricity is generated by a series of hydropower plants in the Sevan-Hrazdan and Vorotan cascades, more than 150 small hydropower plants, and one small wind farm.

Armenia's dependence on imported fuels creates security of supply risks as well as affordability problems for customers. The sector is highly susceptible to fuel supply interruptions and price volatility. Between 1991 and 1996—because of disruptions in gas supply—customers suffered through several of Armenia's brutal winters with little more than two hours of electricity supply per day. Meanwhile, the import price of natural gas has continued to increase. The increases of the price of imported gas meant steady increases in end-user tariffs for natural gas and electricity. Between 2005 and 2013, the end-user natural gas tariff increased by 170 percent. End-user residential tariffs for electricity increased 52 percent during the same time period.

Therefore, geothermal energy can become an affordable source of base-load electricity that is generated utilizing indigenous resources, thus, contributing the country's energy security. Private investors are typically not willing to assume the resource risk and do not finance exploratory drilling. With SREP support, the Government can confirm the resource and, if the resource is confirmed, pursue development of the geothermal power plant with private sector involvement.

Project Objective

The overarching objective of the Geothermal Power Project is to construct a geothermal power plant at Karkar site. The specific objectives are to: (a) confirm the availability of geothermal resource suitable for power generation; (b) if the resource is confirmed, then support feasibility study for the Karkar geothermal power plant and transaction advisory services to implement a PPP.

Scope of Work

The geothermal power project would include the activities described below. The SREP resources will be used to support Tasks 1-3 below.

Task 1: Exploratory Drilling at Karkar Geothermal Site:

This step requires carrying out exploratory drilling at the site to determine whether or not power could be produced from the resource. The exploratory drilling project involves the below key steps:

- Confirming the test well locations: This will require additional soil gas diffusion measurements and GeoRadar study to determine the precise location of the test wells drawing on recommended approximate locations of two test wells following comprehensive geo-technical investigation works implemented under the GeoFund 2: Armenia Geothermal Technical Assistance Project. The Government plans to complete the above studies by September 2014.

- Environmental and social impact assessment. This will include assessment of environmental and social impacts of the exploratory drilling, including development of mitigation measures and management plan.
- Preparatory civil works. This includes construction of an access road, preparation of the rig site, and securing access to sufficient water supply.
- Drilling. This will include drilling of two exploratory wells to depths of up to 1,800 meters.
- <u>Well logging and mud logging</u>. This will include analyses of the cuttings from the borehole, hole temperature and pressure measurements and gathering of essential data (such as drilling progress, circulation losses, changes in flow line temperatures, pump pressure data, etc.), both as the drilling progresses and at the end of each drilling stage. This is for the purpose of having the best information at hand for decision making and problem-solving, as well as gathering all the information on the formation being drilled and estimating rock/brine temperatures. When the drilling is finished, an injection test will be performed to estimate if the permeability of the well is sufficient or not.
- <u>Flow testing, chemical sampling and analysis:</u> This will include an assessment of: (a) the possible power output of the well, the ratio between brine and steam, and (b) enthalpy. It will also include sampling of the brine to analyze the resource as well as estimation of possible problems during power production, such as scaling and/or corrosion. This will assist in deciding what kind of power conversion techniques should be used and if any additional installation, such as inhibitors, will be needed.
- <u>Technical supervision:</u> This will include hiring of a technical expert to be on site during the entire duration of the drilling to collaborating on daily basis on the site to ensure adherence of the drilling contractor to the requirements of the contract and making decisions on behalf of the Government in order to prevent costly delays in the project.

<u>Task 2: Feasibility Study for Karkar Site</u>

If the presence of a resource is confirmed, a full feasibility study will need to be prepared to recommend the type of geothermal technology/plant to be constructed, reassess the economic and financial viability, compliance with environmental and social safeguards, and to complete legal and regulatory due diligence. The legal and regulatory due diligence will include recommendations on the need for a feed-in tariff specific to geothermal or a recommended structure and method for procuring as a public private partnership in a way that determines the tariff through bidding (for example, a reverse auction). It will also be necessary to evaluate the potential for grid interconnection at the chosen site, and whether or not grid upgrades will be necessary for the potential geothermal power plant to be connected to the grid.

<u>Task 3: Transaction Advisory Services</u>

The Government would procure the project as a Public Private Partnership (PPP). Therefore, advisory services will be needed to help structure the PPP (for example, as a Build-Operate-Transfer or Build-Own-Operate contract) and procure a private investor and operator. The exact commercial arrangement will need to be developed through further consultation within government, with donor partners, and with potential investors. However, the arrangement currently envisaged would involve a private operator having a BOT or BOO agreement under which they finance, build and operate the power plant and have a power purchase agreement with the distribution company. The Government would own the steam fields, thereby taking risk on the resource availability.

Task 4: Development of Geothermal Power Plant

As noted above, it is expected that the private sector will make the capital investment required for generation of electricity (the power plant itself). This investment plan assumes a plant with net installed capacity of 28.5 MW, based on the average size of geothermal plants elsewhere. The actual size of the plant will depend on the resource potential identified in earlier activities.

It is also expected that the MDBs, including their private arms (IFC in the World Bank Group, PSOD at ADB, or EBRD), may be able to provide financing to the project as a way of making it more attractive to other private investors. Support from public sector MDBs may include concessional lending to Government for the transmission lines, roads or other infrastructure required at the site.

Implementation Readiness

Armenia has no installed geothermal power plants, but preliminary surface studies suggest that geothermal resources suitable for power production may exist at several sites, including the following four promising sites: Karkar, Jermaghbyur, Grizor, and along the Armenian-Georgian border. In 2009-2011, comprehensive surface investigation works were conducted for Karkar site, including field scouting, magneto-telluric sounding, three-dimensional magneto-telluric sounding as well as early-stage economic and financial appraisal. Evidence from these activities indicates that a geothermal resource may exist at the site, and can only be confirmed by the drilling of an exploratory wells.

The proposed geothermal power project has high level of implementation readiness Specifically, the following activities are underway or completed: (1) the World Bank is supporting the Government with preparation of a detailed exploratory drilling program, including types of test wells; estimated cost of drilling and associated services; identification of potential companies that may be interested to bid for an exploratory drilling project; (2) the study to determine the precise locations of test wells will be initiated in May 2014 and completed by July 2014; (3) preparation of technical inputs for bidding documents for procurement of drilling contractor; (4) implementing entity with experience in implementation of donor-funded projects is designated, the R2E2 Fund.

Rationale for SREP Financing

SREP resources would be used for further exploration of Armenia’s most promising geothermal site, thereby demonstrating how geothermal power is a viable renewable energy resource in Armenia. Of the known potential geothermal sites in Armenia, the Karkar site has been the most comprehensively assessed through comprehensive surface studies and is the most promising site to date, with possible output estimated at around 28.5 MW. Exploratory drilling is required to confirm the availability and quality of the resource for power generation. By using SREP grant funding for drilling, the Government can help reduce the risk of developing the site. If a geothermal resource exists at the site, this support can help make geothermal power a financially attractive investment for private investors and an affordable source of electricity. This support will serve to demonstrate the feasibility of geothermal power in Armenia.

The geothermal project is compliant with SREP criteria. Table 10.2 shows how the project complies with SREP criteria.

Results Indicators

The main results indicators are expected to be the following:

- Resource confirmation for the Karkar site.
- Roughly 28.5 MW of additional electricity generation resulting from the project, depending on resource confirmation
- If the resource is confirmed, adoption of a legal, and regulatory framework in to enable future private investment in geothermal power generation,
- If the resource is confirmed, formal government approval of the concept and PPP scheme for construction of a geothermal power plant.

The results indicators will be further specified during preparation of the project.

Financing Plan

Table 10.2 presents a plan for financing of the geothermal power project. As the table shows, US$10 million of SREP funding is expected to catalyze roughly 12 times as much investment, most of it from the private sector (as equity or debt), and the commercial lending windows of the MDBs. The actual amounts financed by each will be determined once the resources if confirmed and as the project moves head.

The financing modalities will be determined at the time of appraisal, but it is expected that the geothermal exploratory drilling project will be funded through: (i) an SREP grant to government, or (ii) a guarantee to private sector entities who might want to undertake the drilling as part of early site development. If suitable resource potential is found, the site would be financed by a private sector developer whose remuneration would be based on a feed-in-tariff or on the terms of a power purchase agreement. It is assumed that the private sector would use a mixture of debt and equity for the investment.

Table 10.2: Indicative Financing Plan for Geothermal Power Project

<u>SREP Project</u>	SREP	Respon-sible MDB	Gov. of Armenia	MDBs	Private Sector (Equity)	Com-mercial / Private arms of MDBs	Total
Geothermal Development	**(Million US$)**						
Project Preparation	0.3	IBRD	0.1				**0.4**
Geothermal Resource Confirmation	8.1		2.3				**10.4**
Transaction Advisory Services (structuring of PPP for power plant)	0.6		0.2				**0.8**
Investments in 28 MW plant		TBD after drilling	6	30	35	35	**106**
Subtotal: Geothermal Development	**9.0**		**8.6**	**30**	**35**	**35**	**117.6**
SREP Leverage	**12**						

Lead Implementing Agencies

The project will be implemented by the World Bank as the lead MDB. The R2E2 Fund will be the implementing agency on behalf of the Government.

Table 10.3 shows an indicative timeline for the Geothermal Exploratory Drilling Project. This timeline has taken into account the “window of opportunity” for accessing the site (mid-May to mid-September), indicating that at least two seasons would be needed to complete the drilling program. The implementing entity should also initiate the necessary licensing processes as early as possible, which would include carrying out the required environmental and social assessment.

It is expected that the project will be negotiated with the World Bank by January 2015 and will become effective by March 2015. The project will be submitted to SREP Sub-committee no-objection by December 2014.

Project Preparation Grant

The Government of Armenia is requesting a preparatory grant of US$300,000 to prepare the project.

Table 10.3: Timeline for Geothermal Exploratory Drilling Project

		2014			2015									2016							
	Days	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	feb	mar	apr	may	jun	jul	aug	sep
Additional surface exploration		■																			
Obtaining licensing and permitting		■	■	■																	
Finalization of bidding documents *				■	■																
Selection of road construction contractor					■	■	■	■													
Procurement of long lead time material**									■												
Procurement of drilling service									■	■	■										
Road construction									■	■	■										
Procurement of rig site construction											■	■									
Drill platform construction	45											■	■								
Selection of drilling supervision consultant														■							
Procurement for logging and flow testing														■	■						
Mobilization and rig up	15																■				
Drilling of well B1	53																■	■			
Mobilization between wells and rig up	10																	■			
Drilling of well B2	53																		■	■	
Initial short term flow testing of well B1	14																			■	
Initial short term flow testing of well B2	14																				■

*Both for civil works and for drilling services (separate tenders). Tender documents for mud logging and flow testing could also be prepared at this time
** Well head

SREP INVESTMENT PROGRAMME Project Preparation Grant Request			
1. **Country/Region**:	Armenia/ Eastern Europe, Central	2. **CIF Project ID#**:	(Trustee will assign ID)
3. **Project Title:**	Geothermal Power Project		
4. **Tentative SREP Funding Request (in USD million total) for Project[a] at the time of Investment Plan submission (concept stage):**	Grant: US$10 million		
5. **Preparation Grant Request (in USD):**	US$300,000	MDB: IBRD	
6. **National Project Focal Point**:	Ms. Tamara Babayan		
7. **National Implementing Agency (project/programme):**	Renewable Resources and Energy Efficiency Fund		
8. **MDB SREP Focal Point and Project/Programme Task Team Leader (TTL)**:	MDB SREP Focal Point: Gevorg Sargsyan, SREP Program Manager	TTL: Arthur Kochnakyan, Energy Economist, IBRD	

Description of activities covered by the preparation grant:

The grant will cover activities related to the preparation of

- Independent review of gas diffusion and GeoRadar study to determine precise location of test wells.
- Environmental and social impact assessment of the exploratory drilling operation;
- Finalization of bidding documents for exploratory drilling;
- Detailed designs for construction of access road and water supply infrastructure, and preparation of rig site;
- Bidding documents for construction of access road and water supply infrastructure, and preparation of rig site;
- Incremental operating costs of R2E2 Fund

9. Outputs: Policy Framework

Deliverable	**Timeline**
Independent review of the results of gas diffusion and GeoRadar study	October, 2014
Report on Environmental and Social Impact Assessment	November, 2014
Detailed designs for access road, water supply infrastructure and rig site	December, 2014
Final set of bidding documents for preparatory civil works and exploratory drilling	January, 2015

10. Budget (indicative):

Expenditures[b]	**Amount (USD) –** estimates
Consultants/technical assistance	270,000
Equipment	0
Workshops/seminars/trainings	5,000

Travel/transportation	
Others (admin costs/operational costs)	15,000
Contingencies (max. 10%)	10,000
Total cost	300,000
Other contributions:	
• Government	100,000 (Government expert's staff time and taxes)
• MDB	50,000 (World Bank/ESMAP grant for GeoRadar and Gas Diffusion Studies)
• Private sector	-
• R2E2 Fund	20,000 (staff-time)

11. **Timeframe** (tentative): For World Bank:
SREP Sub-committee approval by July 2014
World Bank approval/Board approval by August 2014

12. **Other partners involved in project design and implementation**[d]: Geology Institute of the Republic of Armenia

13. **If applicable, explanation for why the grant is MDB executed: N/A**

14. **Implementation Arrangements** (including procurement of goods and services)**:**

The R2E2 Fund will implement the project since it has adequate capacity and significant experience in implementing Bank financed projects. The R2E2 Fund is a non-profit organization established by the Government in 2005 with the mandate to promote the development of renewable energy and energy efficiency markets in Armenia and to facilitate investments in these sectors. The implementation of the project as well as overall R2E2 Fund operations will be supervised by the Board of Trustees (BOT), consisting of representatives of government agencies, NGOs, and the private sector, thus, ensuring required professional expertise. The BOT is chaired by the Minister of Energy and Natural Resources. The most recent assessment conducted by the World Bank suggested that the R2E2 Fund has satisfactory procurement and financial management capacity.

a. Including the preparation grant request.
b. These expenditure categories may be adjusted during project preparation according to emerging needs.
c. In some cases, activities will not require approval of the MDB Board.
d. Other local, national, and international partners expected to be involved in project design and implementation.

MDB Request for Payment for Project Implementation Services (MPIS)

SCALING UP RENEWABLE ENERGY PROGRAM IN LOW-INCOME COUNTRIES **World Bank Request for Payment of Implementation Services**		
1. **Country/Region**:	Armenia/Eastern Europe, Central Asia	2. **CIF Project ID#**: (Trustee will assign ID)
3. **Project Title:**	Geothermal Power Project	
4. **Request for project funding (USD mill.):**	*At time of country program submission (tentative):* Grant of US$9 million	*At time of project approval:*
5. **Estimated costs for MDB project implementation services (USD mill.):**	*Initial estimate - at time of Country program submission:* US$300,000 *Final estimate - at time of project approval:*	*MDB: IBRD* *Date: January 2015*
6. **Request for payment of MDB Implementation Services Costs (USD mill.):**	☐ First tranche: US$100,000 ☐ Second tranche: US$200,000	
7. **Project/program financing category:**	a - Investment financing - additional to ongoing MDB project ☐ b- Investment financing - blended with proposed MDB project ☐ c - Investment financing - stand-alone ❖ d - Capacity building - stand alone ☐	
8. **Expected project duration** (no. of years):	3 years	
9. **Explanation of final estimate of MDB costs for implementation services:**	***If final estimate in 5 above exceeds the relevant benchmark range,***	
10. **Justification for proposed stand-alone financing in cases of above 6 c or d:** N/A		

A.2 Utility-Scale Solar PV

Problem Statement

Poor utilization of energy resources plagues an otherwise robust and sustainable Armenian energy sector. Armenia's thermal power plants operate at low efficiency, hydropower plants have low reliability and high operation and maintenance costs, grid losses are high, and export potential is not fully realized. The sector relies on the old Metsamor nuclear power plant, the decommissioning of which has been postponed twice, from 2016, to 2020, and recently to 2026. When decommissioned, Metsamor will leave a substantial power supply gap. To address these concerns, Armenia plans to increase development of indigenous energy resources, especially renewable energy. Solar photovoltaic (PV), with an estimated potential of over 1 GW, has the highest potential but is not fully utilized due to high investment costs. Armenia's solar research and technical experience is limited to solar water heaters, off-grid and small-scale PV applications.

