UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

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United Nations Development Account project
Promoting Energy Efficiency Investments
for Climate Change Mitigation and Sustainable Development

Case study

ARMENIA

COGENERATION BASED DISTRICT HEATING RESTORATION PROJECT IN AVAN DISTRICT OF YEREVAN CITY

Implemented in the framework of the project
Armenia - Improving the Energy Efficiency of Municipal Heating and Hot Water Supply
UNDP-GEF/00035799

Empowered lives.
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Contents

Abbreviations

AMD	Armenian dram
CIS	Commonwealth of Independent States
CJSC	Closed joint stock company
DH	District heating
Gcal	Giga Calorie (10^9 cal)
GDP	Gross domestic product
GEF	Global Environment Facility
GHG	Greenhouse gas
GoA	Government of Armenia
GWh	Gigawatt hour (10^9 Wh)
HPP	Hydropower plants
kWh	Kilowatt hour (10^3 Wh)
kWe	Kilowatt (10^3 W) electrical energy
kWt	Kilowatt (10^3 W) thermal energy
LTD	Limited liability company
MENR RA	Ministry of energy and natural resources
MNP RA	Ministry of nature protection of the Republic of Armenia
MUD RA	Ministry of urban development
MWh	Megawatt hour (10^6 Wh)
NEEAP	National Energy Efficiency Action Plan
ANPP	Armenian Nuclear Power Plant
O&M	Operation and maintenance
OECD	Organization for Economic Cooperation and Development
PPP	Purchasing Power Parity
PSRC	Public Services Regulatory Commission of the RA
RA	Republic of Armenia
RF	Russian Federation
R2E2	Renewable Resources and Energy Efficiency Fund
TPES	Total primary energy supply
TPP	Thermal power plant
toe	Ton oil equivalent
UNDP	United Nations Development Programme
USD	United States dollar
WB	World Bank

Executive Summary

UNDP-GEF project "Armenia – Improving the Energy Efficiency of Municipal Heating and Hot Water Supply" was designed to address the barriers and promote solutions for energy efficient heat supply in Armenian cities and to lay a foundation for the sustainable development of the heat supply market in the country.

The project successfully contributed to the improvement of the energy efficiency regulatory framework of the heat supply sector, application of advanced energy efficient technologies and renewable energy resources in the heat supply by implementing over 20 small-scale pilot projects, and by building the capacity of the associated energy service companies, thereby replicating the experience gained from the pilot projects and increasing the market penetration of these technologies. However, the most tangible achievement is the initiation and implementation of Armenia's first large-scale district heating restoration project.

As a direct outcome of the Project's technical assistance, more than 9 million USD of foreign direct investments were leveraged in restoration of district heating system in Armenia on the basis of high-efficiency cogeneration.

The restored system is based on provision of heat energy from newly constructed combined heat and power (cogeneration) based energy center and reconstructed heat networks, ensuring apartment level metering and regulation and consumption based payment system.

The attraction of the private investments into restoration of the district heating system was achieved through the holistic approach developed by the UNDP-GEF project aimed at reducing commercial risk while ensuring competitive and affordable level of heat energy for consumers. This was mainly achieved through a pricing method of electricity and heat produced by cogeneration units. The method served as a basis for subsequent adoption of the Government Decision guaranteeing purchase at favorable price of electricity produced by new cogeneration units of the district heating project.

Besides, the Project substantiated and justified the need for public-private support scheme, which was ensured through the Government Decision on handing over for the free use heat supply infrastructure of the demonstration project area to the newly established heat supply company.

Further, the Project approach to the pricing of electricity and heat produced from cogeneration units aimed at promotion of district heating restoration on the basis of high-efficiency cogeneration underlain the regulatory framework drafted by the Project and approved by the Public Services Regulatory Commission of Armenia. The regulation was mainly focused on reduction of commercial risk to a level that stimulates private investments in new cogeneration installations in heating sector and proved to be attractive for their mobilization. This was confirmed by initiation of new cogeneration based heat supply projects after adoption of regulation.

As mentioned above, the Project's efforts aimed at promoting energy efficiency investments in heating cogeneration attracted more than 9 million USD of foreign direct investments. For the

completion of the district heating restoration demonstration project, another 6 million USD are should be invested by 2014 according to the approved investment plan of the district heating company.

Basic Data

The Republic of Armenia is located in the north east of the Armenian Highlands, at the border of Caucasus and Near Asia. Armenia borders Georgia from the north, Azerbaijan from the east, Turkey from the west and southwest, Iran from the south.

Armenia is a mountainous landlocked country; the country covers 29.8 thousand square kilometers, 76.5% of the territory is at altitudes of 1,000 - 2,500 meters above sea level. Yerevan is the capital city of the Republic of Armenia. The population of the Republic of Armenia amounts to 3,262 thousand (as of 2010) with 64% settled in urban areas.

