



Republic of Armenia

**Scaling Up Renewable Energy Program
(SREP)**



Investment Plan for Armenia

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FOREWORD

An affordable, secure and sustainable energy supply is essential for the prosperity of the people of Armenia, and for the growth of our economy. Because of Armenia's dependence on energy imports, energy prices are largely beyond our control. Over the past decade as we emerged from an energy crisis, we learned the importance of developing our domestic energy resources, and transformed our government institutions to support private sector involvement in the energy industry. In just a few years, a robust and thriving small hydropower industry has emerged from these efforts. Despite this success, our energy sector remains vulnerable to price shocks and reliability problems, and climate change continues to threaten our natural resources and well-being.

Yet in the face of these risks, we have a great opportunity: much of Armenia's conventional energy generation infrastructure will need to be replaced in the coming years. If we can replace some of this with indigenous renewable energy resources, we can improve energy security while simultaneously reducing our contributions to global climate change. Furthermore, we can leverage our scientific and technical talent to build domestic renewable energy industries that will create new employment opportunities for years to come.

At this crucial juncture, the Scaling-up Renewable Energy (SREP) Investment Plan will assist us as we chart a new future for Armenia's energy industry. This Investment Plan identifies the renewable energy technologies and projects that can best contribute to the Government's energy, economic and environmental development goals. As such it is an update and further elaboration of the Renewable Energy Roadmap developed in 2011. It outlines the activities that must be carried out to realize a new energy future by deploying technologies that have as of yet only been implemented on a small scale, but which have enormous potential. Particular focus has been given to minimizing risk for private investors in renewable energy, and to initiatives that can help reduce domestic consumption of imported fuels. SREP will support the Government in reaching its goals for the energy sector, and help leverage private sector funds to exponentially expand investment in clean, domestic energy resources.

The SREP Investment Plan was developed collaboratively in consultation with representatives from Government, private industry and academia. Our development partners, the WBG, the EBRD, and the ADB provided expertise and support that was critical to the successful creation of the plan. I thank these institutions and I look forward to their continued support in this timely and important initiative.

Armen Movsisyan

Yerevan, April 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\$0.08-0.19/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 costs 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 2020-2030¹

	Capacity installed (MW)		Generation (GWh)	
	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

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 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

¹ Excludes generation from the large hydro cascades.

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 and large scale geothermal. 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 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.

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.

- **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 two 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. Two 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..
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

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.

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.

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 four 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	MDB Responsible	Government of Armenia	World Bank/ Asian Development Bank	Private Sector (Equity)	Commercial / Private arms of MDBs	Total
Geothermal Development	(Million US\$)						
Project Preparation	0.3	WB (IBRD)	0.1	-	-	-	0.4
Geothermal Resource Confirmation	9.0		2.3	-	-	-	11.3
Transaction Advisory Services (structuring of PPP for power plant)	0.7		0.2	-	-	-	0.9
Investments in 28 MW plant			tbd	tbd	tbd	tbd	106⁴
Subtotal: Geothermal Development	10.0		2.5	-	-	-	118.6
Development of Utility-Scale Solar PV							
Grant for Project Preparation, Feasibility studies, site measurement and monitoring	2.0	ADB	0.5	-	-	-	2.5
Transaction Advisory Services	0.5		0.1	-	-	-	0.6
Investments in power plants (total of 40-50 MW)	17.5		4.4	20.00	30.00	27.50	99.4
	10.0	WB (IBRD)	2.5	10.00			22.5
Subtotal: Development of Utility-Scale Solar PV	30.0		7.5	30.00	30.00	27.50	125.0
Grand Total	40.0		10.00	30.00	30.00	27.50	243.6
SREP Leverage	5.1						

⁴ Assuming Flash cycle design of the plant. Source of capital cost estimate: "Economic and Financial Appraisal of the Potential Geothermal Power Plant at Karkar ," Nov. 2012; GeoFund 2: Armenia Geothermal Project.

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	n/a	260
Geothermal heat pumps	n/a	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.

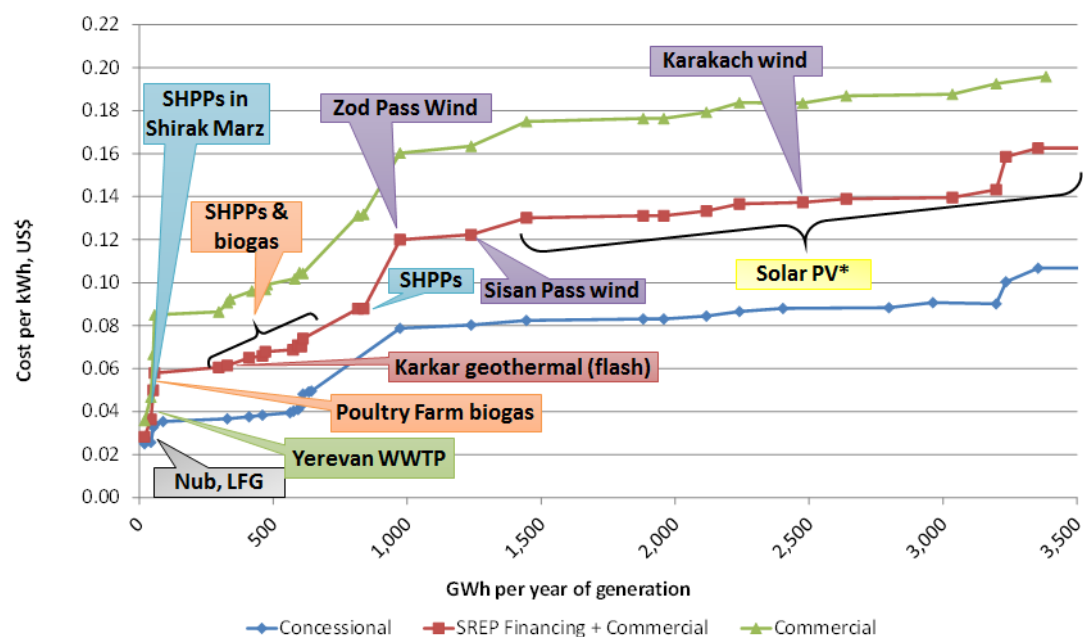
^c Solar PV and CSP were evaluated as options for development in the same areas. Therefore, the total resource potential includes only the generating potential for one of these technologies (Solar PV). For this reason, the total is not the same as the sum of the resource potential listed for each technology.