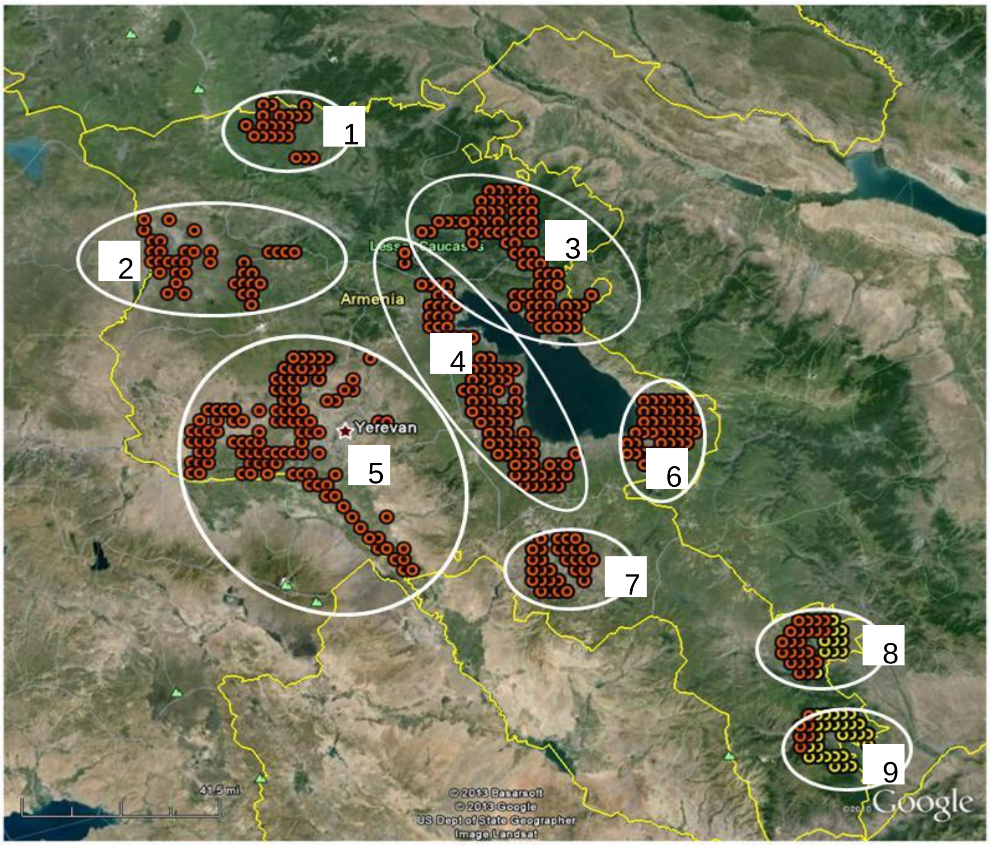
Utility-scale solar PV is now cost-competitive on a life-cycle basis with the other power generation options available to Armenia, given the technological and manufacturing advancements combined with continued cost declines internationally. Armenia will benefit from developing its capacity to scale-up PV technology and take advantage of these cost reductions as these happen.

Current Efforts

Armenia has good solar PV resources, with annual average global horizontal irradiation (GHI) ranging from 1,490 kWh/m^2 to over 2,100 kWh/m^2. By comparison, average annual GHI is 1,000 kWh/m^2 in Europe. The total resource potential for utility-scale solar PV is over 6,500 MW. However, after accounting for undevelopable areas, the developable resource potential is assumed to be much lower.

Assuming polycrystalline solar PV modules mounted at a fixed angle to the sun are deployed in ground-mounted utility-scale plants, solar PV systems could theoretically achieve capacity factors of 20 to 24 in Armenia (dependent on location). If single-axis tracking solar PV technology is deployed, capacity factors could be as high as 30 percent. As part of the preparation of the Investment Plan, nine zones were identified where large-scale, ground-mounted solar PV projects could be built. Figure 10.1 shows the solar zones identified as part of the investment plan.

Figure 10.1: Solar Zones



Project Objective

The objective of the utility-scale solar project is to deploy the first of a series of utility-scale solar PV projects which, through cost reductions and gradual tariff increases will eventually become commercially viable without SREP/MDB support. These first projects will be so small as to have only a very minor impact on the overall cost of generation in Armenia, but could have a catalytic effect on the market for solar PV through:

- Lower solar installation costs that will result as a domestic industry develops around it;
- Lower financing costs as lenders become more comfortable with the technology, and

The foreseen increase in thermal generation costs in Armenia will move solar toward financial viability. Armenia's new thermal plants will require substantially higher tariffs than many of the existing plants, because they are fully (or near fully) depreciated and no longer recover depreciation charges nor debt service through their generation tariffs.

Scope of Work

SREP resources would be used to develop roughly 40-50 MW of utility-scale solar PV. SREP support would help catalyze private investment in a first new plant (or plants), and show the potential for deploying solar PV on a commercial basis. The utility-scale solar PV project would include activities described below.

Task 1: Project Preparation, Feasibility Studies, Site Measurement and Monitoring

SREP grant funds would first be used to fund more detailed resource assessments, and the identification of possible sites and possible projects. The activities in this task include:

- Additional site measurement and monitoring. Relatively coarse resolution solar data are publicly available for Armenia. Given the nature of solar energy resources, these coarse data are generally acceptable for understanding the nature of the resource and conducting a high-level financial analysis. However, additional measurement and monitoring will be needed to characterize the solar resource potential in the areas targeted for solar development in more detail.
- Evaluation of grid interconnection requirements. It will be necessary to evaluate the potential for grid interconnection at the chosen site, and whether or not grid upgrades will be necessary before the project is interconnected.
- Feasibility study. Once a potential site or sites have been identified, a full feasibility study will be needed to reaffirm the economic and financial viability of the projects, assess compliance with environmental and social safeguards, and complete the legal and regulatory due diligence.

Task 2: Transaction Advisory Services

Transaction advisors would be hired to help government tender for the projects identified in Task 1. Private operators would be procured through competitive tender. Bidders would be selected based on technical and financial criteria, the financial criteria being the level of tariff required or, alternatively, the level of concessional support required.[39] Developers offering lower tariffs or requiring less concessional support would receive higher scores.

The activities in the transaction advisory work include:

- The identification of specific structuring options for the projects where "structuring" means arrangements related to:
  - The detailed allocation of responsibilities between public and private partners (design, construction, operations, and, if appropriate—financing);
  - The way in which the private partner will be remunerated (for example, through availability payments, tariffs payments, or some combination);
  - The allocation of risks between public and private partners, and mechanisms for mitigating such risks;
  - The length, or term of the PPP contract, and mechanisms during the term of the contract for cost pass-through or indexation, revenue resets or adjustments;

[39] Bidders will be offered, as part of the conditions of tender, access to SREP capital contributions.

- A strategy for procurement, including whether to tender bundle or tender separately for design, construction, and operations.

- The development of model tender documents for the structures recommended, where such model documents will include:
  - A project information memorandum: The project information memorandum will present the project justifications, objectives, scope, information about the structure of the PPP, the location of the assets, land and other conditions, environment, sanitation and labor safety, required permits and licenses, operational information on existing assets, project output, demand, legal environment, contract management, monitoring of private partner's performance, etc.
  - A request for qualifications (RFQ) or request for expressions of interest (EoIs)
  - A Requests for Proposals (RFP). The RFP will describe the project proposal, instructions to bidders, evaluation criteria for the proposal, the timeline for the tender period including the proposal deadlines, instructions for preparation of financial and technical proposals, the process and timing for opening of bids, information about any bid security and guarantees, and clear procedures for communication between the public authority and bidders.
  - A draft PPP agreement, including the necessary schedules to the agreement.

Task 3: Power Generation Project Development

SREP funds would be made available to the Government of Armenia which would on-lend SREP funds at concessional rates to private operators bidding on the projects being tendered. The private operators would contribute equity and also source loans from commercial banks and from the commercial lending arms of the MDBs. Government estimates that, given current capital costs for utility-scale solar PV, SREP funds could be used with these other sources of financing to support roughly 40-50 MW of solar. Initial studies indicate that Gegharkunik Marz has some of the highest solar PV potential in Armenia, and would be considered as a first potential area for development. This could be a single plant, or several plants with a total capacity of 40-50 MW, as development of solar is often more effective if there are multiple sites, in areas with different solar profiles (to provide more stability by diversifying generation profiles).

Implementation Readiness

Solar PV deployment in Armenia to date has been limited to relatively small-scale rooftop-based installations at schools, hospitals, office buildings and municipal sites throughout Armenia.[40] It is estimated that less than 100 kW of solar PV is currently operational.[41]

Utility-scale solar is non-existent because, until recently, it was perceived as a high cost technology relative to Armenia's alternatives. Also, while solar PV power plants are quick to install, considerable time is required to gather solar irradiation and weather data, to develop energy yield models for simulation, prepare bankable projects for financing, and to procure equipment and consulting services.

Solar PV has become more attractive in recent years as the capital costs of utility-scale solar PV projects have declined. The Government has set a target of 40 MW of solar PV by 2020 and 80 MW of solar PV by 2025. There is, moreover, considerable research and development (R&D) and interest in solar PV within Armenia's academic institutions. A solar PV project could catalyze further research and development and facilitate the transfer of capacity for increased participation in solar PV value chain.

Armenia's development partners, ADB and the World Bank, have a solid track record and experience in solar development in the region and have developed solar insolation maps and atlases for several countries including Armenia.

Rationale for SREP Financing

One of the most significant barriers to renewable energy in Armenia is the high cost of investment, therefore higher cost per kWh, relative to the currently low-cost electricity generation mix. The current low cost of generation makes it difficult for consumers to understand the need for higher-cost renewable energy generation over the medium to long term which will satisfy –at least initially—only a small portion of demand. There are also legitimate concerns about affordability. The poorest quintiles of the population allocate a relatively higher share of their budgets to electricity than other households. These households are likely to experience more significant pressures on their budgets as a result of increased energy tariffs.

SREP support would help catalyze private investment in a first new plant (or plants), and show the potential for deploying solar PV on a commercial basis. A utility-scale commercial project would not only enable the country to take advantage of this technology in the future when its costs decline even further, but reduce costs for future projects because of learning effects, efficiency gains and competition.

Concessional SREP financing brings down the cost of solar PV generation closer to grid parity and addresses both viability concerns for developers and affordability concerns for consumers. Commercial financing is available but there is a shortage of qualified developers, with enough risk appetite and willingness to invest despite the lack of specific targets and specific feed-in-tariffs for solar PV. Site-specific solar resource assessments and institutional capacity are also non-existent. These concerns are addressed through technical and capacity building assistance and concessional project financing.

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[40] USAAA/US Embassy/EcoTeam/UNDP/GEF, "Use of Renewable Energy Sources in the World and Armenia Through Innovations to Clear Technologies," 2010

[41] Preparation of Renewable Energy Development Roadmap for the Republic of Armenia Task 2 Report," February 2011

Results Indicators

The main results indicators are expected to be the following:

- Roughly 40-50 MW of additional electricity generation resulting from the project, depending on resource confirmation.
- A legal, and regulatory framework in place to enable future private investment in utility-scale solar PV, including either: (1) a feed-in tariff for future utility-scale solar PV projects; or (2) a framework for procuring utility-scale solar PV on a Public Private Partnership (PPP) basis.

The results indicators will be further specified during preparation of the project.

Financing Plan

As Table 10.4 shows, US$28 million of SREP funding is expected to catalyze roughly 3.6 times as much investment in solar PV, most of it from the private sector (as equity or debt), and the commercial lending windows of the MDBs.

The SREP concessional funds will be used to finance private-sector led utility scale solar PV power plants. The SREP Utility Scale Solar PV Financing Facility will blend SREP funds with ADB and World Bank public sector financing to provide loans to cover up to 50 percent of the total investment cost for one or two projects, the rest is expected to be mobilized from a combination of equity from investors/developers and additional project financing, as appropriate, from other financial institutions that may include EBRD, IFC, and ADB's Private Sector Operations Department..

In its Armenia Country Operations Business Plan (COBP) 2014-2016, the ADB has allocated US$20 million from its Ordinary Capital Resources for the project for approval in 2016. The World Bank may also consider allocating US$10 million for the potential solar PV project. The combination of SREP financing ($28 million), IFI financing ($30 million), Government co-financing ($8 million), and project sponsors ($63 million) will help to finance construction of around 40-50 MW utility-scale solar PV capacity. The ADB may provide additional financing subject to receipt of formal request from the Government. The Renewable Resources and Energy Efficiency Fund will be the implementing agency (IA) and will act as financial intermediary and project management office.

SREP will provide a technical assistance grant of US$1.5 million for onsite solar irradiation and weather measurements, pre-feasibility studies including up to 2 project feasibility studies and project preparation for the first solar PV project/s to be auctioned.

ADB has also allocated US$0.3 million technical assistance grant in 2015 to prepare the Financial Intermediary Loan for ADB approval in 2016. SREP grant funding of US$0.5 million is also expected to finance transaction advisors to assist the IA in structuring and developing the PV project to be financed under the SREP Loan Facility. Transaction advisors provide advice on optimal commercial and financial structures, conduct due diligence, prepare bidding documents and project contracts, marketing/roadshow, assist in bid evaluation, auctioning, and financial closing.

A reverse auction, instead of a feed-in-tariff mechanism, will be used for setting the solar PV tariff. The tariff for a predetermined maximum aggregate PV capacity will then be based on the lowest qualifying bid. An indicative tariff will be calculated based on the financing terms offered under the SREP Loan Facility and used as a benchmark for evaluating bids. This tariff is not set officially nor declared as a ceiling for the auction. The auction will be announced for one or more high solar potential sites as assessed and prioritized through the SREP technical assistance.

Table 10.4: Indicative Financing Plan for Utility-Scale Solar Power Project

SREP Project	**SREP**	**Respon-sible MDB**	**Gov. of Armenia**	**MDBs**	**Private Sector (Equity)**	**Com-mercial/ Private arms of MDBs**	**Total**
Development of Utility-Scale Solar PV	**(Million US$)**						
Grant for Project Preparation, Feasibility studies, site measurement and monitoring	1.5	ADB	0.5				**2.0**
Transaction Advisory Services	0.5		0.1				**0.6**
Investments in power plants (total of 40-50 MW)	17	ADB	4.4	20	36	27.5	**104.9**
	9	IBRD	2.5	10			**21.5**
Subtotal: Development of Utility-Scale Solar PV	**28**		**7.5**	**30**	**36**	**27.5**	**129.0**
SREP Leverage	**3.6**						

Lead Implementing Agencies

The project will be implemented as a joint operation by ADB and the World Bank, and will be led by ADB. The R2E2 Fund will be the implementing agency on behalf of the Government.

It is expected that the project will be negotiated with ADB and the World Bank by April 2016 and will become effective by June 2016. The project will be submitted to SREP Sub-committee no-objection by January 2016.

SREP funding would be provided to Ministry of Finance, which would on-lend to developers.

The R2E2 Fund, which has extensive experience implementing donor-financed projects in renewable energy and energy efficiency, would be responsible for implementation of the project.

Project Preparation Timetable

The estimated timetable for the Utility Scale Solar PV Development program is in the table below. The technical assistance may be proposed as one TA, but done in phases, which could start with capacity development and feasibility studies followed by project preparation.

Table 10.5: Indicative Project Preparation Timetable for Utility-Scale Solar Power Project

Technical Assistance (TA) and Project Processing Milestones	
Capacity Development and Project Preparation TA (CDTA)	**SREP (US$1.5 Million)**
Advanced Procurement of Consultants	June-July 2014
Approval of Armenia SREP IP	May 2014
Consultant Mobilization	July 2014
Completion of solar resource mapping /modeling	September 2014
Screening of potential sites	September 2014
Procurement of on-site measurement stations	July 2014
Selection of priority solar project sites; Procurement of hourly time-series data for sites.	October 2014
Installation of Meteostations	October-November 2014
On-site measurements and data analysis	November 2014 – November 2015
Preparation and submission of pre-feasibility studies	January-November 2015
Technical, Financial, Economic, Governance, Environmental and Social Safeguards Due Diligence for priority sites	January-November 2015
Submission of draft feasibility studies for sites (based on 6 months of measurements)	June 2015
Feasibility studies	March 2015-December 2015
Capacity Building Program	November 2014-January 2016
Project Preparation TA (PPTA)	**ADB (US$0.3 Million)**
Concept Paper Preparation and ADB Review	February-May 2015
Advanced Procurement of PPTA Consultant	March –July 2015
ADB Approval of PPTA	July 2015
Consultant Mobilization	August 2015
Project preparation	August 2015- February 2016
Advance procurement of Project Implementation Consultant	November 2015-March 2016
ADB/World Bank Loan Approval	April 2016
Transaction Advisory Services (February 2015-October 2016)	**SREP (US$0.5 Million)**
Engagement of TAS	February 2016
Preliminary Structuring and Due Diligence	August - January 2016
Roadshow	January - March 2016
Tender and Selection of Preferred Bidder	March – May 2016
Negotiation and Award	June 2016 – August 2016

Project Preparation Grant

The Government of Armenia is requesting a preparatory grant of US$1.5 million to prepare the project.

SREP INVESTMENT PROGRAMME

Project Preparation Grant Request

1. **Country/Region**:	Armenia/ Eastern Europe, Central Asia	2. **CIF Project ID#**:	(Trustee will assign ID)
3. **Project Title:**	Utility-Scale Solar Power Project		
4. **Tentative SREP Funding Request (in USD million total) for Project[a] at the time of Investment Plan submission (concept stage):**	US$28 million		
5. **Preparation Grant Request (in USD):**	US$1.5 million	MDB: ADB	
6. **National Project Focal Point**:	Ms. Tamara Babayan		
7. **National Implementing Agency**	Renewable Resources and Energy Efficiency Fund		
8. **MDB SREP Focal Point and Project/Program Task Team Leader (TTL)**:	MDB SREP Focal Point: Gevorg Sargsyan, SREP Program Manager	TTL from ADB: Cindy Tiangco (Energy Specialist) TTL from IBRD: Arthur Kochnakyan (Energy Economist)	

Description of activities covered by the preparation grant:

The preparation grant will cover the following key activities:

- Solar resource mapping/modelling;
- Screening of potential sites;
- Preparation of feasibility studies for identified highest-potential sites;
- Capacity building for R2E Fund, including organization of reverse auctions;
- Incremental operating costs of the R2E2 Fund.