The collapse of the Soviet Union and disruption of the economic relations with Soviet republics, followed by a severe energy crisis, led to the economic downturn of 1991-1994. Later, Armenia managed to overcome the difficulties of the transition period and to ensure economic stability and rapid growth. The Gross Domestic Product (GDP) of Armenia annually increased by 5.4% in average during 1995-2000, and in 2001-2006 the average annual GDP growth reached to 12.4%. As a result of the worldwide financial crisis, GDP annual growth slowed to 2.2% in average during 2007-2010.

In 2010, the Armenian GDP reached 9.37 billion USD or 16.56 billion USD GDP (PPP) with the following structure: 16.4% share of industry, 19.4% - of agriculture, 19.0% - of construction and 45.4% - of services. At the same time, GDP (PPP) per capita amounted to 5,711 USD. Despite the rapid growth, the small GDP base does not yet allow for achievement of a GDP per capita that would establish a high level of living standard improvement.

The growth in gross domestic investments and foreign direct investments (FDI) in Armenia testifies to the increase of economic agility, improvement of business environment and stabilization of the economy. However, given competitiveness and relative advantages, the volumes of investment are still insignificant.

Energy Sector of the Republic of Armenia

Armenia has no domestic resources of fossil fuel and heavily depends on imported primary energy resources to meet its energy demand. Fuel for more than 90 % of the country's energy needs is imported. Armenia is dependent on the import of hydrocarbons for transport, all gas used for heating, cooking, and generation of electricity (roughly one-third of the country's generating capacity), and all of the uranium needed for the Armenian nuclear power plant (source: WB, Charged Decisions: Difficult Choices in Armenia's Energy Sector, October 2011). Domestic primary energy resources, namely hydro resources, meet only 8.1% of Armenia's energy demand (Fig.1).

In these terms, ensuring energy security, including diversification of imported and domestic energy resources, maximum utilization of renewable sources of energy, promotion of energy saving and

environmentally friendly energy supply are considered as key priorities of the strategic development of Armenia's energy sector formulated in the Law of RA on Energy Saving and Renewable Energy (2004), Energy Sector Development Strategy in the Context of Economic Development of Armenia (2005), the National Program on Energy Saving and Renewable Energy of the Republic of Armenia (2007) and National Energy Efficiency Action Plan (2010).

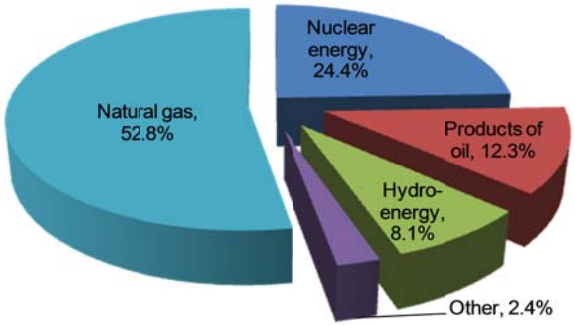

Figure 1. Structure of primary energy resources in 2010 with "other" including firewood, manure, and coal (source: "ArmRusGasProm" CJSC, "Settlement Centre" CJSC of the RA MENR, survey is done by WB, FLEG, UNDP projects and expert judgments)

In 2010, total primary energy supply (TPES) in Armenia amounted to 2,570 ktoe with the major share of natural gas of 52.8 % (Fig.1).

The main consumers of fossil fuel are the power industry (24%), housing and public sector (23%) and transport (20%).

In 2010 energy consumption per capita was 0.79 toe and energy intensity of GDP was 0.274 kg o.e./USD or 0.16 kg o.e./USD(PPP). For comparison, in 2007, energy intensity of GDP(PPP) was 0.17 kg o.e./USD in Armenia, while it was 0.20 - worldwide, 0.17 - for OECD countries, and 0.41 – in CIS countries (source: International Energy Agency, 2009).

The World Bank Study "Charged Decisions: Difficult Choices in Armenia's Energy Sector", October 2011, identifies the following principal challenges of Armenia's energy sector for the next 20 years: (i) ensuring adequate energy supply; (ii) safeguarding energy security, and (iii) keeping energy supply affordable for customers while maintaining financial sustainability of the sector.

Electricity. Electricity is generated by thermal, nuclear, hydro power plants and small plants, including small hydro, wind power, cogeneration and biogas (Fig.2).