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\$0.08/kWh – US\$0.19/kWh when a new nuclear plant is put into service in 2026.⁵

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



⁵ As noted above, the cost depends on the size of the plant, and whether concessional or commercial financing is used to finance it.

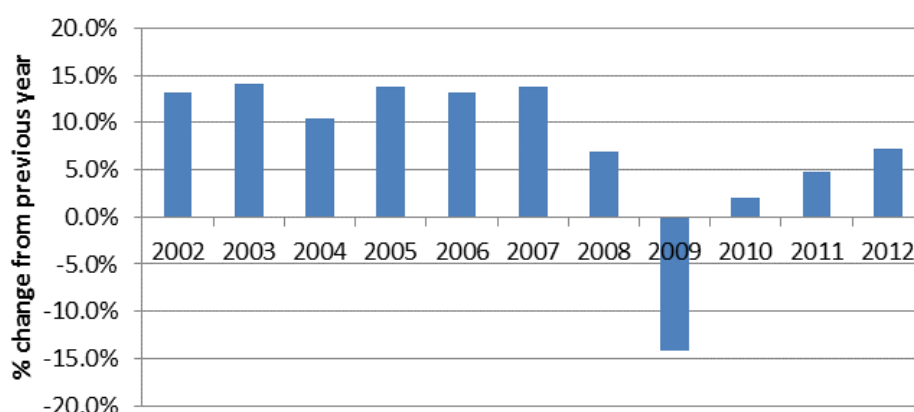
2 Country Context

The Republic of Armenia is a mountainous, landlocked country of 30 thousand km² located in the South Caucasus region of Eurasia.⁶ 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 km². It is one of the most densely populated countries in the region.⁷ The majority of the population lives in urban areas and approximately 38 percent of the population lives in the capital city, Yerevan.⁸ 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 2025.⁹

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

⁶ The Government of the Republic of Armenia, "Geography," <http://www.gov.am/en/geography/>

⁷ The Government of the Republic of Armenia, "Demographics," <http://www.gov.am/en/demographics/>

⁸ The World Bank, "World Development Indicators Database," Accessed August 2013.

⁹ The World Bank, "Health Nutrition and Population Statistics: Population estimates and projections Database," Accessed August 2013.

depressed in the post-crisis period. Poverty levels also increased as a result of the crisis, with the percentage of the population living below the poverty line increasing from 27.6 percent in 2008 to 35 percent in 2011.¹⁰ 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.¹¹

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;

¹⁰ National Statistical Service of the Republic of Armenia, "Statistical Yearbook of Armenia, 2004-2012," www.armstat.am.

¹¹ 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.

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

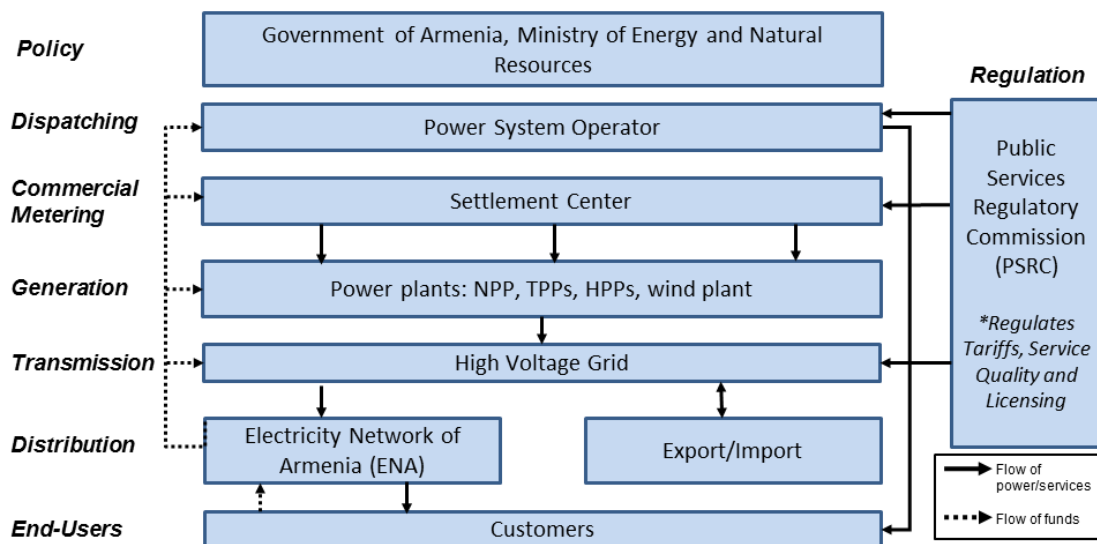
The Law also provided for the establishment of the R2E2 Fund. The R2E2 Fund was formed in 2006. The role of the R2E2 Fund is discussed in more detail in Section 2.1.3

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.¹² 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

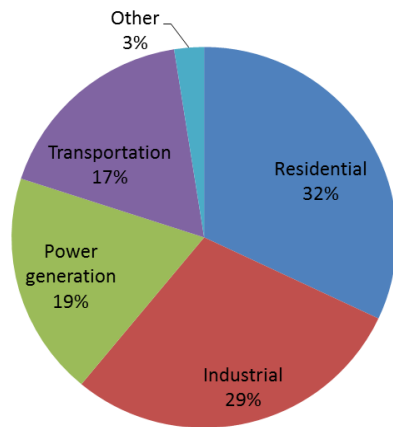
Armenia has no proven oil or natural gas reserves and imports most of its fossil fuel resources from Russia and Iran. ArmRusGazprom, 100% owned by Gazprom, and the state-owned Yerevan TPP are the only companies licensed to import gas. ArmRusGazprom is the sole distributor of natural gas in Armenia. The company manages 10,483 km of gas pipelines and has approximately 640,000 consumers.¹³ 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.¹⁴

¹² Energy Institute of Armenia, Energy Consumption Data, 2013.