9. Outputs: Policy Framework

Deliverable	**Timeline**
Report on solar resource mapping/modelling	September 2014
Report on screening of potential sites	September 2014
Feasibility study for identified sites	March-December 2015

10. Budget (indicative):

Expenditures[b]	**Amount (USD) –** estimates
Consultants/technical assistance	1,000,000
Equipment (meteo-stations, computers, data)	313,000
Workshops/seminars/trainings	20,000
Vehicle/transportation	10,000
Others (admin costs/operational costs)	80,000
Contingencies (max. 10%)	77,000
Total cost	**1,500,0000**
Other contributions:	

• Government	400,000 (Government experts' time and taxes)
• MDB	-
• Private sector	-
11. **Timeframe** (tentative): For ADB and World Bank: SREP Sub-committee approval of the project: August 2015 ADB approval: August 2015	
12. **Other partners involved in project design and implementation**[d]: National Academy of Sciences	
13. **If applicable, explanation for why the grant is MDB executed:** N/A	
14. **Implementation Arrangements** (including procurement of goods and services)**:** The R2E2 Fund will implement the project since it has adequate capacity and significant experience in implementing Bank financed projects. The R2E2 Fund is a non-profit organization established by the Government in 2005 with the mandate to promote the development of renewable energy and energy efficiency markets in Armenia and to facilitate investments in these sectors. The implementation of the project as well as overall R2E2 Fund operations will be supervised by the Board of Trustees (BOT), consisting of representatives of government agencies, NGOs, and the private sector, thus, ensuring required professional expertise. The BOT is chaired by the Minister of Energy and Natural Resources. The most recent assessment conducted by the World Bank suggested that the R2E2 Fund has satisfactory procurement and financial management capacity.	

a. Including the preparation grant request.

b. These expenditure categories may be adjusted during project preparation according to emerging needs.

c. In some cases, activities will not require approval of the MDB Board.

d. Other local, national, and international partners expected to be involved in project design and implementation.

MDB Request for Payment for Project Implementation Services (MPIS)

Scaling Up Renewable Energy Program in Low-Income Countries **ADB Request for Payment of Implementation Services Costs**			
1. **Country/Region**:	Armenia/Eastern Europe, Central Asia	2. **CIF Project ID#**:	(Trustee will assign ID)
3. **Project Title:**	Utility-Scale Solar Power Project		
4. **Request for project funding (USD mill):**	*At time of country program submission (tentative):* ADB: US$17 million	*At time of project approval:*	
5. **Estimated costs for MDB project implementation services (USD mill.):**	*Initial estimate - at time of Country program submission:* ADB: US$320,000 *Final estimate - at time of project approval:*	*MDB: ADB* *Date:*	
6. **Request for payment of MDB Implementation Services Costs (USD mill.):**	☐ First tranche: ADB: US$100,000 ☐ Second tranche: ADB: US$220,000		
7. **Project/program financing category:**	a - Investment financing - additional to ongoing MDB project ☐ b - Investment financing - blended with proposed MDB project ❖ c - Investment financing - stand-alone ☐ d - Capacity building - stand-alone ☐		
8. **Expected project duration** (no. of years):	4		
9. **Explanation of final estimate of MDB costs for implementation services:**	***If final estimate in 5 above exceeds the relevant benchmark range, the exceptional circumstances and reasons***: Not Applicable		
10. **Justification for proposed stand-alone financing in cases of above 6 c or d:** N/A			

SCALING UP RENEWABLE ENERGY PROGRAM IN LOW-INCOME COUNTRIES

World Bank Request for Payment of Implementation Services

<table>
<tr><td>1. Country/Region:</td><td>Armenia/Eastern Europe, Central Asia</td><td>2. CIF Project ID#:</td><td>(Trustee will assign ID)</td></tr>
<tr><td>3. Project Title:</td><td colspan="3">Utility-Scale Solar Power Project</td></tr>
<tr><td>4. Request for project funding (USD mill.):</td><td colspan="2">At time of country program submission (tentative):
IBRD: US$9 million</td><td>At time of project approval:</td></tr>
<tr><td>5. Estimated costs for MDB project implementation services (USD mill.):</td><td colspan="2">Initial estimate - at time of Country program submission:
IBRD: US$320,000
Final estimate - at time of project approval:</td><td>MDB: IBRD
Date:</td></tr>
<tr><td>6. Request for payment of MDB Implementation Services Costs (USD. mill.):</td><td colspan="2">☐ First tranche:
IBRD: US$100,000
☐ Second tranche:
IBRD: US$220,000</td><td></td></tr>
<tr><td>7. Project/program financing category:</td><td colspan="3">a - Investment financing - additional to ongoing MDB project ☐
b - Investment financing - blended with proposed MDB project ❖
c - Investment financing - stand-alone ☐
d - Capacity building - stand-alone ☐</td></tr>
<tr><td>8. Expected project duration (no. of years):</td><td colspan="3">4</td></tr>
<tr><td>9. Explanation of final estimate of MDB costs for implementation services:</td><td colspan="3">If final estimate in 5 above exceeds the relevant benchmark range, the exceptional circumstances and reasons: Not Applicable</td></tr>
<tr><td colspan="4">10. Justification for proposed stand-alone financing in cases of above 6 c or d: N/A</td></tr>
</table>

A.3 Geothermal Heat Pump and Solar Thermal Project

Problem Statement

One of the key challenges of the power sector is the emerging supply gap; (b) threatened supply reliability; and (c) increasingly unaffordable power tariffs.

Emerging power supply gap: Electricity plays an important role in space heating and hot water supply in Armenia, due to the dilapidation of other heating infrastructure. This exacerbates an emerging power supply gap. While Armenia currently has sufficient capacity to meet its demand, under the base-case power demand growth scenario, a generation capacity shortage of 230 MW will emerge in 2017 when the old and dilapidated Hrazdan TPP is phasing out (>40 years). The shortage is expected to reach 1,100 MW by 2030 if no new generation is built and the existing nuclear power plant is retired in 2026 (as currently planned).

Threatened energy security: Heavy reliance on imported fuels puts Armenia at risk of supply interruptions, price fluctuations, and possible outages. Armenia imports 100% of the gas it needs for heating and power generation as well as all the fuel for the nuclear reactor. Overall, 70% of Armenia's power generation and 100% of its non-electric heating demand depends on imported fuel.

Therefore, in order to reduce the impending capacity shortage and improve energy security, Armenia is committed to develop the country's indigenous renewable energy resources.

Geothermal heat pumps and solar water heaters can help reduce the need for new generation capacity, gas imports, and generate significant environmental benefits. Specifically, gas, wood and electricity account respectively for 50%, 30%, and 15% of heating fuels used by Armenian households.[42] Thus, increased deployment of geothermal heat pumps and solar water heaters will help reduce gas imports through reduction of demand for gas-based electricity and gas used for heating/hot water. Second, increased use of heat pumps and solar water heaters will also reduce the amount of illegal logging in the country.

There are a number of barriers that stand in the way of financing and implementing sustainable energy options. Energy conservation investment is hampered by a number of market imperfections that give rise to an "efficiency gap" – a discrepancy between the best available solution and the ones implemented. Commercial banks and their borrowers each face barriers.

Energy efficiency is also a priority. There exists significant potential for improvement of energy efficiency in Armenia. Armenia's energy intensity is about 2 times that of the EU-27 and energy prices are very high considering the income levels of the population (25% higher than OECD countries adjusted for PPP).

The EBRD credit line (Caucasus Energy Efficiency Program (CEEP)) which is currently active in Armenia helps to address the lack of financing for promotion of

[42] Dry animal dung accounts for remaining 5%. Source: National Statistical Service, 2013.

environmentally sustainable renewable energy technologies and energy efficiency measures as well as some other barriers mentioned below.

For commercial banks, the principal barriers are:

- Limited access to technical expertise for appraisal. Limited information and misconceptions about the technical risks and financial benefits of energy conservation.
- No specific understanding of marketing approaches for financing of such activities.
- Additional costs in appraisal, consideration and monitoring of sector specific projects.
- Access to adequate amounts of longer term funding. Longer term funding is necessary as sub-borrower tenors beyond the banks' current horizons are necessary for financing; this is driven by the barriers (perceived and real) that prevent sub-borrowers from pursuing energy efficiency.

For borrowers, the principal barriers are:

- Planning which has not taken into account the upward trend in energy prices.
- A tendency to focus on core business and short term investment outlook which stresses upfront costs rather than long term benefits. Also, expansion investments are more attractive than cost-reduction investments and tend not to take into account the potential for energy efficiency.
- The relatively high cost of capital which discourages "testing" of new technologies.
- In enterprises, a lack of dedicated in-house energy management expertise to assess and promote such projects. Normally, there is separation of responsibilities between energy expenditure and conservation. In the residential sector there is a lack of knowledge about alternative options. Aside from high upfront costs, uncertainty and lack of information about available options, best practice and related financial reward prevent investment decisions in favour of renewable technologies.
- Poor coordination between technical experts and management to understand the benefits of EE and convert it into investment decision
- Poor project management and capital investment appraisal skills

Project Objective

The project will be included under the planned extension EBRD's existing Caucasus Energy Efficiency Program (CEEP), subject to internal EBRD approval procedures. The CEEP seeks to increase investments in energy efficiency and renewables through financial intermediation, by providing financing for rational energy utilization, provide benefits in terms of energy resource utilization and assist in mitigating increasing energy prices and high energy intensity in Armenia. The project will add further volume to the funds available for renewable technologies under CEEP, and is fully additional.

The results of CEEP will lead to a package of projects that, in aggregate, will: (i) improve energy efficiency at the sub-borrower level and in the country as a whole, (ii) have a direct positive effect on rational energy utilization with the related environmental benefits, (iii) improve the commercial prospects of sub-borrowers, and (iv) demonstrate the benefits of rational energy utilization to other financiers and sub-borrowers. Grant resources for technical assistance will be utilized for project development and to overcome barriers to such investments.

Scope of Work

The geothermal heat pump and solar thermal project will be added to the existing EBRD CEEP program. Under this program, EBRD extends loans to local commercial banks for sub-lending to industrial companies for energy efficiency and rational energy utilization investments which include geothermal heat pumps and solar water heaters. Loans will also be extended on demand-drive basis:

Examples of renewable energy projects already in the pipeline or under implementation under CEEP include:

- Wind farms
- Run-of-river hydro or small hydro power Sub-projects
- Solar water systems generating hot water for processes and/or heating
- Biomass systems generating heat only or heat and electricity
- Gas engines using biogas
- Diesel engines using biodiesel
- Geothermal heat pumps

The SREP funding would lead to a significant scaling up of the activity in solar water heating and geothermal heat pumps, and enable a strong focus on the residential sector for these technologies.

The Project includes grant funding to engage consultants in order to prepare energy audits, review investment proposals, support companies in securing funding from PBs and implementation support. The project also supports advanced residential appliances which are currently promoted via a list of pre-approved eligible material and equipment available on line and an investment incentive of 10% to the end borrower. The geothermal heat pump and solar water heaters will be integrated in the list and will benefit from a higher incentive which rate will be calculated based on a market assessment of the barriers preventing their deployment.

Implementation Readiness

The CEEP is under implementation in Armenia with four commercial banks participating in the project as financial intermediaries, with a volume of committed funds of US$9 million. The implementation progress of the project has been satisfactory with 6 SME loans and 700 residential loans approved as of 30th April 2014 (USD 5 m utilized). The facility is expected to be extended in Armenia and total commitments in the country are expected to double.

Rationale for SREP Financing

Use of $3 million of SREP funds will help to increase the size of CEEP, while ensuring sufficient financing for geothermal heat pumps and solar water heaters until $20 million of E5P funds become available by 2016. By providing the SREP funding now, transformational impact will be achieved by sustainably growing the market in anticipation of the substantial funding increase expected from the E5P in the future. The use of credit lines through local banks and technical assistance will create an effective financing mechanism. The existing technical assistance package, financed by the Austrian Ministry of Finance, will ensure the pursuit of good lending opportunities that are well assessed.

The absence of long-term, low-cost capital is cited by Armenian geothermal heat pump and solar water heat suppliers as one of the main barriers to the technology's deployment. The SREP funding will help to ensure sufficient financing until other lager sources of financing become available, including possible expansion of EBRD CEEP project.

Expected Outcomes

The project is expected to have two principal results:

- Demonstration effects of successful implementation of geothermal heat pumps and solar water heating projects. This is expected to result in:
  - Commercial/economic success of the investments financed
  - Energy savings (in currency and/or kWh) as a result of the projects
  - Renewable capacity added (in kW)
- Transfer of skills. The project is also expected to transfer and build expertise, among both banks and companies, related to investments in geothermal heat pump and solar thermal technologies. The banks will build expertise in assessing the risk and creditworthiness of clients for such loans, while the enterprises are expected to become more familiar with bank requirements for providing loans. Individuals will become aware of the benefits of such investments and markets should be created for the supply of the technologies. The project is expected to contribute to lowering the transaction costs for financing sustainable energy investments and the facility's success would lead to more sustainable lending by commercial banks without the requirement for grant finance.

Financing Plan

Table 10.2 presents a plan for financing the geothermal heat pump and solar thermal project. As the table shows, US$3 million of SREP funding is expected to catalyze roughly 3 times as much investment, from the private sector (as equity or debt), or the commercial lending windows of the MDBs. The actual amounts financed by each will be determined once the resources if confirmed and as the project moves head.

Table 10.6: Indicative Financing Plan for Geothermal Heat Pump and Solar Thermal Project

SREP Project	SREP	Respon-sible MDB	Gov. of Armenia	MDBs	Private Sector (Equity)	Commercial/ Private arms of MDBs	Total
Development of Geothermal Heat Pumps and Solar Water Heaters	**(Million US$)**						
Investments in geothermal heat pumps and solar water heaters	3	EBRD	0	0	2	7	**12**
Subtotal: Geothermal heat pumps and solar water heaters	**3**		**0**	**0**	**2**	**7**	**12**
SREP Leverage	**3.0**						

Lead Implementing Agencies

EBRD will be the lead MDB for the project and the implementing agency, subject to internal EBRD approval processes. The SREP funding will be added to CEEP and on-lent to participating banks under the project.

It is expected that the project will be submitted to the SREP Sub-committee for no-objection approval by January 2015.

Project Preparation Grant

No project preparation grant is requested since the SREP funds will be added to ongoing project.

MDB Request for Payment for Project Implementation Services (MPIS)

<table>
<tr><th colspan="4">SCALING UP RENEWABLE ENERGY PROGRAM IN LOW-INCOME COUNTRIES
World Bank Request for Payment of Implementation Services</th></tr>
<tr><td>1. Country/Region:</td><td>Armenia/Eastern Europe, Central Asia</td><td>2. CIF Project ID#:</td><td>(Trustee will assign ID)</td></tr>
<tr><td>3. Project Title:</td><td colspan="3">Geothermal Heat and Solar Thermal Project</td></tr>
<tr><td>4. Request for project funding (USD mill.):</td><td colspan="2">At time of country program submission (tentative): US$3 million grant</td><td>At time of project approval: TBC</td></tr>
<tr><td rowspan="2">5. Costs for MDB project implementation services (USD mill.):</td><td colspan="2" rowspan="2">At time of Country program submission based on EBRD fees policy for grants: US$60,000</td><td>MDB: EBRD</td></tr>
<tr><td>Date: January 2015</td></tr>
<tr><td>6. Request for payment of MDB Implementation Services Costs (USD mill.):</td><td colspan="2">Tranche 1: US$60,000
Tranche 2: US$0</td><td>To be paid on disbursement of the grant to EBRD</td></tr>
<tr><td>7. Project/program financing category:</td><td colspan="3">a - Investment financing - additional to ongoing MDB project ☒
b- Investment financing - blended with proposed MDB project ☐
c - Investment financing - stand-alone ☐
d - Capacity building - stand alone ☐</td></tr>
<tr><td>8. Expected project duration (no. of years):</td><td colspan="3">3 years</td></tr>
<tr><td>9. Explanation of final estimate of MDB costs for implementation services:</td><td colspan="3">If final estimate in 5 above exceeds the relevant benchmark range,</td></tr>
<tr><td colspan="4">10. Justification for proposed stand-alone financing in cases of above 6 c or d: N/A</td></tr>
</table>

Annex B: Assessment of Absorptive Capacity

Armenia has sufficient absorptive capacity to implement the projects identified in the IP. This Appendix describes the macroeconomic; regulatory and institutional, technical and managerial dimensions of the country's absorptive capacity.

B.1 Macroeconomic Outlook

Armenia continues to recover from the impact of the global financial crisis. After a contraction of 14 percent in 2009, GDP has grown steadily. GDP grew at a rate of 2.2 percent in 2010, 4.7 percent in 2011, and 7.2 percent in 2012. GDP grew 7.5 percent in the first quarter of 2013.

Armenia's total external debt is estimated at 67.2 percent of GDP by the end of 2012, a large share of which is owed by the public sector. Public external debt has increased substantially since 2008, but does not yet breach indicative thresholds. Public external debt was about 16 percent of GDP at end-2008, reaching 35 percent of GDP at end-2011. Government efforts at fiscal consolidation have been showing results and with continued GDP growth, are projected to lead to a gradual reduction in the debt-to-GDP ratio.