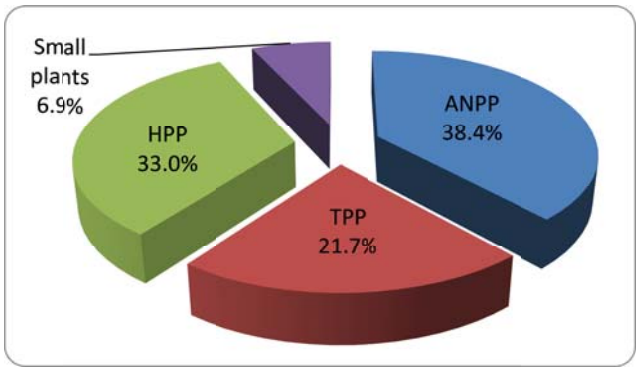

Figure 2. Structure of power generation in 2010 (source: "Settlement Centre" CJSC of the RA MENR)

About 40% of the installed power generating capacity has been in operation for more than 35 years and only around 70% of the capacity is considered to be available. Therefore, modernizing and replacing the generating capacities is essential. The Government of Armenia has already taken steps towards the improvement of the above situation. In recent years, there was a rapid development of small HPPs, a new energy efficient generating capacities were put into operation – combined-cycle gas turbine of a 240 MW capacity at Yerevan Thermal Power Plant (TPP) and a 440 MW gas turbine unit at Hrazdan TPP. The first wind power plant and a number of small cogeneration plants were put into operation as well (15.5 MW, in total).

In 2010, the total power generation amounted to 6,491.2 million kWh, with 38.4% generated by the nuclear power plant, 21.7% - by TPPs, 33% - by HPPs and 6.9% - by small plants.

Population and industry are the major consumers of electricity with the shares of 35.7% and 23.2%, respectively.

Armenia has intersystem connections with all neighboring countries, but actually there is the power interchange with Iran and Georgia only.

Gas Supply System. Armenia relies extensively on natural gas to generate electricity and produce industrial output. Armenia imports natural gas from Russia via Georgia, and from Iran. The gas transportation system includes high-pressure main pipeline and the underground gas storage facility. The gas distribution system expanded rapidly in recent years and the number of consumers reached 620 thousand which exceeds that of the Soviet period (Fig.3). The annual gas consumption is in the range of 1.8 to 2.2 billion m^3. As of 2011, residential buildings' gasification level reached 79%.

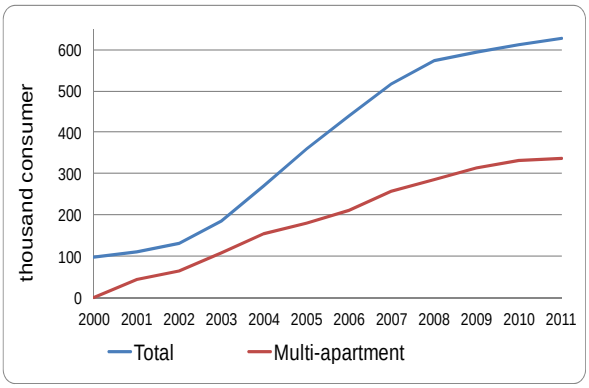

Figure 3. Expansion of natural gas network in the housing (source: the RA National Statistical Service)

Heat Supply. Until the economic and energy crisis of 1990s, district heating (DH) systems in Armenia used to supply nearly all of the heating and hot water to residential and public buildings: 35% of the housing stock, and 90% of residential and public buildings in the country were supplied from DH systems, operating on natural gas and with mazut as a reserve fuel. Heat supply of the housing sector was provided both by large heat sources – TPPs and heat plants (35%), and by medium and small-scale heat plants (65%).

The first phase of the development of heat supply systems in Armenia started in 1950s, when there was a rapid construction of residential apartment buildings and gasification of residential areas. In this phase heat supply to residential areas was provided by medium and small-scale heat plants.

The second phase of the development started in the beginning of 1970s and ended in 1980s and involved construction of large DH systems supplied from Yerevan, Hrazdan, Vanadzor TPPs as well as heat plants of 120-150 MW capacity. The already constructed small-scale boiler houses were reconstructed to central heat substations (CHS), which allowed incorporation of the existing distribution networks into larger systems.

Thus, by the end of 1980s the existing DH systems supplied heat and hot water to 55 settlements of Armenia or to 9,400 residential apartment buildings and 3,800 public buildings in total.

Due to closure of the nuclear power plant in 1989 accompanied with regular interruptions of Russian gas imports through neighboring countries, Armenia became almost entirely dependent on its hydropower resources for electricity generation purposes. Heat production fell sharply in 1992 and most of the DH systems discontinued operation after 1992 (Fig.4). As a consequence, residents were

forced to rely only on individual heating solutions and use expensive electricity, wood, kerosene or any other available means, which resulted in significant safety, economic, health and environmental problems.