¹³ PSRC. 2010. The Gas Sector of Armenia. [http://www.naruc.org/international/Documents/13 Gas system in Armenia-ENGLISH.pdf](http://www.naruc.org/international/Documents/13%20Gas%20system%20in%20Armenia-ENGLISH.pdf).

¹⁴ http://www.iea.org/stats/gasdata.asp?COUNTRY_CODE=AM

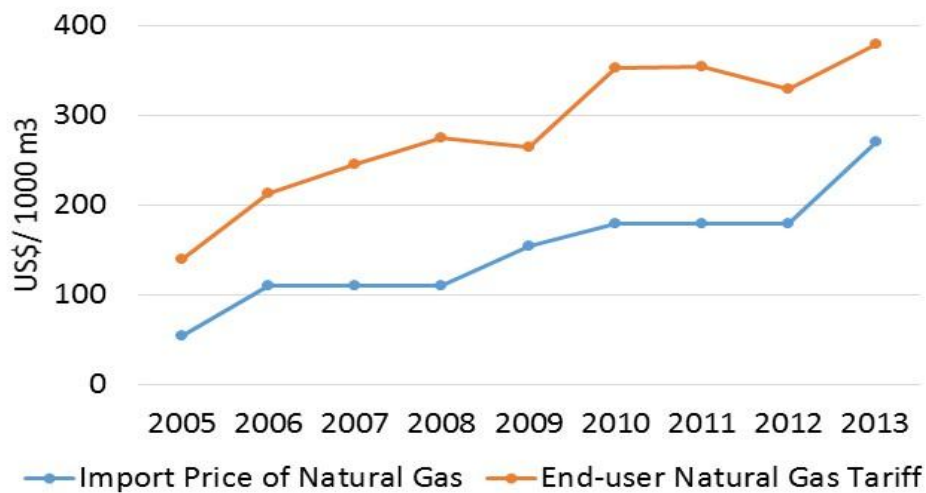
Figure 2.3: Natural Gas Consumption by End-Use



Source: Public Services Regulatory Commission

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 percent¹⁵. 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, 2005-2013¹⁶



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>

¹⁵ For end-user consuming less than 10,000 cm per month.

¹⁶ 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.

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.¹⁷ Many of the largest generating assets will need to be 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.

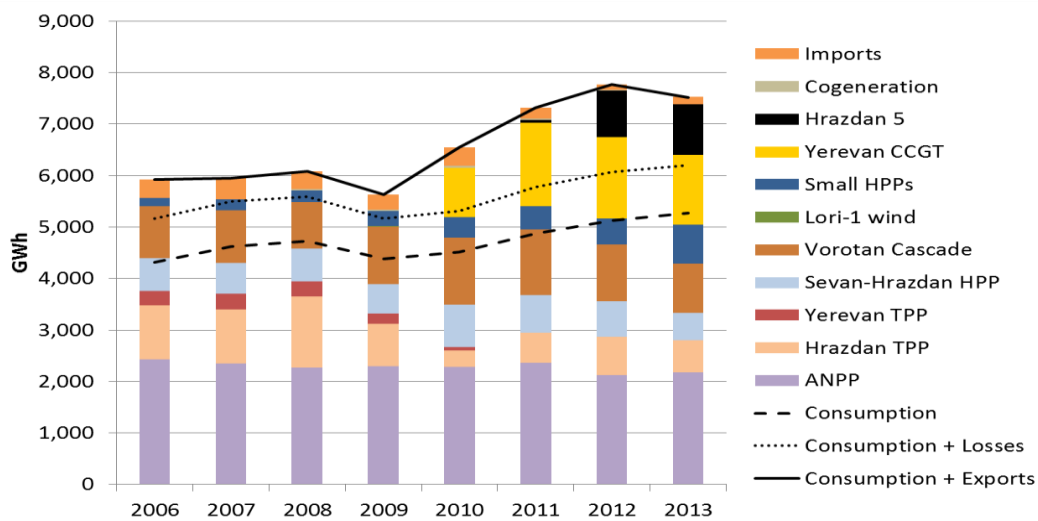
The NPP provides baseload capacity. Other HPPs, including the Vorotan Cascade and several HPPs in the Sevan-Hrazdan Cascade, provide daily load regulation, while thermal plants operate to meet shoulder peak especially in the winter and to serve baseload for several weeks in autumn when the NPP goes offline 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.¹⁸ Figure 2.5 shows Armenia's electricity balance including net generation, consumption, exports, imports and transmission and distribution losses.

¹⁷ Estimated based on available capacity of plants greater than 10 MW.

¹⁸ PSRC. Main Characteristics Indicators.

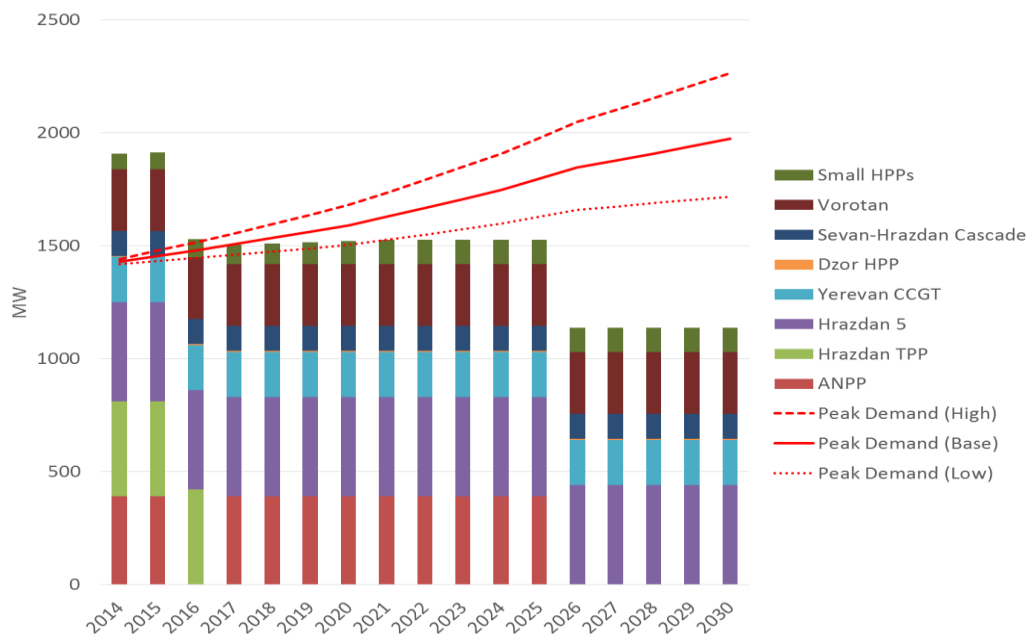
Figure 2.5: Net Generation and Consumption, 2006-2011