Gross external financing (debt service payments) has remained around 3 percent of GDP over the last decade. During the recent IDA-16 Mid-Term Review, Armenia and a few similar countries were deemed ineligible for concessional financing under IDA-17.[43] However, Armenia applied for deferral of its graduation.

More recently, inflation has become a problem for Armenia, due largely to higher energy and food prices. The 12-month inflation was 3.2 percent in December 2012, well within the central bank's target range of 4±1.5 percent. However, in July 2013, the PSRC increased domestic natural gas and electricity tariffs to reflect an increase in the cost of gas imports from Russia. End-user natural gas and electricity tariffs were increased by 18 percent and 27 percent, respectively.

B.2 Legal, Regulatory and Institutional

A combination of policy, legal, regulatory and institutional reforms has helped to achieve remarkable results in the energy sector. Government has made a consistent—if often difficult—effort to create a legal, regulatory and institutional environment which provides good quality, reliable electricity supply that is affordable for end-users, and conducive to private sector investment.

Overview of Reforms

Armenia undertook major power sector reforms after the severe electricity crisis that followed independence. Between 1992 and 1996, customers suffered through brutal winters with little more than two hours of electricity per day. By 1995, fiscal and quasi-fiscal subsidies to the power sector had reached a level of roughly 11 percent of Armenia's GDP. Cash collections were around 50 percent, and nearly 25

[43] IDA (2012), "IDA16 Mid-Term Review Graduation Paper", Concessional Finance and Global Partnership (CFP), World Bank, September 2012.

and nearly 25 percent of all power produced disappeared before the meters as commercial losses (mostly electricity theft).

The power sector included the following.

- **Unbundling and privatizing the power system.** Efforts began in 1995 to unbundle the power system and privatize the power sector. Armenergo, the state-owned vertically integrated utility, was separated into generation and distribution entities. In March 1997, a Presidential Order and new Energy Law formalized separate generation, distribution, transmission and dispatch. During 2002-03, ownership of several major generating plants was transferred from the Government in exchange for state debt forgiveness.
- **Establishing an independent regulator.** The Presidential Order and the Energy Law enacted in 1997 established an independent energy sector regulator, the Armenian Energy Regulatory Commission (AERC). The Law on the Regulatory Body for Public Services, enacted in 2004, changed the name of the regulator to the Public Services Regulatory Commission (PSRC) and expanded its authority to other sectors, including water, drainage and sewage, and telecom.
- **Achieving sectoral financial sustainability.** Three steps were essential to increase collections, reducing commercial losses and improving the overall financial sustainability of the sector. The steps were:
  - Installing meters. Between 1997 and 1998, twelve thousand new tamper-proof meters were installed throughout the power system at a variety of voltage levels down to 0.4 kV. Residential customer meters were relocated to public areas. An Automated Metering and Data Acquisition System (AMDAS) was installed in 2001 and linked to a settlement center to facilitate accurate meter reading at the 110 kV and above
  - Bringing tariffs to cost recovery levels. In 1994, Armenia began a gradual transition to cost-based tariffs by bring household tariffs to the average level of other retail tariffs. A schedule was established for further household tariff hikes. Since 1999, household tariffs have remained well above the overall average tariff
  - Increasing transparency in collections and billing. The Electricity Distribution Company (EDC) installed a computerized customer information system to better track utilization and billing. In 1999, the EDC established a new collection scheme requiring bill payments at post offices instead of cash payments at local EDC offices, which reduced opportunities for collusion between customers and EDC inspectors

The result of the reforms are clear. Since 1996, 24-hour electricity service has been restored and gradually customers have switched to cheaper, more efficient gas heating. Meanwhile, tariff increases and operating efficiency improvements have helped create commercially viable service providers, technical and non-technical losses have decreased, and collections have increased. The energy sector is now one of the largest taxpayers in Armenia.

Reforms targeting renewable energy

The reform efforts have included the development of domestic energy resources that have helped to improve Armenia's security of energy supply. Energy security is a central concern of the Armenian Development Strategy (ADS) and National Security Strategy (NSS). These documents emphasize the importance of renewable energy and energy efficiency in addressing this concern.

In 2007, the PSRC set renewable energy feed-in tariffs to stimulate private investment in renewable energy. ENA is obliged to off-take all of the power generated by the new plants under the 15-year power purchase agreements mandated by the legislation. According to the feed-in tariff methodology, the PSRC must adjust feed-in tariffs annually in line with changes in inflation and the USD to AMD exchange rate fluctuations (USD/AMD for SHPPs, USD/EUR for wind). The feed-in tariff regime has been successful in attracting private investment in more than 200 MW of small hydropower.

B.3 Technical and Managerial

Public and private entities in Armenia have extensive experience working with MDBs and implementing MDB-financed projects.

- **MENR** has excellent technical staff with long-standing experience in the power sector reform process. MENR also enjoys the support of the Energy Institute CJSC, a research entity with extensive experience in Armenia's energy sector.
- **The R2E2 Fund** is a non-profit organization established by the Government in 2005 with the mandate to promote the development of renewable energy and energy efficiency markets in Armenia and to facilitate investments in these sectors. The implementation of the project as well as overall R2E2 Fund operations will be supervised by the Board of Trustees (BOT), consisting of representatives of government agencies, NGOs, and the private sector, thus, ensuring required professional expertise. The BOT is chaired by the Minister of Energy and Natural Resources.

  The R2E2 Fund has strong experience in implementing donor-financed projects. For the World Bank it is currently implementing the GeoFund 2: Armenia Geothermal Project, and in the past has implemented several World Bank-financed projects including the Urban Heating Project, Renewable Energy Project and an Electricity Supply Reliability Project.
- **Private banks.** As describe elsewhere in this document, there are a number of commercial banks in Armenia (Ameria Bank, Analik Bank, HSBC, Byblos Bank and others) who have experience on-lending donor funds for renewable energy projects.

Annex C: Stakeholder Consultations

Armenia's SREP Investment Plan is the result of an extensive internal and public consultation process, led by the Government of Armenia and represented by the Ministry of Energy and Natural Resources, to identify priorities in the development of renewable energy technologies for electricity and heating. The consultations included a wide range of government agencies, as well as representatives from the private sector, civil society, and academia. Discussions were informed by the analysis of the Renewable Resources and Energy Efficiency (R2E2) Fund and its consultants.[44] Feedback was sought through many one-on-one meetings, a workshop with the Government's SREP working group, as well as an open forum.

Scoping Mission (July 2-12, 2012)

The purpose of the scoping mission was to explore potential areas of engagement for SREP, and discuss plans for preparing the investment plan.

The scoping mission included discussions with MENR, PSRC, donors and bilateral agencies (KfW, USAID, UNDP, JICA, UNIDO), R2E2 Fund, the Energy Institute of the Republic of Armenia, commercial banks and several private sector entities engaged in renewable energy projects. A consultative workshop was also held and attended by 60 participants from the Government, private sector, donors, and academia. In addition, the MDB team also conducted site visits to two small hydro power plants, a biogas power plant, and a solar water heating installation.

First Joint Technical Mission (June 3-6, 2013)

The purpose of the first joint technical mission was to get feedback on the set of criteria to be used to evaluate and prioritize projects for the IP, and to collect data for use in evaluating each technology or resource against the criteria.

The first joint technical mission included discussions between MENR, Ministry of Finance, R2E2 Fund, its consultants, and the MDB team working on SREP. R2E2 Fund and its consultants also met with HVEN, the Armenian Power System Operator, a private geothermal heat pump developer, the Armenian Scientific Research Institute of Energy, the Institute of Geological Sciences at the National Academy of Sciences of Armenia, commercial banks, Yerevan Municipal Government, and various technical experts in geothermal, solar and other technologies being considered.

Second Joint Technical Mission (August 28-September 3, 2013

The purpose of the second joint technical mission was to solicit feedback from stakeholders on substantive portions of the draft IP. The second joint technical mission included discussions between MENR, Ministry of Finance, R2E2 Fund, its consultants, the MDB team working on SREP, and other key stakeholders.

The analytical work completed in preparing the IP included a comprehensive assessment of renewable energy technologies identified during the first technical

[44] Lists of stakeholders consulted during the joint missions are also available in various Aide-Memoire posted on the Climate Investment Funds (CIF) website (https://www.climateinvestmentfunds.org/cifnet/country/armenia).

mission. The technologies included: wind: utility-scale solar PV; concentrating solar PV, distributed solar PV, small hydropower, pumped storage hydropower, wastewater treatment plant (WWTP) biogas-to-power, agricultural biogas-to-power, landfill biogas-to-power, biomass (wood/grain), geothermal power, solar thermal water heating, geothermal district heating and geothermal heat pumps.

The mission included two stakeholder consultation workshops to get feedback on the analysis:

- **On August 30, 2013**, the proposed priority RE technologies to be developed in Armenia were presented to the multi-sectoral task force established in 2011 for review/discussion of issues pertaining to development of renewable energy and energy efficiency in the country. The task force approved the priority RE technologies proposed to be supported under the SREP IP.
- **On September 2, 2013**, the Government also organized open public consultations with representatives of civil society, NGOs, private sector, project developers, research institutions, academia, and donor organizations. The participants were overall supportive of main findings, conclusions and recommendations regarding priority RE technologies to be supported in Armenia. There was unanimous support for development of utility-scale PV, given consensus on the estimated large potential and increasingly attractive unit costs of energy given significant reduction in module costs over the last several years. The participants also suggested to include in the priority list some RE technologies, which had low levelized energy costs (LEC) and other benefits, such as biogas, however, the Government noted the limited potential for scaling up those technologies in the country.

In addition to the two workshops, the main findings of the analysis and proposed RE priorities were posted on the web-site of the R2E2 Fund for public comments.[45]

[45] On August 24, 2013.

Annex D: Co-Benefits

Section 5 highlighted some of the environmental, social and gender co-benefits likely to result from Armenia's SREP IP. This section focuses specifically on the co-benefits tracked under SREP's Revised Results Framework (as of June 1, 2012). Annex Table D.1 lists the co-benefits considered under SREP's Revised Results Framework, and describes how those co-benefits will be achieved in Armenia.

Annex Table D.1: Co-Benefits Associated with SREP Impacts and Outcomes

Results	Co-benefits	Description
SREP Transformative Impact		
Support low-carbon development pathways by increasing energy security.	Avoided GHG emissions	▪ As described in Section 0, all of the technologies in Armenia's SREP IP could be used to offset thermal generation during daily dispatch, and ultimately forestall the need for additional thermal (nuclear or gas) generation. The generation government has targeted for new solar and geothermal plants promises to offset roughly 83,000 tonnes of CO_2 by 2020 and 234,000 tonnes of CO_2 by 2030.[46]
	Employment opportunities	▪ Potential short-term job creation during exploration of the geothermal site. Potential for both short and long-term job creation during the development and operations of a geothermal and utility-scale solar PV plant. Estimates from one study suggest that geothermal project funded by SREP could generate as many as 850 job-years, and the solar project could generation 237 job-years.[47] ▪ Given the remote location and rural nature of the Karkar geothermal site and the Gegharkunic Marz solar site, the projects could also help reduce rural unemployment in the surrounding areas. ▪ Solar thermal and geothermal heat pump technologies will create short and potentially long term jobs in project installation and operations (jobs for operations are only expected for larger systems). Given the size of the resource potential it is possible that an entire industry could around installation, thus creating many jobs. ▪ Some components of geothermal heating and solar thermal systems can be manufactured in Armenia. A large domestic market for these technologies could encourage the development of a domestic manufacturing industry

[46] Given Armenia's estimated Grid Emissions Factor of 181 g CO_2/kWh, based on estimate by the Climate Registry (http://www.theclimateregistry.org/downloads/2013/01/2013-Climate-Registry-Default-Emissions-Factors.pdf)

[47] Job-years are calculated instead of just calculating "jobs" because each technology creates both short-term and long-term jobs. In order to compare each technology using just a single metric, "job-years" created over the life of the project are calculated. These are estimated using the costs estimated for each technology in this project and data from Wei M., Patadia S., Kammen D.M. (2008) 'Putting renewables and energy efficiency to work: how many jobs can the clean energy industry generate in the US?'p.14. Note that job creation estimates presented here are somewhat uncertain because estimates of the job creation potential of renewable technologies are only available for developed countries.

		for renewable heating technologies.
SREP Program Outcomes		
Increased supply of renewable energy (RE) New and additional resources for renewable energy projects/programs	Increased reliability	▪ All of the technologies in Armenia's SREP IP would ultimately improve long-term reliability of supply, by strengthening energy security and reducing the risk that fuel supply interruptions could lead to reliability problems. The technologies are effectively a hedge against future gas import price hikes. ▪ The geothermal power project could, in particular, improve supply reliability because it represents a potential source of base load generation, rather than interruptible supply. ▪ Grid enhancements required to connect the solar PV and geothermal projects may also offer improvements in grid reliability. ▪ Investments in geothermal heat pumps, and solar thermal can also improve reliability of supply. Geothermal heat pumps and solar thermal projects reduce dependence on imported natural gas.
	Reduced costs of RE	▪ SREP support for exploratory drilling at Karkar will reduce the generation tariff required by private investors because the grants (or insurance) will be used to absorb the cost of the riskiest stage of development of a geothermal site. ▪ SREP capital contributions for utility-scale solar PV will reduce the generation tariff required by the first plant(s). More importantly, SREP support will pave the way for more competitive solar PV plants in the future, by giving Armenia some experience in utility-scale solar PV. This early experience will help to bring down the costs of future plants and improve investors' perceptions of the risk of utility-scale solar in Armenia. ▪ Credit lines for geothermal heat pumps, solar thermal and rooftop solar PV will help make these technologies more affordable by resolving the cash-flow constraints preventing investors from using them.

Annex E: Existing Activities in the Field of Renewable Energy

Existing activities in the field of renewable energy in Armenia involve the continued development of private small HPPs, the rehabilitation of existing large HPPs and the development of some new large HPPs, the exploration of the Karkar geothermal site, and the implementation of some small pilot renewable heating projects. This Annex describes each of these activities.

Hydropower Project Rehabilitation and Development

Small HPPs make up the vast majority of Armenia's renewable energy industry (excluding from large HPPs). As of May 2013, 221 MW of small HPPs are operating, and 168 MW of SHPPs have received licenses for development from the PSRC. Small HPP development has been supported by both private, commercial banks in Armenia, as well as international development banks. KfW has been supporting the development and rehabilitation of small HPPs through Ameria Bank and other commercial banks in Armenia. Through this program, domestic commercial banks have been able to offer relatively low-cost, long-term capital for small HPP development.

There has also been activity in the large hydropower industry. EBRD is financing the rehabilitation of the Sevan-Hrazdan HPP and KfW is financing the rehabilitation of the Vorotan cascade. Iran is allegedly providing financing for the construction of the Meghri hydropower project, which is scheduled to come online in 2021. The energy from the Meghri plant is expected to go to Iran for the first 15 years of its operation before ownership of the plant is given to Armenia.

Geothermal

The World Bank has financed ongoing assessments of the Karkar geothermal site, including an economic and financial appraisal of a potential plant at the site. In September 2013, a team of World Bank staff and consultants traveled to the Karkar site to identify next steps for surface studies and exploratory drilling at the site.

Renewable Heating

Recently, two solar thermal heating projects have been implemented in the Shirak region of Armenia, through the GEF Small Grants Programme. One of these projects involved the implementation of solar thermal heating at a housing complex, and reduced natural gas consumption by approximately 40 percent. The other project was implemented at a kindergarten, and there are plans to expand the project to a nearby greenhouse. Greenhouses are major consumers of heat energy in Armenia and this project could provide valuable demonstration benefits for this particular implementation of renewable heat technologies.