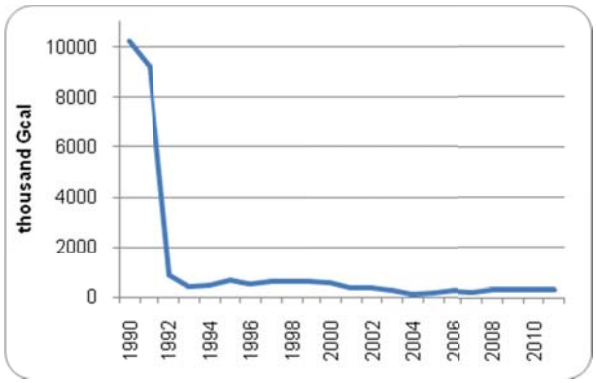

Figure 4. Heat production by DH systems in RA (source: MENR for 1992 to 2002 and "ArmRusGasProm" CJSC for 2003 to 2011)

Since 1996, despite the restoration of gas and electricity supply, district heating services continued to decline because of the liberalization of primary energy prices and the worsening social and economic conditions of the population. Besides, operation of those systems revealed a number of obvious shortcomings: low reliability, poor maintenance, significant heat losses, lack of regulating and measuring equipment, extremely low collection rates.

Current Policy in Heat Supply Sub-Sector

Heat supply sub-sector is one of the major consumers of energy resources and one of the largest GHG emitters in Armenia. As of 2006, its share in primary energy resources consumption exceeded 20 %, its share in energy sector's GHG emissions was about 20% and 14% - in the country's total emissions (The Second National Communication of Armenia under UNFCCC, 2010).

Heat supply being one of the most important life support systems, has a significant potential for energy saving: according to the National Program on Energy Saving and Renewable Energy (2005), energy saving potential through improving energy efficiency in buildings is assessed at 331 ktoe, that is, 33 % of total energy saving potential of Armenia.

Considering the emergency of the heat supply and aiming to ensure efficient, safe, affordable and clean heating services, in 2002, the Government adopted the Urban Heating Strategy. The Urban Heating Strategy provided the strategic framework for the short and medium term development of the country's urban heating sector.

The Strategy envisaged the reforms' implementation in three phases: i) survival - keep existing centralized heating systems operational with minimum investments and take first measures to offer affordable centralized heat supply (2 years); ii) recovery - develop and start implementing sustainable heating options (3 to 5 years); and iii) growth - attraction of investments for centralized heat supply rehabilitation and large scale dissemination of decentralized systems.

For the Strategy implementation, a mix of measures were envisaged: commercialization of heat supply, social support schemes, regulatory, institutional, social, environmental, public awareness and other measures.

Unfortunately, the adoption of the Strategy did not contribute to any significant changes in the heat supply sector and individual solutions remained the only means for the population to cover their heating needs. In terms of gasification level increase (as of 2011, residential buildings' gasification level reached 79%), the population was able to widely use different types of gas consuming space heaters. The share of natural gas in the heating mix increased over the past decade. From 2003 to 2009, the use of firewood for heating dropped nearly 91 %, while the use of natural gas for heating increased by more than five times (source: WB, Charged Decisions: Difficult Choices in Armenia's Energy Sector, October 2011).

Individual heating by gas-fired heaters becomes most attractive for the population because of the relatively low price for natural gas compared to electricity (for example, in 2007, 1 kWh of electrical energy cost 21.7 AMD, while 1 kWh of heat energy from gas-fired heaters with open combustion chamber cost 15.7 AMD and 16.8 AMD from those with close combustion chamber), as well as the possibility for regulating the level of comfort in the apartments depending on the financial well-being of the consumer.

The remaining operating DH systems that supplied space heating to residential areas did not even survive the two-year period defined by the Strategy, due to: poor management, absence of metering and control systems, illegal use of hot water from the heating system due to discontinuance of hot water supply to the population; low collection rate and consequently financial shortage for proper maintenance and modernization of the system, etc. These few systems that supplied space heating finally collapsed in 2004 after the Government had abolished the considerable subsidies for the natural gas.

Actually, in 2005, when UNDP-GEF Project was initiated, the situation of the heat supply sector in Armenia could be characterized as follows:

- practical collapse of municipal DH systems: heat generation by DH systems in 2005 fell to about 2.5% of that in 1990 (Fig. 4).
- lack of political will for the development, management and regulation of the sector i.e. lack of: law regulating the sector and authorized body responsible for the sector, targeted social support schemes for poor families and financial support schemes (lending schemes at low interest rate aimed at heat supply restoration);
- spontaneously spreading individual heating solutions to meet the minimum vital needs of the population in heating and hot water;
- expansion of the gas supply system and relaxation of safety requirements for using natural gas for heating purposes in multistory residential buildings.

The key barriers hampering the sustainable development of the heat and hot water supply services as identified during the Project development phase were as follows:

- Weak institutional, legal and regulatory framework:

- Lack of short and long-term planning for the development of feasible, energy efficient, environmentally friendly heat supply systems;
- Lack of favorable business environment for attracting private investments in the heat supply sector;
- Lack of a clear assignment of responsibilities and accountability among governmental and local authorities for making a key decisions on heat supply issues;
- Lack of a regulatory framework for ensuring appropriate relations between apartment owners in multistory buildings after privatization, in terms of common rules and responsibilities;
- Lack of social support schemes for essential heating needs;
- Lack of appropriate tariff policy promoting energy efficient and environment friendly heat supply solutions.