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 170 MW of new capacity will be needed by 2018 to meet peak demand and maintain an adequate reserve margin. An additional 830 MW of new capacity will be needed starting from 2026 when the existing NPP is retired. 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: MENR

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>

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	n/a	260
Geothermal heat pumps	n/a	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.¹⁹

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.²⁰

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 December 2005 under a grant from Iran. The plant has a capacity factor of approximately 11 percent and generates 2.5 GWh per year.²¹

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

¹⁹ 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

²⁰ R2E2, "Renewable Energy Roadmap for Armenia Task 4 Report," May 2011

²¹ USAID, "Wind Energy In Armenia: Overview of Potential and Development Perspectives," March 2010

sites, as well as along the Armenian-Georgian border. In 2009-2011, comprehensive 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. Evidence from these activities indicates 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. 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 extent 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/m² to over 2,100 kWh/m². By comparison, average annual GHI in Europe is 1,000 kWh/m².²² 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 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

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

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/m² to 2,453 kWh/m². The minimum DNI level threshold for viability for CSP plants that is generally accepted in the industry is 2,200 kWh/m². 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 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

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.

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 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

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

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

(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.

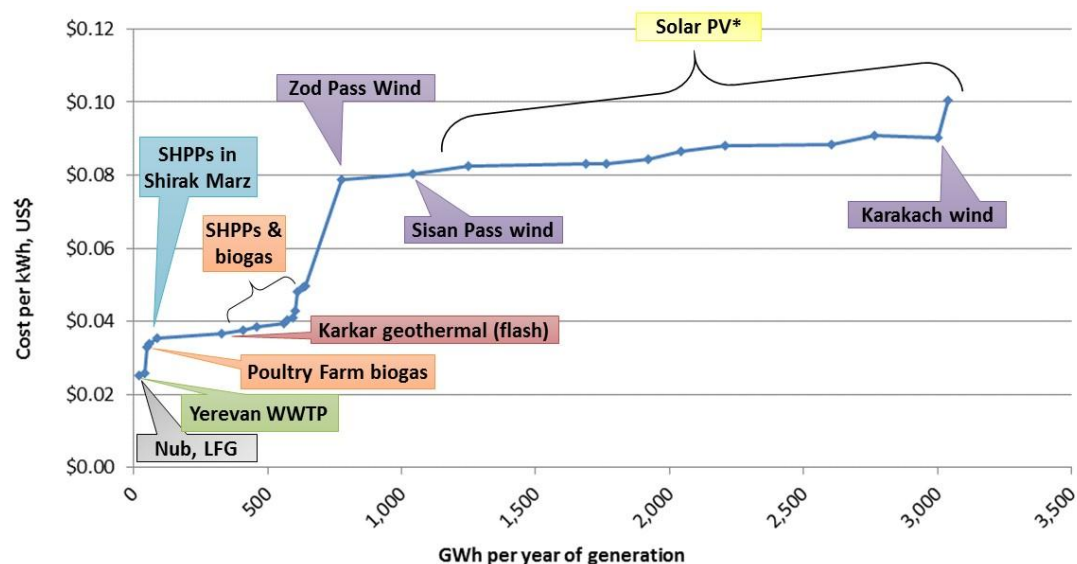
Table 3.2: Concessional, Commercial and SREP/Commercial Financing Assumptions

	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.

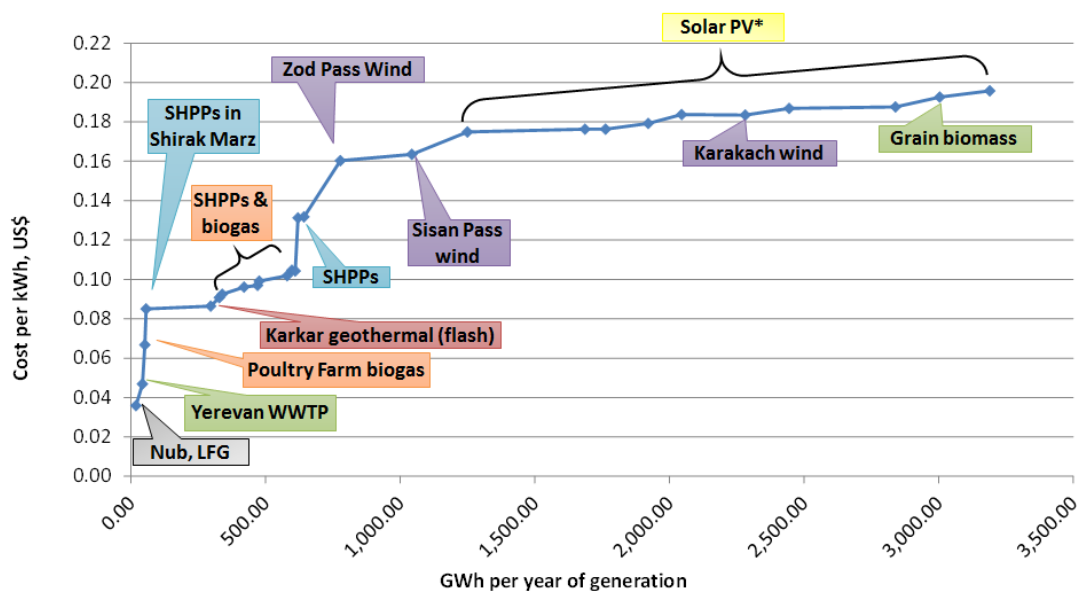
Figure 3.1: Renewable Energy Supply Curve for Armenia, Concessional Financing Assumptions, LEC of Less Than US\$0.10/kWh