Annex F: Assumptions Used in Estimating Levelized Energy Costs

Annex Table F.1: Commercial Financing Assumptions

Assumption	*Units*	*Value*
Debt percentage	%	70%
Equity percentage	%	30%
Debt interest rate	%	10.69%
Equity return	%	18.00%
Income tax rate	%	20.00%
Loan term	Years	20
Inflation	%	2%

Annex Table F.2: Concessional Financing Assumptions

Assumption	*Units*	*Value*
Debt percentage	%	100%
Equity percentage	%	0%
Debt interest rate	%	3%
Equity return	%	0%
Income tax rate	%	20.00%
Loan term	Years	20
Inflation	%	2%

Annex Table F.3: Plant-Specific Assumptions

											Allocation of construction cost					
Resource ID	Technology	Net capacity	Capacity factor	Heat rate	Fuel type	Asset life	Capital cost	Fixed O&M	Non-fuel variable O&M	Output degradation / year	1	2	3	4	5	6
		(MW)	(%)	(BTU/ kWh)		(Years)	(US$/MW net capacity)	(US$/kW-yr)	(US$/kWh)	%	(%)	(%)	(%)	(%)	(%)	(%)
North Karakhach	Wind	80	23	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
Karakhach Pass	Wind	100	27	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
Eastern Karakhach	Wind	40	21	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
Pushkin Pass	Wind	25	23	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
E. Pambak mountains	Wind	60	20	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
Semyonovka Pass	Wind	35	20	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
Areguni mountains	Wind	50	19	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
Sotk Pass	Wind	50	31	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
Fontan	Wind	75	21	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
Sisian Pass	Wind	100	30	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
Western Goris	Wind	50	19	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
South Shamb	Wind	60	23	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
South Harjis	Wind	50	21	0		20	2,200,000	50	0	0.0%	33	33	33	0	0	0
FPV-1	Fixed PV	20	21	0		25	2,500,000	25	0	0.7%	100	0	0	0	0	0
FPV-2	Fixed PV	35	25	0		25	2,500,000	25	0	0.7%	100	0	0	0	0	0

											Allocation of construction cost					
Resource ID	Technology	Net capacity	Capacity factor	Heat rate	Fuel type	Asset life	Capital cost	Fixed O&M	Non-fuel variable O&M	Output degradation / year	1	2	3	4	5	6
		(MW)	(%)	(BTU/ kWh)		(Years)	(US$/MW net capacity)	(US$/kW-yr)	(US$/kWh)	%	(%)	(%)	(%)	(%)	(%)	(%)
FPV-3	Fixed PV	193	23	0		25	2,500,000	25	0	0.7%	100	0	0	0	0	0
FPV-4	Fixed PV	200	25	0		25	2,500,000	25	0	0.7%	100	0	0	0	0	0
FPV-5	Fixed PV	59	24	0		25	2,500,000	25	0	0.7%	100	0	0	0	0	0
FPV-6	Fixed PV	94	25	0		25	2,500,000	25	0	0.7%	100	0	0	0	0	0
FPV-7	Fixed PV	74	25	0		25	2,500,000	25	0	0.7%	100	0	0	0	0	0
FPV-8	Fixed PV	79	24	0		25	2,500,000	25	0	0.7%	100	0	0	0	0	0
FPV-9	Fixed PV	82	23	0		25	2,500,000	25	0	0.7%	100	0	0	0	0	0
TPV-1	Tracking PV	20	25	0		25	3,375,000	30	0	0.7%	100	0	0	0	0	0
TPV-2	Tracking PV	35	30	0		25	3,375,000	30	0	0.7%	100	0	0	0	0	0
TPV-3	Tracking PV	193	28	0		25	3,375,000	30	0	0.7%	100	0	0	0	0	0
TPV-4	Tracking PV	200	30	0		25	3,375,000	30	0	0.7%	100	0	0	0	0	0
TPV-5	Tracking PV	59	29	0		25	3,375,000	30	0	0.7%	100	0	0	0	0	0
TPV-6	Tracking PV	94	31	0		25	3,375,000	30	0	0.7%	100	0	0	0	0	0
TPV-7	Tracking PV	74	30	0		25	3,375,000	30	0	0.7%	100	0	0	0	0	0
TPV-8	Tracking PV	79	28	0		25	3,375,000	30	0	0.7%	100	0	0	0	0	0
TPV-9	Tracking PV	82	27	0		25	3,375,000	30	0	0.7%	100	0	0	0	0	0
CPV-1	Concentrating PV	52	12	0		25	3,250,000	35	0	0.7%	100	0	0	0	0	0
CPV-2	Concentrating PV	91	18	0		25	3,250,000	35	0	0.7%	100	0	0	0	0	0
CPV-3	Concentrating	193	16	0		25	3,250,000	35	0	0.7%	100	0	0	0	0	0

											Allocation of construction cost					
Resource ID	Technology	Net capacity	Capacity factor	Heat rate	Fuel type	Asset life	Capital cost	Fixed O&M	Non-fuel variable O&M	Output degradation / year	1	2	3	4	5	6
		(MW)	(%)	(BTU/ kWh)		(Years)	(US$/MW net capacity)	(US$/k W-yr)	(US$/kWh)	%	(%)	(%)	(%)	(%)	(%)	(%)
	PV															
CPV-4	Concentrating PV	225	18	0		25	3,250,000	35	0	0.7%	100	0	0	0	0	0
CPV-5	Concentrating PV	264	17	0		25	3,250,000	35	0	0.7%	100	0	0	0	0	0
CPV-6	Concentrating PV	109	20	0		25	3,250,000	35	0	0.7%	100	0	0	0	0	0
CPV-7	Concentrating PV	74	19	0		25	3,250,000	35	0	0.7%	100	0	0	0	0	0
CPV-8	Concentrating PV	79	17	0		25	3,250,000	35	0	0.7%	100	0	0	0	0	0
CPV-9	Concentrating PV	82	16	0		25	3,250,000	35	0	0.7%	100	0	0	0	0	0
CSP-1	Concentrating solar power	52	15	0		25	7,500,000	100	0	0.0%	25	25	25	25	0	0
CSP-2	Concentrating solar power	91	25	0		25	7,500,000	100	0	0.0%	25	25	25	25	0	0
CSP-3	Concentrating solar power	193	20	0		25	7,500,000	100	0	0.0%	25	25	25	25	0	0
CSP-4	Concentrating solar power	225	25	0		25	7,500,000	100	0	0.0%	25	25	25	25	0	0
CSP-5	Concentrating solar power	264	23	0		25	7,500,000	100	0	0.0%	25	25	25	25	0	0
CSP-6	Concentrating	109	27	0		25	7,500,000	100	0	0.0%	25	25	25	25	0	0

Resource ID	Technology	Net capacity	Capacity factor	Heat rate	Fuel type	Asset life	Capital cost	Fixed O&M	Non-fuel variable O&M	Output degradation / year	Allocation of construction cost 1	2	3	4	5	6
		(MW)	(%)	(BTU/ kWh)		(Years)	(US$/MW net capacity)	(US$/kW-yr)	(US$/kWh)	%	(%)	(%)	(%)	(%)	(%)	(%)
	solar power															
CSP-7	Concentrating solar power	74	26	0		25	7,500,000	100	0	0.0%	25	25	25	25	0	0
CSP-8	Concentrating solar power	79	22	0		25	7,500,000	100	0	0.0%	25	25	25	25	0	0
CSP-9	Concentrating solar power	82	20	0		25	7,500,000	100	0	0.0%	25	25	25	25	0	0
Dist PV-Yerevan	Rooftop PV	25.6	16	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Aragatsotn	Rooftop PV	0.64	16	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Ararat	Rooftop PV	2.56	16	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Armavir	Rooftop PV	3.2	16	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Gegharquniq	Rooftop PV	2.56	17	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Lori	Rooftop PV	7.68	13	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Kotayq	Rooftop PV	5.76	16	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Shirak	Rooftop PV	5.76	17	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Syniq	Rooftop PV	3.2	16	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Vayots Dzor	Rooftop PV	0.64	17	0		25	6,875,000	0	0	0.7%	100	0	0	0	0	0
Dist PV-Tavush	Rooftop PV	1.92	16	0		25	6,875,000	0	0	0.7%	100 %	0	0	0	0	0

											Allocation of construction cost					
Resource ID	Technology	Net capacity	Capacity factor	Heat rate	Fuel type	Asset life	Capital cost	Fixed O&M	Non-fuel variable O&M	Output degradation / year	1	2	3	4	5	6
		(MW)	(%)	(BTU/ kWh)		(Years)	(US$/MW net capacity)	(US$/kW-yr)	(US$/kWh)	%	(%)	(%)	(%)	(%)	(%)	(%)
Jermaghbyur	Geothermal	25	89	0		25	3,750,000	0	0.036	0.0%	32%	51	17	0	0	0
Georgian border	Geothermal	25	89	0		25	3,750,000	0	0.036	0.0%	32%	51	17	0	0	0
Karkar - Kalex	Geothermal	6	84	0		25	15,906,000	203.13	0	0.0%	15%	55	30	0	0	0
Karkar - ORC	Geothermal	6	84	0		25	11,687,000	203.13	0	0.0%	13%	54	32	0	0	0
Karkar - Flash	Geothermal	28.5	96	0		25	3,723,000	70.18	0	0.0%	32%	51	17	0	0	0
Ararat HPPs	Small HPP	5	41	0		30	2,000,000	$33.48	0	0.0%	33%	33	33	0	0	0
Aratsotn HPPs	Small HPP	3.5	41	0		30	2,000,000	$30.99	0	0.0%	33%	33	33	0	0	0
Gegharkunik HPPs	Small HPP	7.7	47	0		30	2,000,000	$32.79	0	0.0%	33%	33	33	0	0	0
Kotaik HPPs	Small HPP	3.6	32	0		30	2,000,000	$27.69	0	0.0%	33%	33	33	0	0	0
Lori HPPs	Small HPP	12.9	45	0		30	2,000,000	$35.16	0	0.0%	33%	33	33	0	0	0
Shirak HPPs	Small HPP	1.1	51	0		30	2,000,000	$36.24	0	0.0%	33%	33	33	0	0	0
Syunik HPPs	Small HPP	28.1	42	0		30	2,000,000	$31.77	0	0.0%	33%	33	33	0	0	0
Tavush HPPs	Small HPP	20.8	45	0		30	2,000,000	$33.15	0	0.0%	33%	33	33	0	0	0
Vayuts Dzor HPPs	Small HPP	7.9	32	0		30	2,000,000	$26.16	0	0.0%	33%	33	33	0	0	0
Wood biomass	Biomass	4	85	16,500	Wood biomass	20	5,000,000	$250.00	0	0.0%	25%	25	25	25	0	0
Grain biomass	Biomass	25	85	13,648	Grain biomass	20	4,000,000	$200.00	0.005	0.0%	25%	25	25	25	0	0
Araks	Biogas	1.4	90	0		20	3,876,000	$58.00	0	0.0%	33%	33	33	0	0	0

											Allocation of construction cost					
Resource ID	Technology	Net capacity	Capacity factor	Heat rate	Fuel type	Asset life	Capital cost	Fixed O&M	Non-fuel variable O&M	Output degradation / year	1	2	3	4	5	6
		(MW)	(%)	(BTU/ kWh)		(Years)	(US$/MW net capacity)	(US$/kW-yr)	(US$/kWh)	%	(%)	(%)	(%)	(%)	(%)	(%)
Trchnafabrika CJSC																
Arzni Pedigree PBS OJSC	Biogas	0.8	90	0		20	3,997,000	$85.00	0	0.0%	33%	33	33	0	0	0
Armavir Poultry Farm	Biogas	1.1	90	0		20	2,665,000	$61.00	0	0.0%	33%	33	33	0	0	0
Nubarashen landfill	LFG	2.5	90	0		20	1,500,000	$0.00	0.01	0.0%	50%	50	0	0	0	0
Yerevan WWTP	WWTP	3	90	0		20	1,680,000	$70.00	0	0.0%	33%	33	33	0	0	0
Aghbyurak HPS	Pumped storage hydro	150	57	0		30	2,800,000	$93.33	0.0523	0%	33%	33	33	0	0	0
Tolors HPS	Pumped storage hydro	150	57	0		30	2,800,000	$93.33	0.00523	0%	33%	33	33	0	0	0
Shamb HPS	Pumped storage hydro	150	57	0		30	2,800,000	$93.33	0.00523	0%	33%	33	33	0	0	0

Annex G: Comments from Independent Technical Reviewer

Mr. Mike Allen provided an independent technical review of the investment plan. He reviewed two drafts of the Investment Plan, one from September 2013, and a revised draft from April 2014. His comments on each of the drafts, and the Government of Armenia's replies, are included below.

Reviews of Mr. Allen's responses prompted a request for memoranda prepared by Iceland Geosurvey for the World Bank. Those memoranda are contained in Annex H.

Independent Technical Reviewer: Mike Allen

Comments delivered on September 30th, 2013

1.0 Introduction

The review of the Investment Plan for Armenia has been undertaken ahead of the submission of the plan to the SREP Sub-Committee of the Strategic Climate Funds, within the Climate Investment Funds at the World Bank.

These notes are based on a review of the draft plan of 18th September 2013; it should be noted that the reviewer has not visited Armenia nor been involved in the preparation of this plan. The lack of a visit to Armenia and direct contact with the ministries, agencies, institutions and various stakeholders has an impact on some of the interpretations that have been drawn in this review; the reviewer has not been involved with energy opportunities in Armenia so has limited familiarity with the energy situation in the region.

It is recognised that, as stated in the IP, "*Armenia's population has nearly universal access to electricity and natural gas energy resources, therefore Armenia's IP is not about access to modern energy services but about using renewables to improve energy security and reliability, and reduce the future cost of supply. Energy security, reliability and cost are challenges that investments in renewable energy can help overcome given Armenia's unique energy context"* and it is in this context that this review has been undertaken.

Given the specific areas of focus under the Plan, geothermal, utility scale solar and development of geothermal heat pump and solar-thermal projects, the review first considers each of the sectors then summarises the overall compliance under SREP criteria.

2.0 Specific Comments on Investment Plan

2.1 Geothermal Power Development

Current Situation

Based on the information presented in the report, independent background work and brief correspondence with those who have prepared the IP, there does not appear to be a strong case to support the use of SREP funds for geothermal exploration.

It is acknowledged that geothermal exploration finance is difficult to source but the IP and background suggest that:

- The Karkar geothermal prospect is not well understood and exploration data gathered to date does not appear to provide a convincing model of a resource at a stage where drilling should be immediately contemplated;

***Response**: The Karkar geothermal field was thoroughly studied through a number of comprehensive surface studies: (a) field scouting; (b) magneto-telluric investigation study (MT); (c) independent interpretation of the results of MT study; (d) 3D MT study; and (e) independent interpretation of the results of 3D MT study. Those studies were led by reputable international consulting firms specializing on geothermal energy. Moreover, the recommendations and key findings of those studies were reviewed by the Iceland Geosurvey (ISOR), which confirmed that the methodology employed for the surface studies was robust, the key results indeed confirm that the Karkar is a geothermal site, and that the only way to confirm the suitability of resource for power generation is to conduct exploratory drilling.*

- Assumptions in giving geothermal a high ranking in terms of potential and cost are not substantiated in the IP nor by background documents;

***Response:** Geothermal power is assigned the second lowest ranking in terms of "scale-up potential." However, this is partially because of the fact that Armenia's geothermal resources have not been well-explored (except for Karkar site) and it is possible that there is more resource potential than has been quantified here.*

- Indications are that any resource at Karkar will be of modest temperatures; all analyses and cost comparisons in the IP assume a high temperature resource; lower temperatures resources are acknowledged in the IP as non-competitive;

***Response**: The temperature of the resource cannot be known for sure until the exploratory drilling is conducted and flow testing, chemical sampling and analyses is completed. The surface studies that were conducted for Karkar site and are described in the IP concluded that two conceptual geothermal models or their combination might exist for the Karkar site:*

***Model A**: Model A assumes that low resistance is not present in the geothermal zones of interest. In such a case, Model A would provide only for a diffuse source of heat and characterizes the field as a reservoir of moderately warm waters (less than 100^{o}C).*

***Model B**: Model B assumes that low resistance may be present in geothermal zones of interest. In such a case, Model B would provide for a localized high-temperature source of heat. Along with this, some of the layers could be characterized as a reservoir of high-temperature water (more than 250^{o}C).*

The definitive answer on the characteristics of the geothermal resource can be obtained only after exploratory drilling.

The costs are presented in the IP for a high-temperature resource because it is assumed that project development will only occur if a high-temperature resource is identified at the site through the exploratory well drilling.

- The assumption that with this background that an IPP can be attracted to contribute as indicated is probably unrealistic meaning that additional public funds would be required to move any successful project forward.

***Response**: It is recommended that SREP funding supports these exploration activities and IPP investment is assumed to follow if successful exploration is carried out. Therefore, it is assumed that*

an IPP will not be attracted with the background information available in the IP, but rather with a confirmed geothermal resource that has been identified through exploratory drilling.

Near Term Consideration of Geothermal

Accepting that the geothermal potential may be limited, if there is a consensus that the case for further investment is unclear, the use of limited funds from SREP to convene a focused peer review of current status could be considered.

It is not suggested that the allocation of a larger portion of SREP funds be predicated on the outcome of such a review but more that it may be reasonable to use funds (less than suggested for the feasibility study) to attempt to provide a more definitive assessment of the Karkar resource. If the review were to provide a convincing argument to consider the next stage of exploration at Karkar then it could be used to seek alternative funding.

Response:* *We are confident that any additional study for Karkar site will generate marginal amount of useful information and data. Therefore, we are convinced that exploratory drilling is the warranted next step to be undertaken to confirm the resource. As mentioned above, all of the above studies conducted for Karkar concluded that exploratory drilling is warranted. The need for and the justification for exploratory drilling was also confirmed by the independent reviewers (ISOR from Iceland) of the key conclusions and recommendations of the geo-technical studies conducted for Karkar.

Recommendation on Geothermal Power

At this stage it is not recommended that SREP funds be directed into geothermal power development, other than in supporting a review as outlined above.

Response: We do not think that the level of knowledge about the Karkar site will benefit from further reviews as outlined above.

2.2 Utility Scale Solar

General compliance

While there is limited solar PV experience at any large scale, the potential has been identified and the construction of commercial, grid connected units reflects international experience. It is noted that there are nationally based companies engaged in this field and that there is a strong R&D background in the field within Armenian academia.

It is understood that to encourage private sector participation that part of the SREP funds may be made available to help buy down the initial capital costs, Help is being sought to develop an acceptable FIT and also to work with the government in agreeing how private sector participation will be structured.