- Lack of incentives and implementation plan for restructuring and commercialization/privatization of the existing DH companies;
- Lack of capacity, experience and appropriate skills of local authorities and residents of multi-apartment building management bodies to manage existing small-scale heat supply systems.

UNDP-GEF Project Intervention

Concept of a Demonstration Project

Recognizing the important role of the state in defining the heating strategy of the Republic of Armenia and in creating appropriate legal and regulatory framework, it was obvious that only the private sector participation will allow restoring the district heating and provide affordable and environmentally sustainable heating services.

As it was indicated in the Urban Heating Strategy, to meet real heating needs of the population, the Republic of Armenia needs a new approach. Any centralized option will have to be reliable and competitive with individual and flexible options like individual gas-fired heaters.

The assessment conducted in 2006 by the Project experts confirmed the idea, that in terms of the existing and forecasted prices for natural gas, DH systems on the basis of heat-only boilers become noncompetitive compared to the individual heat supply solutions. Thus in case of gas import price of 110 USD/1000 Nm^3, heat energy from small-scale heat only boilers based centralized systems cost 24.8 AMD/kWh, while 1 kWh of heat energy from gas-fired heaters with open combustion chamber cost 15.7 AMD and 16.8 AMD from those with close combustion chamber.

Therefore the UNDP-GEF Project in 2006 initiated the studies for identification of feasible alternatives for refurbishment and restoration of DH in the two most promising districts (Avan and Davidashen) with high heat density selected among those envisaged by the master plan of Yerevan city. The feasibility studies developed by the Project have considered two alternatives for DH reconstruction: i)

conventional scheme (on the basis of boiler houses); and ii) on the basis of cogeneration. Both alternatives had to meet the following requirements: high energy efficiency, quality and reliability of heat supply, affordability of heat tariff, availability of apartment level metering and regulation.

The cogeneration based alternative proved to be feasible and environmentally friendly solution for the selected areas, ensuring affordable heat tariff and having higher GHG emissions mitigation potential. Thus, at gas import price of 110 USD/1000Nm^3, this approach allowed to keep heat energy tariff for Avan project equal to 14.6 AMD/kWh, while 1 kWh of heat energy from Avan DH system on the basis of boiler houses was equal to 22.7 AMD/kWh.

Brief Description of the Demonstration Project

Avan residential district was built in the mid-1970s. It is a large residential area in North East of Yerevan with around 32,000 residents (218 high-rise apartment buildings) covering 150 ha and is located at 1200 to 1300 meters above sea level. The former DH system started operating in mid-1970s and provided heat and hot water to consumers in Avan residential area. DH fully operated until 1992, and from 1994 to 2003 operation was limited only to heat supply. The DH system was shut down in 2003. According to the study of the French BCEOM company (1996), the efficiency of Avan DH system was around 50%.

The pre-feasibility study for the Avan DH system restoration developed by the Project envisaged: construction of green field autonomous energy centers with cogeneration units and heat only boilers to meet the peak space heat load, full reconstruction of main and distribution networks, redesign of the internal distribution system in the buildings (from vertical distribution into horizontal one), installation of new heating and hot water supply network and radiators equipped with regulators in the apartments, installation of apartment level heat and hot water meters for introducing consumption based payment system.

Stage-by-stage implementation of the Avan DH system restoration project was envisaged: the first stage included 76 buildings (3,350 apartments and more than 10,000 residents) to be supplied from the new Autonomous Thermal Power Plant (“ATPP-1”) equipped with two cogeneration units of 2,000 kWe and 2,180 kWt capacity each and two peak heat-only boilers with the capacity of 7.56 MW each.

The project technical assistance to the Avan DH system reconstruction project included: i) development of the pre-feasibility study; ii) development of the regulatory framework aimed at reducing commercial risk through establishing public private partnership and setting preferential tariff for electricity generated from cogeneration units and two-part tariffs for supplied heat; iii) assistance in negotiations between private sector and national authorities – Government, Regulator and Yerevan Municipality in the course of initiation and implementation of the pilot project; iv) organization of consultations with Avan district community and condominiums; v) surveys of public opinion in the pilot area; vi) bringing in international experience, particularly, involving Ramboll A/D company as consultant and organizing study tour for national decision makers to Denmark; vii)

provision of apartment level heat and hot water metering equipment; viii) monitoring of the system operation.

Improvement of Economic and Administrative Environment for Attracting Private Investments and Reducing Commercial Risk

Considering the existing situation in the heat supply sector and limited budgets of municipalities as well as the existing and future unpredictable natural gas price escalation, it was clear that restoration of the deteriorated district heating in Armenia can be achieved only through the involvement of the private sector and on the basis of cogeneration. The bottom-line is a need for investor confidence that he will get an adequate return on his investment. Therefore, the Project's efforts during development of the feasibility study for cogeneration-based DH restoration were ultimately focused at reducing commercial risk while ensuring competitive and affordable level of heat energy for consumers.