*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

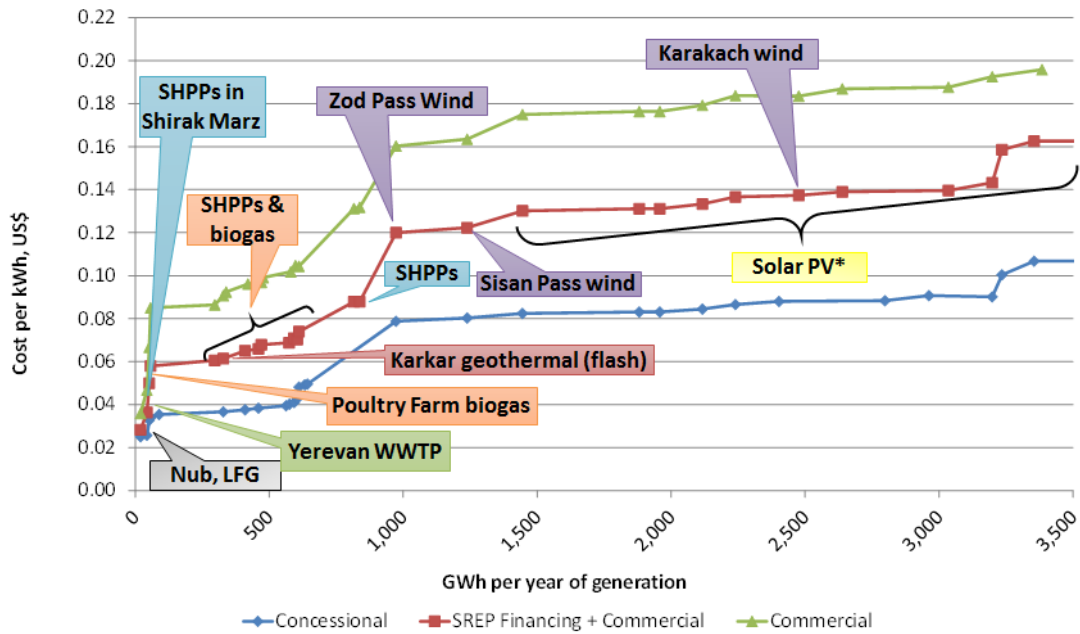


* Assumes Fixed PV

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

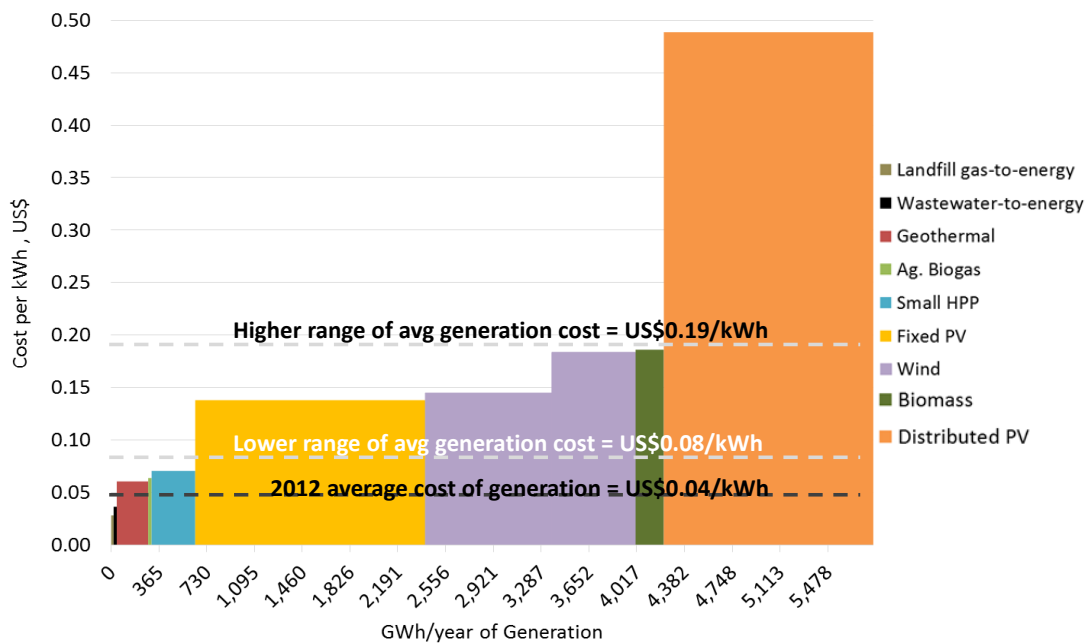


* Assumes fixed PV

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.

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.

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



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.

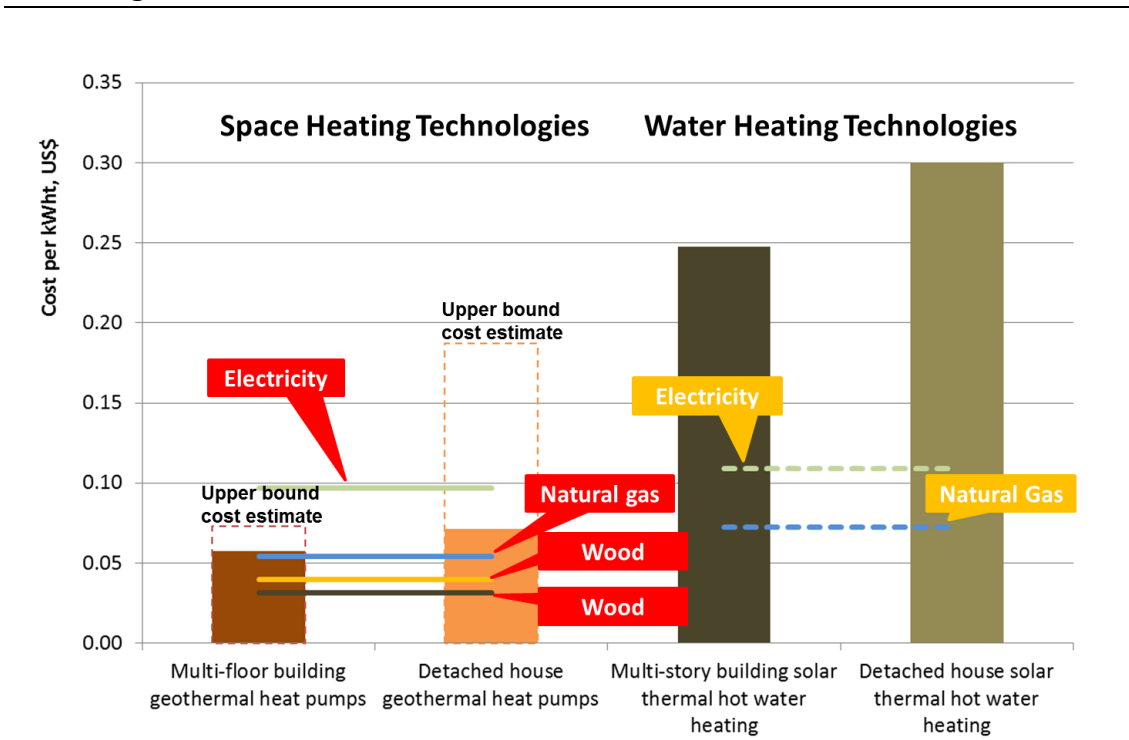
Table 3.3: Levelized Energy Cost Ranges of Various Solar Power Technologies in Armenia, Assuming Mixed SREP/Commercial Financing