Capacity to execute and technical assessment of proposed approach

There are a number of barriers that have been recognised as hampering the growth in the sector and these have been identified within the Plan. It is suggested that these are manageable; the technology risk is largely one of lack of familiarity coupled with a lack of education amongst the population about the benefits they can bring.

Although the market has been opened up, and success in attracting IPPs noted in the small hydro power sector, it is also noted that there are administrative and regulatory issues that may hamper quick uptake by the private sector of other technologies.

The Plan is non-specific about which institutions will address these issues but it paints a positive picture of government activities in the sector and its privatisation over recent years. It is noted that at all stages SREP will be consulted as strategies, structures and plans are being prepared and adequate monitoring and evaluation will be mutually important to ensure success.

Impact

The plan outlines the use of funds to provide support to a broader MDB and donor funded programme which is envisaged will provide utility solar electricity of some 30 MW in total capacity. This is based on obtaining a total of $70.75m (SREP $24.5m; MDBs $24.5m and $21m from private sector / commercial banking sources). The securing of these additional funds and the active engagement of the private sector is obviously critical to the level of impact that will be achieved.

Use of investment; capturing and dissemination of lessons learned; stakeholder engagement

This is all a new venture and so there is no real history of such development in Armenia to draw on. It will be important that there be an open and transparent sharing of information and experiences as the project is planned and implemented.

Social considerations

It is recognised that the challenge for Armenia is to build security of supply as all have access to energy but the geo-political and energy supply dependency of the country are the key issues to be addressed with the focus on renewables. The normal benefits of renewables in terms of emission reductions will of course apply.

Attraction of additional investment

The programme proposed for the utility solar project is heavily dependent on access to investment from a number of groups as noted above. It is unclear what the level of commitments from other sources is at this stage. There is however a provision for support with transaction services that should help overcome recognised bottlenecks but project implementation will only be achieved to the level that available funds allow.

Overall Summary

The utility solar programme is aggressive but appears to offer one of the better options for Armenia in looking towards growth in renewables. Tackling solar PV on a larger scale basis should offer quicker growth in this sector and the combination of SREP, MDB and private financing provides a potentially balanced scenario for this growth. The project is a mix of public demonstration of commercial viability of this opportunity and then the securing of financing from MDB and private sector sources; increasing the scale of activities and drawing all the elements of the programme together, while addressing the issues that have been seen as bottlenecks in the past, will require strong strategic planning and on-going review to ensure that the anticipated growth target can be met.

2.3 Geothermal Heat Pump and Solar-Thermal Projects

General compliance

To date there have been limited developments utilising geothermal heat pumps and/or solar thermal installations. However given the heating needs within Armenia and the opportunity that these approaches may give to displace the use of gas, this programme appears appropriate. Small scale projects (supported by GEF) have helped begin to demonstrate the viability of solar thermal installations.

The structure of this project suggests that the intention is to hold this largely within the public sector with financing predominantly from MDB resources.

It is noted that there are nationally based companies engaged in these fields.

Capacity to execute and technical assessment of proposed approach

As with solar PV, there are a number of barriers that have been recognised as hampering the growth in the sector and these have been identified within the Plan. It is suggested that these are manageable; the technology risk is largely one of lack of familiarity coupled with a lack of education amongst the population about the benefits they can bring.

Impact

The plan outlines the use of funds to prepare proposals to gain support from MDBs. It is suggested that obtaining a total of $45m from MDBs would allow dissemination of these technologies in public buildings ($15m) and private facilities ($30m). The securing of these funds and an active programme outside the public sector is obviously critical to the level of impact that will be achieved.

Use of investment; capturing and dissemination of lessons learned; stakeholder engagement

This is all a new venture and so there is no real history of such development in Armenia to draw on. As with the solar PV, it will be important that there be an open and transparent sharing of information and experiences as the projects are planned and implemented.

Social considerations

It is recognised that the challenge for Armenia is to build security of supply as all have access to energy but the geo-political and energy supply dependency of the country are the key issues to be addressed with the focus on renewables. The normal benefits of renewables in terms of emission reductions will of course apply.

Attraction of additional investment

The programme proposed for the geothermal heat pump and solar thermal project is heavily dependent on access to investment from MDBs as noted above. It is unclear what the level of commitments from these sources is at this stage.

Overall Summary

The geothermal heat pump and solar thermal programme is aggressive but appears to offer a constructive option for Armenia in looking towards growth in the non-electric use of renewables. Developing both technologies on a larger scale basis should offer quicker growth in this sector but access to MDB financing is clearly critical.

3.0 Compliance with SREP

Key focuses within the SREP programme can be summarised under the following headings; the response of the Plan to each of these aspects is noted in the following comments. The exception to use of funds for geothermal is noted again.

Catalyse increased investments in renewable energy:

The plan outlines how it is anticipated that SREP investments and programme support will help attract other public and private funding. This is explained in some detail. What is less clear is which government agencies will provide the leadership during implementation. Overall there is no information on the governance of the SREP programme as such.

Response: ***This comment is well-noted. Additional description of implementation modalities will follow in a subsequent draft.***

Enabling environment

The plan acknowledges that there are a number of remaining hurdles to renewable implementation; there are however no clear strategies or allocation of responsibilities to particular agencies to address these. It is assumed that a more definitive strategy will be developed ahead of the release of SREP funding. The proposal to assist with transactional services in the solar sector should offer additional encouragement for private sector participation.

***Response:* This comment is well-noted. Additional description of strategies for improving the enabling environment in specific agencies will follow in a subsequent draft.**

Increase energy access:

As noted, access to energy is not an issue for Armenia; the focus of SREP supported activities is the development of a reliable, cost effective and secure supply of national energy going forward.

Implementation capacity:

The IP explains that the entity responsible for facilitating renewable energy development in Armenia is the R2E2 Fund. The R2E2 Fund was formed in 2006 as part of the Law on Energy Efficiency and Renewable Energy. It is an independent organization that facilitates investments in renewable energy by sponsoring renewable energy studies and projects, and supporting local renewable energy companies and stakeholders. Its role in hydro, geothermal and solar is briefly described but no additional information is provided. It is assumed that it would be a key organisation in proving the governance over the SREP activities.

Improve the long-term economic viability of the renewable energy sector:

The renewable energy sector in Armenia appears to be in a nascent stage. The existing sources of energy do provide a relatively low cost source of electricity and heat and so the growth in renewable sector and the national benefits that it may offer, in terms of energy security, may require subsidisation to some extent. It is noted that there are a number of existing businesses supporting the industry and the SREP activities should be managed to ensure that the national benefits are maximised wherever possible

Transformative impact:

The targeted nature of the proposed SREP investments is seen as a pragmatic approach. As noted above, the renewable sector is relatively immature so it is unlikely that there will be major transformations in the market through SREP alone but, well managed, a focused programme around will add to the emerging strengths within the sector.

4.0 Recommendations

With the exception of the concerns around the geothermal power developments, the Investment Plan as presented is well prepared.

There is limited detail on how SREP funds would be managed, by whom and under what governance structure, and it is suggested that clarification on these points be sought.

If it is agreed that funding proposed for geothermal power development not be offered as requested then there is a clear opportunity to revisit the priorities under the Plan; this might provide for an extension of the other programme areas or the introduction of an additional sector. This decision needs consideration by those closer to the preparation of the Plan.

Overall the Plan responds to the SREP criteria.

This report and these recommendations have not been discussed with those who prepared the Plan, and so should be treated as interim comments; it is hoped that a discussion can be arranged in due course.

ADDENDUM

Summary of Comments re Inclusion of Geothermal Drilling Proposal

Comments

As raised in various communications earlier, there is a concern about the emphasis given to committing almost 50% of the SREP funds to geothermal exploration drilling. A review of the various reports provided and the IP itself do not substantiate that geothermal should be of high priority. This viewed is based on the following:

- The ranking of options in Table 4.1 shows that geothermal (power generation) is considered to rank a “3” for Scale Up Potential and yet all other data suggests that the anticipated geothermal potential is minimal in comparison to other sources – even if this were a “2”, the geothermal average would drop to 1.8. Costs effectiveness (“2”) assumes a high temperature resource (flash technology) which is not able to be demonstrated with confidence.

Response: It appears there is a misunderstanding of the scoring system that has been put forth in the IP. The scoring system has caused confusion for several reviewers, so it is clear that we should change it to be more intuitive, or explain it more explicitly. According to the current scoring system, a score of “3” for “Scale-up potential” actually indicates relatively low scale-up potential.

Table 0.1: Ranking of Renewable Technologies against Selection Criteria

Technology	Selection Criteria					
	Power grid stability	Cost-effectiveness	Potential for	Scale-up potential	Market immaturity	Average score
Geothermal heat pumps	2	1	1	1	1	1.2
Solar thermal heating	2	3	1	2	1	1.8
Utility-scale solar PV	3	2	2	2	1	2
Geothermal power	2	2	2	3	1	2
Small HPPs	1	1	2	3	3	2
Ag. biogas	2	1	3	4	1	2.2
Landfill biogas	2	1	3	4	1	2.2
Wind	2	2	3	3	1	2.2
Distributed solar PV	3	2	3	2	1	2.2

- T h e report "*Economic and Financial Appraisal of the Potential Geothermal Power Plant at Karkar Final Report, November 2012, by Denzel Hankinson*" makes a number of assumptions and is essentially a generic review of geothermal costs. Comments in the report on likely production temperatures, the understood geological setting in Karkar and notes in response to earlier queries, tend to suggest that a conservative view would be that the temperatures will be modest. However all support for geothermal is based on a costing that utilises a flash technology – implying high geothermal fluid temperatures.
- By the analysis in Hankinson's report it is acknowledged that if flash technology cannot be used the geothermal utilising ORC would be non-competitive with other alternatives.
- Based on the assumption that the KarKar resource may be of modest temperature, it would therefore not rank as competitive
- Acknowledging that there is no geothermal development background in Armenia, the IP does not demonstrate a full understanding of the challenges of geothermal development. While it is accepted that drilling will in the end be required to prove the quality of any resource, moving to a drilling programme would not normally be considered until many of the uncertainties expressed in the geothermal studies to date have been addressed.
- Specific geothermal studies have not been reviewed; it is not known what depth of practical geothermal experience those who have undertaken the various studies have had, but it may be that engaging a peer review by groups with extensive practical exploration and development experience would allow a more concrete decision on the geothermal viability.
- Geothermal exploration and development is by its very nature a capital intensive exercise.

There is a concern that, without a clear upside and identified resources to take any geothermal development forward should exploration drilling confirm an exploitable resource, the investment into an exploration drilling programme at this stage may be wasted.

- Available tariffs, the small scale of any project and the conservative assumption that resource temperatures will be modest, suggest that it may be difficult to attract private investment into geothermal. This would then imply that adequate public funding would have to be found to take any project through to completion.

***Response*: the reviewer's comments are noted and his expertise is useful and appreciated for this process.**

Summary of Correspondence and Responses:

In working through the IP I am having a fundamental problem understanding why the priorities have been chosen as they have. In looking at Table 3.1 it appears that the estimates suggest that the most significant potential contributions are from geothermal heat pumps, solar PV and wind in that order? Geothermal power generation is less than 8% and limited likely upside potential?

***Response*: The total resource potential was one of the criteria used to choose RE projects for inclusion in the SREP IP (see table 4.1 for the full set and scoring by technology). You are correct that geothermal power has significantly lower assessed resource potential than wind and solar resources. But this technology scored relatively high on the other criteria used to prioritize technologies for inclusion in the SREP IP, and for this reason it was included. Furthermore, geothermal is a relatively unexplored resource in Armenia, and there very well might be more potential that is not known about. Because of the way that geothermal resource potential is evaluated (compared with wind and solar) only a small amount has been assessed at this point, but there could be more potential that is not yet known about. By funding exploration, SREP can help kick-start the process of identifying geothermal resources in Armenia.**

I can't find much reference to the geothermal sources in Armenia (have requested your recent info/report); what I have found implied that the resources may be very deep (6000m?) and modest temperature hot water – is this what is currently understood? The cost / kWh for geothermal at full (LEC) rates is shown as around US$ Cents 8.5 (?) which looks low given the plant is small, first project, potentially lower temperature etc. The report mentions that this assumes a flash plant which would imply a high temperature (volcanic source) resource. If a binary unit is considered then typically the costs will be higher. It may work with SREP underwriting for 40 years but this won't open up follow on IPP engagement unless heavy subsidisation is continued?

<u>Response</u>: The temperature of the geothermal resource at Karkar site cannot be known for sure until exploratory drilling is done. The comprehensive surface investigation works suggest that there is geological anomaly, the site is geothermal in nature, and, thus, test drilling is warranted. Please note that the geological studies suggest that test wells with the depth of 1500-2000 m are needed and not 6000 m. The resource could be either a high-temperature resource (i.e. at which a Flash plant could be deployed) OR a low temperature resource (i.e. at which a binary plant could be deployed). If the Karkar site has a high temperature resource, then, according to an assessment conducted in 2012 (see the report attached), the Flash plant could have an LEC of around US$0.0864/kWh (under commercial financing terms). This assessment also evaluated the cost of a binary cycle plant, the LEC of energy will be significantly higher. The only way to really find out the nature of the resource is to do test drilling, and this is why the first stage of the proposed geothermal project under SREP involves exploratory drilling.

In looking at comparative costs the Hzardan TPP is referenced; Table 2.1 shows that it has an exceptionally high tariff, between 2.8 x and 3.8 x of the average (incl/excl Hzaradan). Can you please explain why this has been chosen as the reference? If the current average cots were the reference the picture for RE could look rather different.

<u>Response:</u> The Hrazdan TPP is the marginal cost plant on the Armenian system, and it was included in the supply curves for comparison purposes, not as a threshold below which resources would be considered viable. Also, please note that in Figure 3.5 we compare the cost of all renewable energy options to the 2012 average cost of generation (US$0.03/kWh), as you suggest. To be clear: we did not use the Hrazdan TPP to analyze the best renewable energy options, but rather show the cost of that resource just to demonstrate that many renewable energy options are cheaper than the current highest cost generating plant on the system. Perhaps we should add as reference points the lower-cost and more frequently used generation plants (i.e. the new, efficient CCGTs) to the charts in the next draft of the plan.

As before, I acknowledge I am coming in without the background on in-country visits and meetings and familiarity with the market but would expect others to challenge the IP on this basis.

Overall the report appears to document the situation quite well; however there is repeated reference to the difficulty in attracting IPP engagement in RE due to low pricing and this is not really addressed (other than as a potential risk). What are the expectations around this?

Geothermal Power LECs

Potential Site	Technology	Estimated LEC, commercial financing	Estimated LEC, concessional financing
		US$/kWh	
Georgian border*	Flash	0.11	0.08
Karkar**	Flash	0.09	0.04
	Kalex	0.39	0.16
	ORC	0.29	0.13

* This site is currently under preliminary investigation, and has not yet been explored. LEC estimates for this project are purely speculative and based on the analysis conducted for Jermaghbyur. Better data will need to be obtained before these estimates can be considered reliable.
** The existence of a geothermal resource at the Karkar site has not yet been confirmed. Exploration wells must be drilled before this site can be properly characterized. The temperature and mass flow at this site are uncertain, so three different technologies have been studied for this site.

Independent Technical Reviewer: Mike Allen

Comments delivered on April 15th, 2014 (on a later draft of the Investment Plan)

There are a number of issues which are obviously very pertinent to the potential of renewables in Armenia and that should perhaps be reiterated:

1. The current cost for electricity is very low – "average cost of generation in Armenia is roughly US$ 0.035/kWh". This is noted as having a significant impact on the opportunity to introduce new generation capacity, whether renewable or conventional.

Response: ***The current cost of electricity reflects that fact that several of Armenia's major power plants are fully depreciated and therefore do not have fixed charge in the tariff associated with their capacity (in other words, the tariff reflects operating and maintenance costs only). As noted in the revised investment plan, this is going to change soon, as investment in a new thermal plant (nuclear or gas), and rehabilitation of existing plants, will increase tariffs substantially. Gas import prices are also forecast to continue to increase substantially, which will drive up the cost of gas-fired generation in Armenia.***

2. The cost of renewable options remain relatively expensive given the current cost/tariff structure for electricity.

Response: ***As noted above, the average cost of generation in Armenia is likely to increase substantially in the coming years.***

3. The renewable options are important but not a significant portion of likely future generation capacity. Medium term targets suggest small hydro has the most potential (380 MW) with wind, geothermal and PV offering only a combined 140MW. The revised IP suggests that the wind potential may be lower than earlier anticipated.

Response: ***The current operational SHPP capacity is around 240 MW, so the SHPP capacity is expected to increase by 140 MW by 2020. The Government targets for solar, geothermal and wind by 2020 are only 140 MW combined because: (a) the scale-up potential for wind is estimated to be lower than for solar and geothermal; thus, not much of wind capacity is expected to be developed; and (b) construction of geothermal power plant(s) is not likely to begin earlier than 2016 given the time needed for exploratory drilling to confirm the resource.***

4. It appears that geothermal heat pump options have been removed from the IP; it is not clear why this has occurred.

Response: ***The geothermal heat pump, solar thermal and distributed thermal investments have been removed after government reconsidered, in discussion with development partners, its priorities and the likely availability of financing for such priorities. Geothermal heat pumps, solar thermal heating and rooftop solar PV already have financing available through existing donor programs and, therefore, were given lower priority than technologies, which did not yet benefit from support.***

5. There is no additional information provided on the geothermal status / recent reviews; on this basis my original recommendation would stand that no drilling should be

contemplated until an independent peer review, by those who have significant geothermal experience, has been undertaken. There is mention of a review / planning for drilling but no detail has been provided.