Directive 2004/8/EC of the European Parliament and of the Council of Europe on the promotion of useful heat demand based cogeneration outlines the framework for promoting cogeneration, while support schemes for cogeneration at the national level depend on the specifics of the internal markets for electricity and heat.

Public support schemes

Price support

Cogeneration is the combined production of electrical and useful thermal energy from the same primary energy source, i.e. every CHP application involves the recovery of thermal energy that would otherwise be wasted to produce additional useful thermal energy. High efficiency and specifics of cogeneration allowed the project team to apply the following pricing approach to electricity and heat produced by cogeneration enabling to reduce commercial risk while ensuring competitive and affordable level of heat energy for consumers:

(i) the cost of production of heat and electricity by cogeneration units were not separated;

(ii) competitive and affordable heat tariff was determined on the ground of market research (comparison was done with the cost of heat from household appliances), thus the revenue from heat sales were first taken into account and then

(iii) the electricity tariff was calculated as the "left over" costs associated with running the cogeneration system and ensuring the required return on the investment.

With gas import price of 110 USD/1000Nm^3, this approach allowed keeping heat energy tariff for Avan project equal to 14.6 AMD/kWh, while 1 kWh from gas-fired heaters was 16.8 AMD/kWh and 18.1 AMD/kWh – from apartment level boilers. In the same time the purchase tariff of electricity produced from cogeneration units was close to the calculated one-part tariff of the marginal TPP of the Armenian power system.

The mentioned calculations served as the basis for the adoption of a direct price support scheme set by GoA Decision No.509-N dated April 13, 2006 guaranteeing a purchase at favorable price (not exceeding the calculated one-part tariff of the marginal TPP of the Armenia's power system) of electricity produced from the CHP plant of the Avan demonstration project.

Adoption of the preferential feed-in-tariff for electricity produced from cogeneration and sold to the national grid allowed to keep an affordable heat tariff for residents. Thus, the adoption of the GoA Decision led to the mitigation of commercial risk for investors by providing:

- guaranteed high revenue from the electricity sold to the grid at the favorable tariff;
- high revenue from heat sales due to the high connection rate of the residents ensured by competitive and affordable heat tariff

Thus, in the heating season of 2011-2012, the heat tariff in Avan district heating system was 16 AMD/kWh, while the cost of heat produced by apartment-level gas boilers was about 23 AMD/kWh (investment and operation costs), when in case of closed chamber gas-fired heaters only the gas costs makes 17 AMD/kWh.

Setting a preferential tariff for electricity from cogeneration based on useful heat demand is a well-known CHP promotion instrument in the international practice; however this was a precedent of public support for promoting cogeneration based DH restoration in Armenia.

Public-private partnership was also promoted and justified by the Project Focus has been on how the district heating can be a strong asset in the long-term energy strategy for Armenia and thus justify that the government and the municipality should pave the way for district heating, removing institutional barriers and offering favourable conditions. This led to adoption of the GoA protocol decision No.30 dated August 3, 2006. The Yerevan municipality was instructed to hand over for the free use the heat supply assets of Avan district to the new heat supply company.

These GoA Decisions reduced commercial risk and created a favorable economic and administrative environment for attracting private investments to the Avan DH restoration project and were critical to making investment decision by the Russian investor.

Figure 5. Autonomous energy center

In August 2006, a heat supply company, "ArmRusCogeneration" CJSC was founded with the majority of shares owned by a foreign investor and a minority held by the Municipality of Yerevan.

The Avan district heating system was put into operation on 15 December 2009. As a result of the reconstruction, a green field autonomous energy center equipped with CHP units and peak heat-only boilers was constructed to supply 76 apartment buildings (about 3000 apartments) , main and distribution heat networks were reconstructed, the internal distribution system in the buildings was reconstructed (from vertical distribution into

horizontal one), new heating and hot water supply network and radiators equipped with regulators were installed in the apartments, apartment level heat and hot water meters for introducing consumption based payment system were installed.

For optimal efficiency, CHP system was designed and sized to meet a base load thermal demand. As of 2012, taking into account the value of the connected heat load, one CHP unit of 2,000 kW_e and 2,180 kW_t capacity and one heat-only boiler with the capacity of 7.56 MW to meet the peak space heat load were installed so far to supply 30 apartment buildings, one school and two kindergartens. Another CHP unit and peak heat-only boiler of the above mentioned capacities should be installed upon the completion of the reconstruction of distribution and internal heat networks to supply additional 46 apartment buildings (in all 76 buildings). By 2012, about 9 million USD was invested in Avan DH system restoration project.