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						
<p>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.</p>	<p>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</p>	✓	✓			
Legal and Regulatory						
<p>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.</p>	<ul style="list-style-type: none"> ▪ Streamline procedures for issuing permits ▪ Improve coordination between Government authorities (i.e. PSRC and Ministry of Natural Protection (MoNP)) 	✓	✓	✓	✓	✓
<p>Environmental Regulation and Enforcement is not uniform for all RE technologies and responsibilities for enforcing regulations is not clearly defined within the Government</p>	<ul style="list-style-type: none"> ▪ 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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.	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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.	<ul style="list-style-type: none"> 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
	<ul style="list-style-type: none"> ▪ 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 					
<p>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.</p>	<ul style="list-style-type: none"> ▪ Finance pilots with the requirement that there be knowledge transfer to local partners ▪ Provide funding for training workshops for installers 	✓	✓			✓
<p>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.</p>	<ul style="list-style-type: none"> ▪ 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.

Table 3.5: Renewable Energy Generation Capacity and Production Targets 2020-2025³²

	Capacity installed (MW)		Generation (GWh)	
	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

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

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.

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.

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 America 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 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.),

- **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 Programme (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.

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

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-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	2.4

* 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 could be available through local banks under existing EBRD and IFC-financed programs
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 financing is available through local banks under existing EBRD and IFC-financed programs
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 warrant further exploration	Very immature. No geothermal power plants operate in Armenia
Small HPPs	Provides diurnally stable, but seasonally	Very low cost	Labor intensive, but low potential	Many of the best sites have already	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
	variable power			been developed, so 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 two focus areas: geothermal power and utility-scale solar PV. 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. In the process of developing these first 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 first projects will serve to educate consumers on the benefits of renewable energy technologies.

SREP support can help to gradually introduce geothermal power and utility-scale solar PV by: (i) absorbing some of the project development risk on geothermal power, through subsidization of exploratory wells, and; (ii) helping the finance the country’s first utility-scale solar PV projects to attract private investors while minimizing the tariff-impact.

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 170 MW of new capacity by 2018 and 830 MW of capacity when the nuclear plant is retired in 2026.
- 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.
- 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 through 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, runoff and discharge leading to localized changes in river flows and morphology.
 - The potential for localized geological damage through 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 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.

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

- **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.

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 4.5 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.

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: Indicative Financing Plan

SREP Project	SREP	MDB Responsible	Government of Armenia	World Bank/ Asian Development Bank	Private Sector (Equity)	Commercial/ Private arms of MDBs	Total
Geothermal Development	(Million US\$)						
Project Preparation	0.3	WB (IBRD)	0.1	-	-	-	0.4
Geothermal Resource Confirmation	9.0		2.3	-	-	-	11.3
Transaction Advisory Services (structuring of PPP for power plant)	0.7		0.2	-	-	-	0.9
Investments in 28 MW plant			tbd	tbd	tbd	tbd	106³⁷
Subtotal: Geothermal Development	10.0		2.5	-	-	-	118.6
Development of Utility-Scale Solar PV							
Grant for Project Preparation, Feasibility studies, site measurement and monitoring	2.0	ADB	0.5	-	-	-	2.5
Transaction Advisory Services	0.5		0.1	-	-	-	0.6
Investments in power plants (total of 40-50 MW)	17.5	WB (IBRD)	4.4	20.00	30.00	27.50	99.4
	10.0		2.5	10.00			22.5
Subtotal: Development of Utility-Scale Solar PV	30.0		7.5	30.00	30.00	27.50	125.0
Grand Total	40.0		10.00	30.00	30.00	27.50	243.6
SREP Leverage	5.1						

³⁷ Assuming Flash cycle design of the potential plant. Source of capital cost estimate: "Economic and Financial Appraisal of the Potential Geothermal Power Plant at Karkar," Nov. 2012; GeoFund 2: Armenia Geothermal Project.

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: Summary of Projects' Responsiveness to SREP Criteria

Criteria	Geothermal Power Development	Utility-Scale Solar PV Development
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 25 MW, planned for 2020.	Armenia plans to increase installed solar capacity from 0 to 80 MW by 2025. SREP-funded investments will represent the first 40-50 MW.
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, geothermal power and utility-scale solar PV 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.
Affordability and competitiveness of renewable resources	The supply curves shown in Section 3.2 confirm that geothermal power is competitive with Armenia's thermal generation alternatives	The supply curves shown in Section 3.2 show that utility scale solar PV is not yet cost competitive with existing thermal generation options in Armenia. ³⁸ SREP financing

³⁸ 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

Criteria	Geothermal Power Development	Utility-Scale Solar PV Development
	(gas and nuclear).	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
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.
Economic, social and environmental development impact	The development of geothermal power has a number of economic, social and environmental benefits, which are described in detail for each technology in Section 5.	
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.
Leveraging of additional resources	Investments from the private sector, MDBs, and government are estimated to leverage 4.5 times the amount contributed by SREP.	