Response: ***The IP was revised to clearly indicate that under the World Bank/GEF funded GeoFund 2: Armenia Geothermal Project several geo-technical investigation works were conducted for Karkar geothermal site and the results/recommendations of those studies were independently reviewed.***

6. Table 1.3 appears quite optimistic in terms of longer term scale up given the very limited experience with most technologies to date in Armenia.

Response: ***It is true that the targets reflect a faster pace of capacity growth than in the past, but Government has also now placed greater priority on the expansion of RE capacity than in the past, highlighted by the recently adopted "Concept on National Energy Security" for Armenia.***

7. As noted earlier, costs for new generation appear low given the limited experience or first development situation with many of them. For geothermal the assumption of a high temperature resource appears contrary to much of the dialogue in the report.

Response: ***The exact temperature of the resource at Karkar site cannot be known until the exploratory drilling is conducted and flow testing, chemical sampling and analyses is completed. The surface studies that were conducted for Karkar site and are described in the IP concluded that two conceptual geothermal models or their combination might exist for the Karkar site:***

Model A: ***Model A assumes that low resistance is not present in the geothermal zones of interest. In such a case, Model A would provide only for a diffuse source of heat and characterizes the field as a reservoir of moderately warm waters (less than 100°C).***

Model B: ***Model B assumes that low resistance may be present in geothermal zones of interest. In such a case, Model B would provide for a localized high-temperature source of heat. Along with this, some of the layers could be characterized as a reservoir of high-temperature water (more than 250°C).***

8. The use of FITs needs to be very carefully considered as it implies ongoing subsidy that has to be funded from central government if not passed in part or total to consumers.

Response: ***Agreed. As noted in the revised investment plan, the Government is also considering—for utility scale solar PV, in particular—a reverse auction approach to determining the appropriate level of tariff in order to minimize the cost to government and customers.***

9. The success of small scale hydro should be encouraged and supported as needed to ensure that this sector does not suffer where other RE resources are being considered.

Response: Agreed, but substantial financing already exists for small scale hydro from private banks (under-written by financing from development partners). In sum, the

industry is already commercially viable. It is the Government's view that small hydro capacity can continue to grow without additional concessional financing.

Annex H: Memoranda from Iceland Geosurvey (ISOR) on Geothermal Power

H.1 August 2012

The World Bank has assigned ÍSOR, Iceland GeoSurvey, to review results of a comprehensive field investigation works of the Karkar geothermal field, Armenia. Special emphases were on the 3D modeling of MT survey done by WesternGeco and how that contributed to the siting of exploratory wells. Contract was signed August 1st 2012.

The task is as follows:

- Review the overall methodology and recommendations regarding the location, number of wells, depth, and other key parameters for proposed exploratory wells.
- Based on the review, provide expert opinion on proposed justification for exploratory wells and make recommendations for improvements/changes to proposed methodological approach or other related aspects.

In the evaluation we have put most emphases on the 3D resistivity modeling as this is the most up to date method within resistivity surveying.

When referring to results and conclusions of the final report of the project GEF-CS-4/2008 we will not repeat the discussion in the reports in the text here but rather compliment it.

Evaluation of the methodology

MT surveys have been carried out in Karkar geothermal field and the surrounding area at three different times.

In 2004, MT was done on 4 profiles in Jermaghbyur, to the west of Karkar geothermal field. Their total length was almost 18 km and included 172 soundings. Gravity and magnetic measurements were done on two of the profiles. The MT soundings cover the area around borehole N4, which was drilled in 1988. It is the only known borehole in the area, located in the northwestern corner of the Karkar site. The borehole is 1000 m deep. Temperature measurement at 920 m depth show 99°C, 91.5°C at 840 m and 58°C at a depth of 550 m. The temperature gradient in the borhole is around 115°C/km. Temperature logs in the borehole indicate that the heat transfer is primarily through conduction i.e. there are no indication in the temperature profiles of fluid convection in the formation intersected by the borehole. The profiles crossed the Jermaghbyur thermal spring. The MT soundings were interpreted using 1D inversion. The 1D models of individual sites were stitched together to make pseudo-2D resistivity models. The interpretation revealed a small

(~ 400-500 m in diameter) conductive zone (40-60 Ωm) around the Jermaghbyur spring at shallow depth and two conductive zones at 1,000 - 1,500 m depth.
In 2009, MT and TEM soundings were performed on a profile across the Karkar pull-apart basin, including the Karkar - Jermaghbyur fault and the faults bounding the pull-apart basin. The soundings on the profile were interpreted using 2D inversion.

In late 2011, WesternGeco measured 150 MT soundings in the Karkar geothermal field in an area of roughly 27 km^2. The survey area encompasses borehole N4, but did not include the Jermaghbyur spring. Both the MT data acquisition and processing are of high quality and according to the state-of-the-art; both thoroughly described in the Operational Report published in October 2011 by WesternGeco (1). Data quality was, according to the 3D Operational Report published in October 2011 by WesternGeco (2), good for the frequency range from 10^4 to 10^{-3} Hz. According to the few curves published in the reports, the data seem to be fine up to a period of at least a few hundred seconds. The data were used for 3D inversion of the soundings from 2011 only. The 3D inversion seems to be of high quality and according to the state-of-the-art. The frequency range used in the inversion was from 0.003 to 3000 Hz, which means that the model must reach down to at least 10-20 km depth. However, the resistivity model in the report is only shown down to a depth of around 2.5 km. *It would be most beneficial for the conceptual modeling of the Karkar geothermal field to inspect the resistivity model at a greater depth. Also, it would definitely be an improvement of the 3D resistivity model if the MT soundings from 2004 and 2009 were added to the data from 2011 – leading to one 3D resistivity model for the whole area, based on all the available MT data from the three surveys.* It should be kept strictly in mind that 3D modeling of MT data is by far more trustworthy than 1D and in particular 2D modeling. **The greater depth resistivity modelling of Karkar was later done by ISOR. The results are presented in Supplemental Memo from September 1, 2013**.

The main result of the 3D model from 2011 is the existence of a 600 m thick conductive zone lying SSW-NNE at a depth of around 500-1000 m below the surface – similar result as from the two previous MT surveys. One of main aims of the exploratory drilling is to find out the geothermal meaning of this conductive zone. The well must, therefore, reach well below that zone and at the same time cut the fracture zone – hopefully finding permeable fractures and the convective part of the geothermal system.

Gravity data were acquired in 2004 and more extensively in late 2011. In the 2011 survey Scintrex CG-5 gravimeters are used, measuring a total of 257 stations. The station coordinates were determined by RTK differential GPS (dGPS). The gravity data acquisition and the dGPS work is thoroughly described in the Operational Report published in October 2011 by WesternGeco (2). The processing of the gravity data including the data reduction seems to be of high quality and according to the state-of-the-art as explained in the WesternGeco reports. The Bouguer gravity reflects quite well the Karkar pull-apart basin and supports the main ideas about the conceptual model of the area.

Conceptual models A and B

It is clear that a thorough investigation of the potential geothermal reservoir at Karkar has been performed. From what we can derive from reports a good job has been done. All available data have been reviewed in investigations from 2004, 2009 and 2011 and have resulted in two possible conceptual models for Karkar, A and B. There is, however, a misconception of the resistivity structure of a high temperature reservoir presented in the conclusions in the final report (Project GEF-CS-4/2008) page 98.

The question is, as stated in the final report, if Karkar is a **low temperature reservoir** with temperatures under 150 °C, or a **high temperature reservoir** with temperatures exceeding 250 °C. The existence of a low resistivity layer (layer 2) underlain by a higher resistivity (layer 3 and 4) give reason to question if we see high or low temperature resistivity structures. This is correctly derived from the exploration results in the final report and thus conceptual models A and B are suggested.

The two types of geothermal systems have different resistivity structures as we see clearly in high- and low temperature fields in Iceland. The main factors influencing resistivity in rocks are **water content, salinity** and **temperature** of the fluid, and the type of **alteration** of the rocks due to geothermal activity.

In low temperature fields the water content as well as salinity and temperature of the geothermal fluid play the key role in the resistivity. In that case the low resistivity reflects water bearing geological formations saturated with geothermal water that have low resistivity due to higher salinity and higher temperatures than the ground water.

A high temperature geothermal field has a different resistivity structure where geothermal alteration of the rocks plays the key role. A high temperature reservoir is characterized by a low resistivity cap underlain by a high resistivity core and a deep seated low resistivity layer at depth. The low resistivity cap reflects temperatures 100 – 230°C (zeolites and smectite) and the high resistivity core underneath reflects the high temperature (> 250°C) reservoir (chlorites and epidote). The deep seated low resistivity layer is thought to indicate up-flow of heat into the reservoir. A more detailed explanation of the resistivity structure is presented in an Appendix.

Model A is interpreted as being that of a low temperature field and thus the low resistivity in layer 2 is the target for geothermal water.

Model B reflects a high temperature resistivity structure and in that case the high resistivity core is the high temperature reservoir (not the low resistivity as stated in the conclusion, page 98). The low resistivity cap (layer 2) is then interpreted as a clay cap with temperatures under 230°C whereas the higher temperatures (>250°C) are within the resistive core (layer 3 and 4). The low resistivity at depth, in layer 5, would indicate the up-flow zone underneath the reservoir.

These conclusions are highly relevant and we agree fully with this. It is, however, not straight forward to choose between the two.

Chemical analyses of geothermal water give indication of the reservoir temperature. The nearest surface manifestations are at Jermaghbyur hot spring. Geo-thermometers applied on the results of the analyses of the geothermal water at Jermaghbyur give the range of 77 – 180°C reservoir temperature. (Geological field works, Magneto-telluric soundings of the Gridzor and Karkar geothermal fields, Armenia geothermal Project GEF Grant # TF: 092563).

Siting of deep exploration wells

In the final report (Project GEF-CS-4/2008) the next steps, according to the conclusions, are remodeling the 3D model to greater depths and then drilling two exploration wells B1 and B2.

We agree that determining if Karkar field holds low or high temperatures will only be done by drilling exploratory wells. This is well funded in the conclusions of the report. We also consider Karkar field a potential geothermal field. We are inclined to believe rather in the low temperature model and it may well be a “hot” low temperature reservoir with temperatures up to 180°C as suggested by geo-thermometers applied on water from the Jermaghbyur hot spring. The thermal gradient in Borhole 4 also indicates a low temperature field.

In geothermal fields, either high or low temperature fields, the main features controlling the up-flow of geothermal water are tectonic fractures and fissures. Not all fractures hold thermal waters so part of a geothermal exploration is to determine potential permeable features. Fissures not only bring geothermal waters to the surface they also serve as cooling zones where cold water flows down and mines the heat.

We thus consider the fissure zone in the western part of the basin to be the most promising drilling target especially where fissures with different strike intersect.

- **Exploration Well B1**

Well B1 may be sited on grounds of the results of the temperature gradient survey. It will most likely answer the question if Karkar is a low temperatue field or a high temperature field. It should be aimed at the fissure/fracture zone where it intersects with the low resistivity layer.

- **Exploration Well B2**

Exploration well B2 is aimed to verify if the resistivity model reflects a high temperature reservoir. It needs to go through the low resistivity (layer 2) and well into the high resistivity below which is in that case is the geothermal reservoir. We suggest the well drilled down to 1000 – 1200 meters depth.

However, if Well B1 gives the answers that Karkar is indeed a low temperature system the drilling of a Well B2 may depend on the results from Well B1. If the low resistivity layer proves to be the geothermal reservoir the Well B2 is valuable for exploring the reservoir.

Conclusion of the ÍSOR group

Review of the work
A good and thorough investigations of the Karkar field through the years.

Resistivity survey: 3D modeling of MT data from 2011 by WesternGeco. An excellent job done and state of the art. Conclusion well-grounded and sound.
Results may reflect high temperature reservoir as well as low temperature reservoir.

Gravity survey by WesternGeco. An excellent job. Results may reflect a basin of 1500 meters depth, flanked by the fissure zones.

Exploratory drilling
Well B1:
Option 1: Drill a directional well, aimed to cut the fissure zone at a given depth.
Option 2: Drill Well B1, vertical as planned but aimed at the fissure zone and site the well so that it will cut potential permeable features at a given depth. In that case it should be sited east of the targeted fissure/fissures. The distance from the fissures is decided, dependent on the alleged dip of the faults/fractures. See figures below.

Well B2:
Provided that well B1 will be drilled before well B2, the results from well B1 will presumably give information on high temperature field vs. low temperature field. Well B2 will give answers as to what the low resistivity (layer 2) stands for regardless. We do not object to its siting as it aims to cut through the layer 2 where the lowest resistivity is seen.

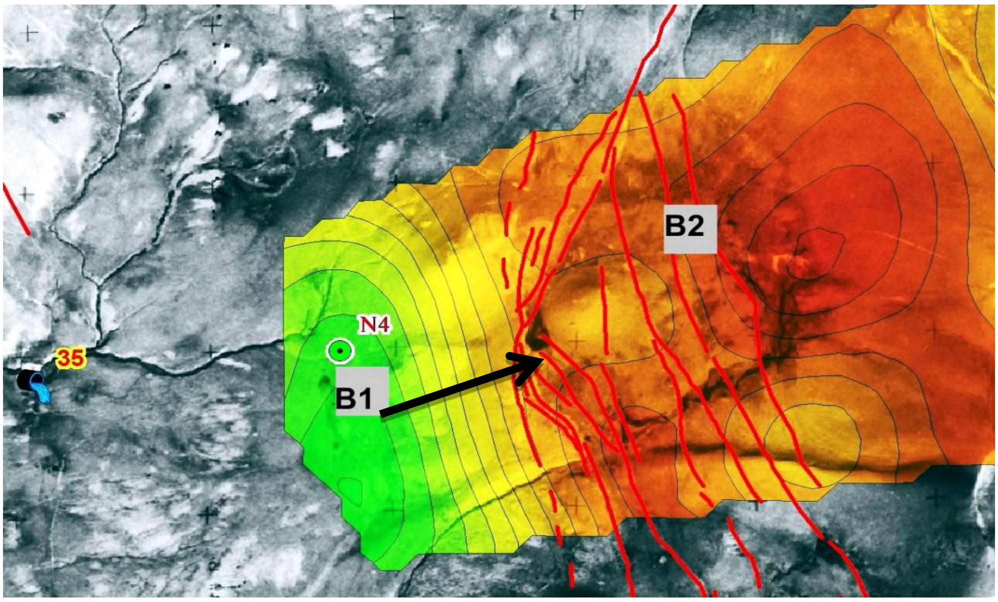
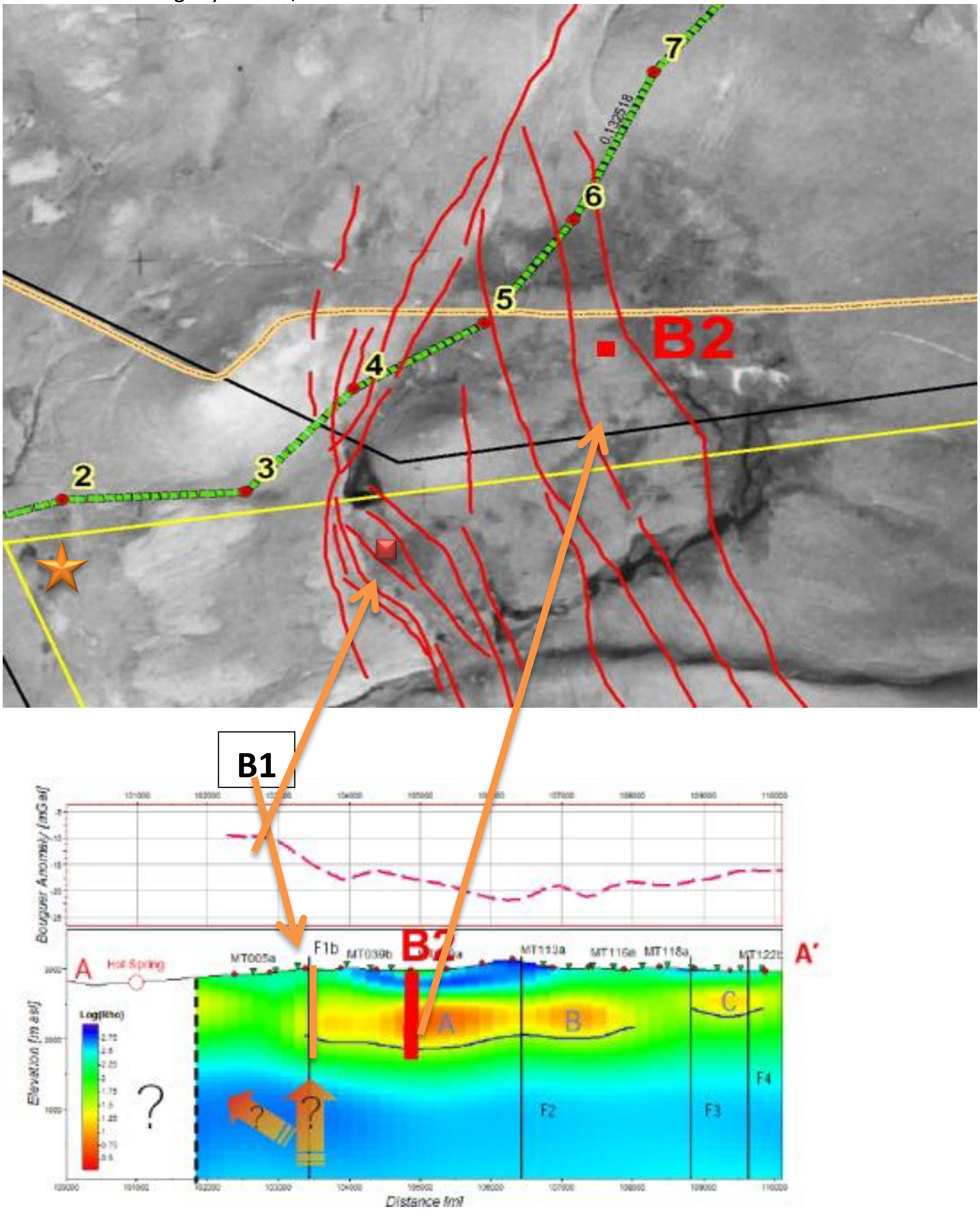


Figure 2.61 in the final report (Project GEF-CS-4/2008). ÍSOR suggests moving the site for B1 to east of the Karkar- Jermaghbyur fault/fissure zone.