Demand side regulation and consumption based billing system proposed by the Project in Avan DH project was the first such experience in Armenia. The actual consumption based payment system creates proper incentives for heat energy saving and formation of clear economic relationships between supply company and consumers. In addition to the advisory role, UNDP-GEF Project also provided apartment level ultrasonic heat measuring equipment and hot water meters for supporting the proposed billing system.

Multipart tariff system for heating and hot water, proposed by the Project mitigates the heat supply company risk connected with heat consumption reduction. Such system creates incentives for demand side energy savings, simultaneously ensuring that heat supply company recovers its fixed costs regardless of customers' consumption level, thus mitigating supply company's risk from reduced heat demand.

Financing of the construction of internal networks in the apartments by the supply company was proposed by the Project with the aim to attract consumers to the DH system. This was considered as a soft loan to the house owners and should be recovered by a separate tariff rate. The experience of the last 2 years of the Avan project implementation confirmed the correctness of this arrangement. This measure contributed to the reduction of commercial risk through expansion of heat supply market and ensuring utmost revenue from heat sale.

Heat supply contract forms regulating relations between supplier and consumer were proposed by the Project considering all above mentioned tariff issues. The forms were discussed with consumers, PSRC and are currently applied by the Company.

Explanation and awareness raising activity implemented by the Project among the residents of demonstration project implementation area was highly essential and important, because the residents still remembered the poor performance of the centralized heating from the last years and were very skeptical. Besides, there was a need somehow to explain to the residents that low tariff for heat energy is not a temporarily measure. This activity contributed to the reduction of commercial risk through expansion of heat supply market.

Assessment Methodology of Energy Savings and GHG Emission Reduction from Cogeneration Based District Heating Systems

Efficiency improvement of the centralized heat supply systems on the basis of cogeneration is assessed by comparison of the cogeneration projects' energy consumption and corresponding emissions with the baseline scenario of the separate production of heat and power.

Baseline. Separate Production

In multi-apartment buildings of Armenia apartment level boilers and gas-fired heaters are commonly used for heating purposes. Hot water needs are met by electrical heaters. The ratio between use of natural gas to power consumption is defined based on the findings of large-scale studies and public surveys.

Annual baseline GHG emissions are determined by the following formula:

$CO_{2eq\ (baseline)} = E_{ng} \times C_{ng} + E_e \times C_{gird} + E_{e\ gird} \times C_{gird}$

where E_{ng} - natural gas consumption by gas-fired heaters, MWh

$E_{ng} = E_{heat} / \eta_{heat}$,

E_{heat} - heat production by gas-fired heaters, MWh

η_{heat} - efficiency of gas-fired heaters,

C_{ng} - natural gas emission factor, t CO_{2eq}/MWh,

E_e - electricity consumption by electrical heaters, MWh,

C_{gird} - combined margin of gird, t CO_2/MWh,

$E_{e\ gird}$ - grid electricity, equal to the electricity from cogeneration, MWh.

Annual baseline consumption of natural gas:

$E_{baseline} = E_{ng} + E_e \times f + E_{e\ gird} / \eta_{cogen(e)}$

where f - specific fuel input for given values of C_{gird} , MWh_{fuel}/MWh_e

$\eta_{cogen(e)}$ - electrical efficiency of cogeneration plant.

Project. Combined Production (cogeneration)

Annual project GHG emissions are determined by the following formula:

$CO_{2eq(project)} = E_{ng\ (blr)} \times C_{ng} + E_{e\ (cogen)} \times C_{gird}$

where $E_{ng\ (blr)}$ - natural gas consumption by the peak hot water boiler, MWh,

$E_{ng\ (blr)} = E_{heat\ (blr)} / \eta_{blr}$

$E_{heat\ (blr)}$ - heat production by the peak hot water boiler, MWh,

η_{blr} - efficiency of the peak hot water boiler,

$E_{e\ (cogen)}$ - power generation by cogeneration unit, MWh

Annual project consumption of natural gas:

$E_{project} = E_{ng\ (blr)} + E_{e\ (cogen)} / \eta_{cogen(e)}$

Annual reduction of GHG emissions:

$\Delta\ CO_{2eq} = CO_{2eq\ (baseline)} - CO_{2eq(project)}$

Annual savings of energy/fuel:

$\Delta E = E_{baseline} - E_{project}$

Energy Efficiency Potential

The GHG emissions reduction assessment of Avan DH restoration project was done by comparison of the project emissions with the baseline scenario were: 75% of households cover their heat needs by individual natural gas-fired appliances and 25% - by electric appliances. The combined margin of Armenian gird is 0.4 t/ MWh. It is relatively low due to the high percentage of nuclear and hydropower in the Armenian generation mix.

In these terms, the annual energy savings for the first phase of the project (76 buildings) make 50,220 MW resulting in 10,200 t $CO_{2eq.}$ GHG emissions reduction. Life time energy savings make 1,004,400 MWh and corresponding GHG emissions reduction is 204 kt CO_{2eq}.