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
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.

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	<p>Utility-scale solar PV, geothermal exploratory drilling and generation 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.</p>	<p>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.</p>	Low
Environmental risks	<p>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.</p>	<p>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.</p>	Low
Social risks	<p>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,</p> <p>There is also the risk that, 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.</p>	<p>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</p> <p>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</p>	Low

Risk	Description	Mitigation	Residual Risk
		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	<p>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.</p> <p>The assessment of potential for utility-scale solar PV is based on fairly coarse resource data and very limited site monitoring.</p>	<p>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.</p> <p>The site-specific higher-resolution solar insolation measurements will be conducted to confirm the solar resources before launching any tender.</p>	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.

Table 10.1 summarizes the proposed monitoring and evaluation (M&E) framework for Armenia's SREP IP.³⁹ 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.

³⁹ 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	Geothermal electricity output: 373 GWh by 2020; 745 GWh by 2025; Utility-scale solar PV output: 88 GWh by 2020; 176 GWh by 2025	SREP Project's M&E system
New and additional resources for renewable energy projects (US\$244 million)	Leverage factor: USD financing from other sources compared to SREP funding	0	5.1	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 Vototan 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.

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.
- Well logging and mud logging. 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.
- Flow testing, chemical sampling and analysis: 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.
- Technical supervision: 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.

Task 2: 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.

Task 3: 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.

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 11 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

SREP Project	SREP	MDB Responsible	Government of Armenia	World Bank/ ADB	Private Sector (Equity)	Commercial / private arms of MDBs	Total
Geothermal Development	(Million US\$)						
Project Preparation	0.30	WB (IBRD)	0.1	-	-	-	0.4
Geothermal Resource Confirmation	9.00		2.3	-	-	-	11.3
Transaction Advisory Services (structuring of PPP for power plant)	0.70		0.2	-	-	-	0.9
Investments in 28.5 MW plant			tbd	tbd	tbd	tbd	106
Subtotal: Geothermal Development	10.00		2.6	-	-	-	118.6
SREP Leverage	10.9						

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:			
<p>The grant will cover activities related to the preparation of</p> <ul style="list-style-type: none"> • 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^a : 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 (USDmill.):	<i>At time of country program submission (tentative):</i> Grant of US\$10 million	<i>At time of project approval:</i>	
5. Estimated costs for MDB project implementation services (USDmill.):	<i>Initial estimate - at time of Country program submission:</i> US\$300,000	MDB: IBRD	
	<i>Final estimate - at time of project approval:</i>	Date: January 2015	
6. Request for payment of MDB Implementation Services Costs (USD.mill.):	<input type="checkbox"/> First tranche: US\$100,000 <input type="checkbox"/> Second tranche: US\$200,000		
7. Project/program financing category:	a - Investment financing - additional to ongoing MDB project <input type="checkbox"/> b- Investment financing - blended with proposed MDB project <input type="checkbox"/> c - Investment financing - stand-alone <input checked="" type="checkbox"/> d - Capacity building - stand alone <input type="checkbox"/>		
8. Expected project duration (no. of years):	3 years		
9. Explanation of final estimate of MDB costs for implementation services:	<i>If final estimate in 5 above exceeds the relevant benchmark range,</i>		
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.

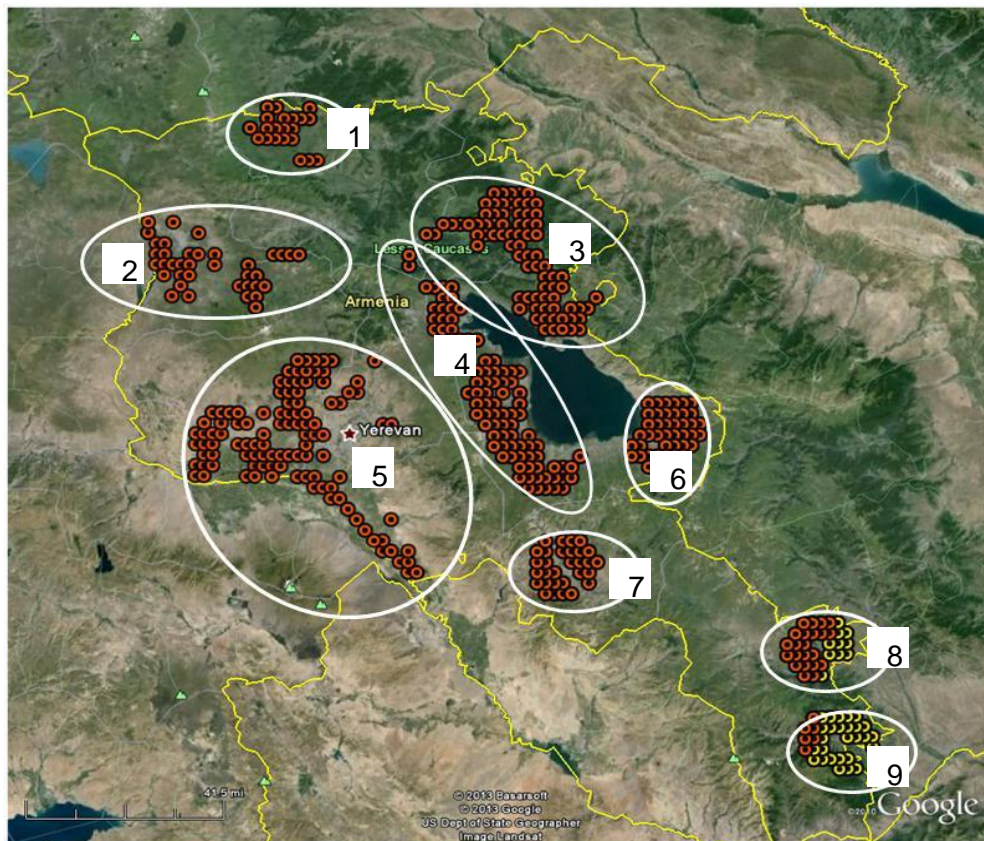
Utility-scale solar PV is now cost-competitive on a life-cycle basis with the other power generation options available to Armenia, given the technological and manufacturing advancements combined with continued cost declines internationally. Armenia will benefit from developing its capacity to scale-up 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/m² to over 2,100 kWh/m². By comparison, average annual GHI is 1,000 kWh/m² 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.⁴⁰ 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;

⁴⁰ 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.⁴¹ It is estimated that less than 100 kW of solar PV is currently operational.⁴²

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.