Figur 2.66 in the final report (Project GEF-CS-4/2008) shows the western flank of the pull-apart basin displaying the Karkar- Jermaghbyur faults/fissure zone (above) and a cross section from the 3D resistivity model (below). Added is the suggested site for B1 (by ÍSOR).

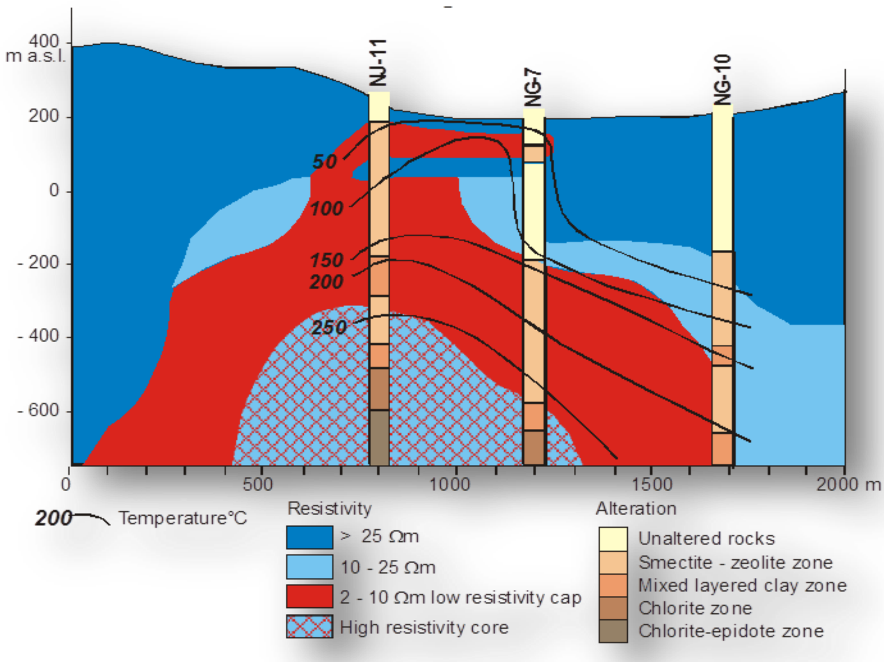
Appendix

Resistivity structure of geothermal fields

The main factors influencing resistivity in rocks are water content, salinity and temperature of the fluid, and the type of alteration of the rocks due to geothermal activity. In essence, water-saturated rocks conduct electrical currents more readily than dry rocks and conductivity increases with increasing temperature up to about 300°C (Violay et al., 2010). Geothermal systems can be distinguished from the surroundings because the electrical conductivity (resistivity) of certain clay minerals (phyllosilicates, such as smectite) found in fractures in the rocks is strongly temperature dependent. The electrical conductivity of the rock is only weakly influenced by the salinity of the fluid, unless the salinity is very high and approaches that of seawater (Flóvenz et al., 2005).

Surface resistivity surveys of high-temperature geothermal systems in the basaltic rocks of the volcanic zones of Iceland (and where the host rocks are volcanic) always seem to reveal basically the same resistivity structure which correlates to the alteration mineralogy zoning. A low resistivity cap is observed on the outer margins of the reservoirs and underlain by a more resistive core. Extensive comparison of this resistivity structure to well data has revealed a consistent correlation to the zones of dominant alteration minerals, where the low-resistivity cap coincides with the smectite-zeolite zone and the transition to the more resistive core occurs at the boundary, or within the mixed layer clay zone. Within the resistive core, chlorite and epidote are the dominant alteration minerals. The alteration mineralogy is, on the other hand, mostly predicted by temperature. This has the important consequence that, the resistivity structure can be interpreted directly in terms of temperature, if the alteration is in equilibrium with temperature. The upper boundary of the low-resistivity cap is found where the temperature is in the range of 50-100°C and the transition to the resistive core occurs at temperatures in the range of 230-250°C Árnason et al., 2000 and Árnason et al., 2010).

The resistivity reflects the alteration caused by the heating of the rocks and reflects the peak temperature experienced by the system, be it at the present or in the past. Thus, resistivity measurements reveal the alteration but do not indicate whether cooling has occurred after the alteration was reached because the resistivity profile only captures the alteration that is present, irrespective of any later cooling in the system and hence the temperature, provided there is equilibrium between alteration and present temperature. In case of cooling the alteration may remain and the resistivity will reflect the temperature at which the alteration was formed. If the resistivity indicates the present temperature of the system will only be confirmed by drilling.



Resistivity cross section from Nesjavellir Iceland. Note temperature derived from well logs and alteration of rocks determined by Xray diffraction of cuttings.

Wherever MT measurements have been conducted in the volcanic zones in Iceland, a deep-seated low-resistivity layer at a 10-15 km depth is seen. The upper boundary (10 Ωm contact) of this low-resistivity layer arches up to a depth as shallow as 2-3 km beneath high-temperature geothermal systems, e.g., in the Krafla area. As the low-resistivity layer is thought to reflect very high temperatures, it is interpreted as providing information about on upwelling of heat into geothermal systems. Plume-like low-resistivity anomalies in limited areas beneath the deep low-resistivity layer, as seen in TEM and MT measurements at Upptyppingar (Vilhjálmsson et al., 2008), also support the idea of active heat up-flow.

References:

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H.2 September 2013

ÍSOR ICELAND GEOSURVEY

Grensásvegi 9
108 Reykjavík
isor@isor.is

Tel: +354 528-1500
Fax: +354 528-1699
www.isor.is

Reykjavik, 1st of September 2013

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM (ESMAP)
C/O
ALMUDENA MATEOS MERINO
PIERRE AUDINET

Memo:

Regarding deep resistivity profiles in Karkar area, Armenia.

As stated in ÍSOR Memorandum 2012-8-3 The World Bank has assigned ÍSOR (Iceland GeoSurvey) to review results of a comprehensive field investigation works of the Karkar geothermal field, Armenia. The main conclusions as written in the Memorandur are:

- *We also consider Karkar field a potential geothermal field.*
- *We agree that determining if Karkar field holds low or high temperatures will only be done by drilling exploratory wells.*
- *We are inclined to believe rather in the low temperature model and it may well be a "hot" low temperature reservoir with temperatures up to 180°C as suggested by geo-thermometers applied on water from the Jermaghbyur hot spring. The thermal gradient in Borehole 4 also indicates a low temperature field.*
- *We thus consider the fissure zone in the western part of the basin to be the most promising drilling target especially where fissures with different strike intersect."*

In recommendations ÍSOR suggested a closer look at the results of the MT survey to greater depths. Resistivity profiles down to about 15 km were provided and after reviewing them ÍSOR concluded the following:

No "deep" low resistivity anomaly is present that might indicate the heat source of a volcanic system. However this does not exclude the Karkar field as a high temperature field, the heat source could possibly be closer to or directly below the volcano itself.

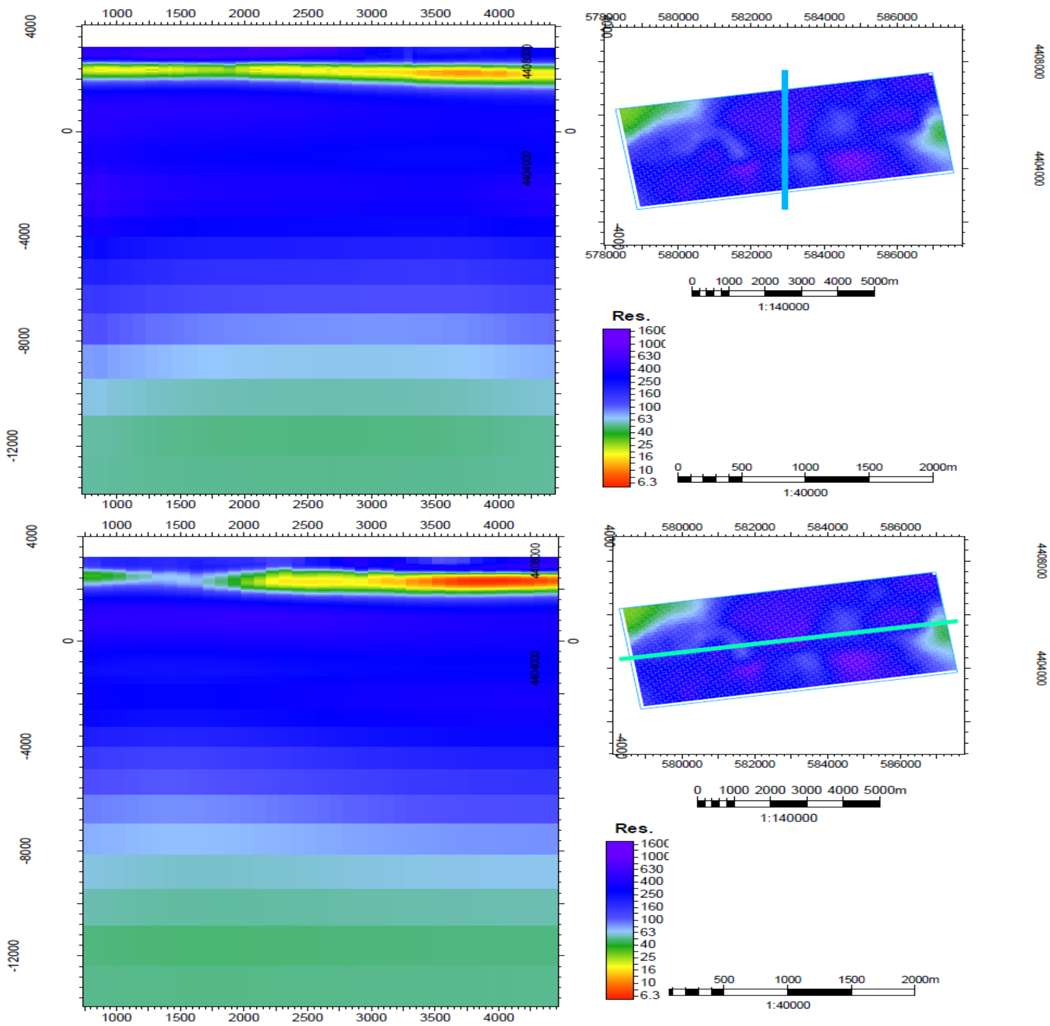
The shallow, low resistivity (5-10 ohmm) present at about 500-1000 meters depth may however indicate hydrothermal alteration in intermediate to high temperatures (180-200°C), producing conductive zone. In that case the heat source / upflow zone may be below the volcano and the low resistivity may thus represent outflow from the geothermal system.

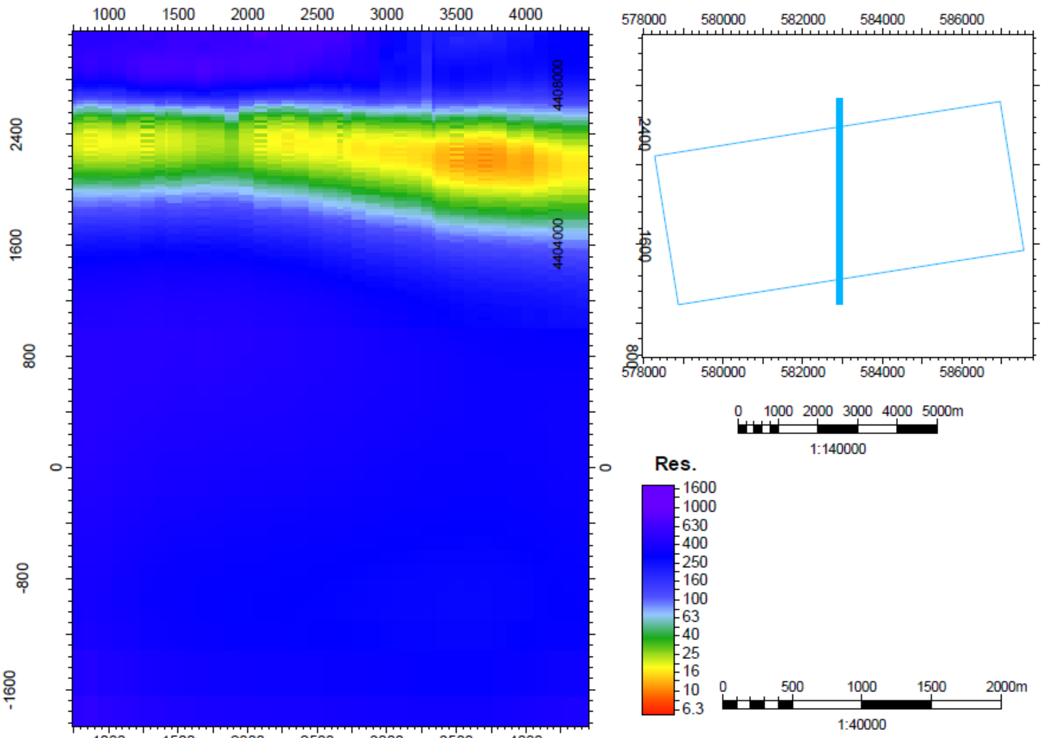
This strengthens the argument for drilling the first well into the fracture zone at the graben boundary.

The question is still there, if Karkar holds high or low temperatures. Drilling into the fracture zone would most likely give information on the nature of the low resistivity layer i.e. if the resistivity structure is that of a fossil or active system. If geothermal fluids are encountered it may give information on the initial temperature of the system.

Ragna Karlsdóttir
Bjarni Richter

Iceland GeoSurvey





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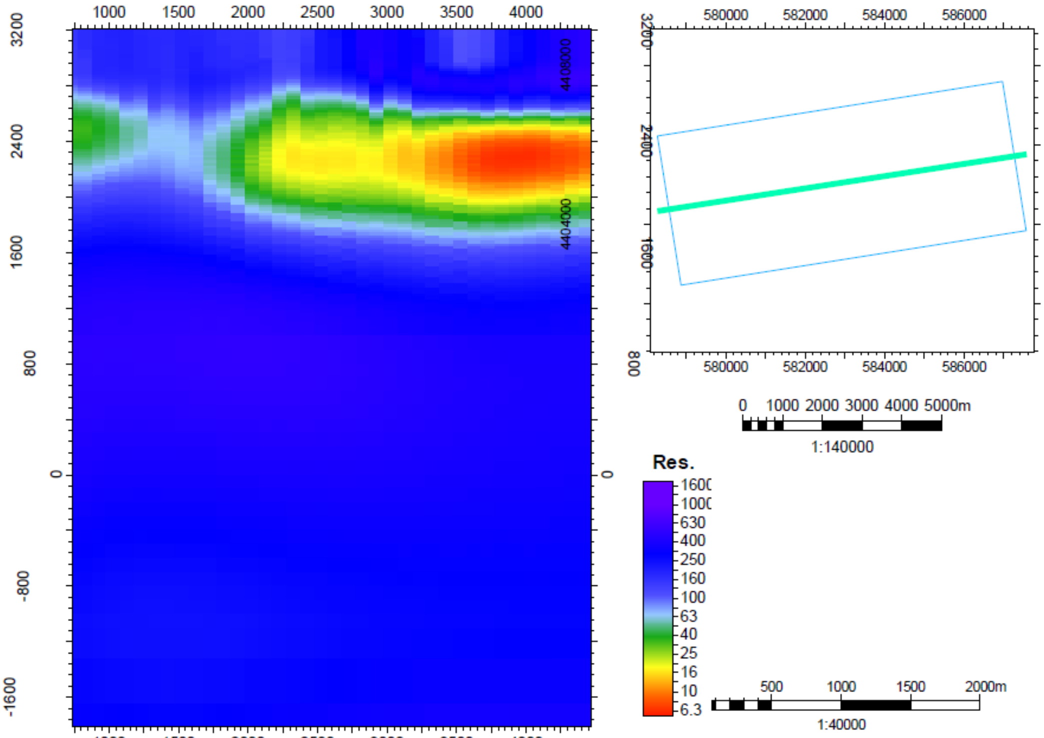

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