⁴¹ USAAA/US Embassy/EcoTeam/UNDP/GEF, "Use of Renewable Energy Sources in the World and Armenia Through Innovations to Clear Technologies," 2010

⁴² 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, roughly US\$30 million of SREP funding is expected to catalyze roughly 3 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 of \$17.5 million, IFI financing and project sponsors will help to finance US\$75 million investments in solar PV (potentially 40-50 MW installed). 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\$2 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	MDB Responsible	Government of Armenia	World Bank/ ADB	Private Sector (Equity)	Commercial / private arms of MDBs	Total
Development of Utility-Scale Solar PV							
Grant for Project Preparation, Feasibility studies, site measurement and monitoring	2.0	ADB	0.5	-	-	-	2.5
Transaction Advisory Services	0.5		0.1	-	-	-	0.6
Investment in power plants (total of 40-50 MW of projects)	17.5	WB (IBRD)	4.4	20.0	30.0	27.5	99.4
	10.0		2.5	10.0			22.5
Subtotal: Development of Utility-Scale Solar PV	30.0		7.5	30.0	30.0	27.5	125.0
SREP Leverage	3.2						

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 Financing Plan for Utility-Scale Solar Power Project

Technical Assistance (TA) and Project Processing Milestones	
Capacity Development and Project Preparation TA (CDTA)	SREP (US\$2.0 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\$2 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\$30 million		
5. Preparation Grant Request (in USD):	US\$2 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/Programme 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:			
<ul style="list-style-type: none"> • 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		1,458,000	
Equipment (meteo-stations, computers, data)		355,000	
Workshops/seminars/trainings		20,000	
Vehicle/transportation		10,000	
Others (admin costs/operational costs)		80,000	
Contingencies (max. 10%)		77,000	
Total cost		2,000,000	
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: June 2014 ADB approval: July 2014	
12. Other partners involved in project design and implementation^a : 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 (USDmill.):	<i>At time of country program submission (tentative):</i> ADB: US\$20 million	<i>At time of project approval:</i>	
5. Estimated costs for MDB project implementation services (USDmill.):	<i>Initial estimate - at time of Country program submission:</i> ADB: US\$320,000	MDB: ADB	
	<i>Final estimate - at time of project approval:</i>	Date:	
6. Request for payment of MDB Implementation Services Costs (USD.mill.):	<input checked="" type="checkbox"/> First tranche: ADB: US\$100,000 <input type="checkbox"/> Second tranche: ADB: US\$220,000		
7. Project/program financing category:	a - Investment financing - additional to ongoing MDB project <input type="checkbox"/> b - Investment financing - blended with proposed MDB project <input checked="" type="checkbox"/> c - Investment financing - stand-alone <input type="checkbox"/> d - Capacity building - stand-alone <input type="checkbox"/>		
8. Expected project duration (no. of years):	4		
9. Explanation of final estimate of MDB costs for implementation services:	<i>If final estimate in 5 above exceeds the relevant benchmark range, the exceptional circumstances and reasons:</i> 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			
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 (USDmill.):	At time of country program submission (tentative): IBRD: US\$10 million	At time of project approval:	
5. Estimated costs for MDB project implementation services (USDmill.):	Initial estimate - at time of Country program submission: IBRD: US\$320,000	MDB: IBRD	
	Final estimate - at time of project approval:	Date:	
6. Request for payment of MDB Implementation Services Costs (USD.mill.):	<input checked="" type="checkbox"/> First tranche: IBRD: US\$100,000 <input type="checkbox"/> Second tranche: IBRD: US\$220,000		
7. Project/program financing category:	a - Investment financing - additional to ongoing MDB project <input type="checkbox"/> b - Investment financing - blended with proposed MDB project <input checked="" type="checkbox"/> c - Investment financing - stand-alone <input type="checkbox"/> d - Capacity building - stand-alone <input type="checkbox"/>		
8. Expected project duration (no. of years):	4		
9. Explanation of final estimate of MDB costs for implementation services:	<i>If final estimate in 5 above exceeds the relevant benchmark range, the exceptional circumstances and reasons:</i> Not Applicable		
10. Justification for proposed stand-alone financing in cases of above 6 c or d: N/A			

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 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

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

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.

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) (<https://www.climateinvestmentfunds.org/cifnet/country/armenia>).

The analytical work completed in preparing the IP included a comprehensive assessment of renewable energy technologies identified during the first technical 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	<ul style="list-style-type: none"> 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 CO₂ by 2020 and 234,000 tonnes of CO₂ by 2030.⁴⁶
	Employment opportunities	<ul style="list-style-type: none"> 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.
SREP Program Outcomes		
Increased supply of renewable energy (RE) New and additional resources for renewable energy projects/programs	Increased reliability	<ul style="list-style-type: none"> 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 baseload generation, rather than interruptible supply. Grid enhancements required to connect the solar PV and

⁴⁶ Given Armenia’s estimated Grid Emissions Factor of 181 g CO₂/kWh, based on estimate by the Climate Registry (<http://www.theclimateregistry.org/downloads/2013/01/2013-Climateregistry-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.

geothermal projects may also offer improvements in grid reliability.

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.

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 America 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

<i>Assumption</i>	<i>Units</i>	<i>Value</i>
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

<i>Assumption</i>	<i>Units</i>	<i>Value</i>
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

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\$/k W-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\$/k W-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\$/kW-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

											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)	%	(%)	(%)	(%)	(%)	(%)	(%)
	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-Gegharqunig	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\$/k W-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\$/k W-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.

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°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).*

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

☒ The 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?

Response: The emperature 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.

Response: 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

Assessment of the Levelized Energy Cost of Renewable Energy Technologies

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.