Policy Design Considerations

Armenian Urban Heating Strategy adopted in 2002 had no any development regarding district heating restoration till adoption of GoA decision in 2006 on support to the Avan district heating restoration project on the basis of high-efficiency cogeneration. Large capital investments and high commercial risk hamper private investor penetration in district heating market. Besides, centralized district heating is so expensive that it cannot compete with the individual heating solutions.

The studies implemented by the Project and the experience of the first cogeneration based DH project proved that in terms of rising gas prices, heat supply through cogeneration is the main way for development of the DH market in Armenia.

Considering that Armenia is extremely dependent on imported fuel to meet its energy demand, district heating on the basis of high-efficiency cogeneration can be used as an instrument contributing to the security of energy supply and reduction of the greenhouse gas emissions from the heat supply sub-sector.

According to the study implemented by the Project, national potential for DH restoration on the basis of high-efficiency cogeneration is estimated about 120-140 MW which working together with peak boilers could meet the peak space load of about 300-350 MW (1000-1200 multistory buildings).

The project promoted price support mechanism proved to be attractive for private investment in cogeneration based DH restoration projects at the same time allowing keeping heat tariff at the affordable level for consumers.

Due to the private investors' interest to the cogeneration based DH restoration following the successful launch of the Avan project, it became necessary to issue regulation supporting cogeneration based DH restoration and define tariff policy in this area.

The Project approach to the pricing of electricity and heat produced from cogeneration units aimed at promotion of district heating restoration underlain the regulatory framework drafted by the Project and approved by the Public Services Regulatory Commission of Armenia. The Project experts drafted two normative documents in compliance with the principles and approaches of the above mentioned EU Directive and submitted them to the Public Services Regulatory Commission of RA (PSRC). In 2007, PSRC adopted two resolutions: No.168-L "Principles of tariffs calculation for cogeneration based on useful heat demand" and No.206-N "Methodology for calculating the tariffs for heat and power from cogeneration based on useful heat demand".

Aiming to create a favorable economic environment for investment in new cogeneration installations, a five-year grace period was stipulated by the Methodology, during which all electricity generated is qualified as "electricity from cogeneration" (electricity generated in a process linked to the production of useful heat) and shall be sold with the favorable price.

The successful launch of the Avan cogeneration based DH project and the subsequent adoption of promotional regulation for new cogeneration installations in DH contributed to increased interest of private investors to the DH projects on the basis of cogeneration.

In 2007, a new cogeneration energy center was constructed with private investments for heat supply and cooling of the Yerevan State Medical University. It was put into operation on 2 November, 2007 (promotional regulation was in place) and four buildings of the University were supplied from the energy center during two seasons.

Aiming to improve the energy efficiency of the energy center, the administration of the University applied to the Project's assistance to develop the feasibility study on the expansion of the centralized heat supply services. Based on the feasibility study developed by the Project, distribution network was expanded in 2010 and 2011 to supply four more hospital buildings.

As a result of the expansion, the annual savings of natural gas, compared to separate production of electricity and heat, reached 9000 MWh/year and GHG emissions reduction amounted to about 1700 t CO_{2eq}/year.

In 2008, another investor - a private investor from the Russian Federation expressed its willingness to implement DH restoration project on the basis of high-efficiency cogeneration in the micro-regions district of Sevan town. At the request of the investor, in 2008 the Project developed a feasibility study for cogeneration based DH restoration for 1646 apartments - more than 120,000 m² of floor area. In 2008, heat supply company "Sevan heating networks" CJSC was established. As of 2009, private investments in the amount of 900,000 USD were already done in the system.

However, given the lack of experience in the construction and operation of cogeneration based DH projects, the PSRC made a decision to cancel the preferential regulation in 2010, postponing the further decision-making until the full completion of the Avan DH restoration project.

In this respect, it should be emphasized that the role of the Avan pilot project is of special importance for development opportunities of cogeneration based DH projects in Armenia. Actually, since the adoption of the preferential regulation for cogeneration based district heating in 2006, debate has taken place regarding the suitability of the support scheme developed within it. Although the PSRC cancelled the preferential regulation in 2010 (under a special GoA Decision, only Avan demonstration project has preferential tariff in place), the PSRC is expected to wait until full completion of the Avan project before further decision. So, in terms of lack of experience in the construction and operation of district heating systems by private investors, successfully constructed and operating Avan project could be the key to unlocking application of cogeneration technology in the heat supply sector of Armenia and the evidence, that only under availability of support schemes such projects could be feasible and attractive for private investors.

Conclusions and Recommendations

Promotion of high-efficiency cogeneration based on a useful heat demand should be considered as a means of not just supporting restoration of DH at affordable prices (social benefits), but also having significant positive benefits for country's national economy with regard to saving primary energy, reducing emissions and contributing positively to the security of energy supply.

Avan project results demonstrated feasibility of district heating reconstruction based on co-generation for investors, affordable price of district heating solutions for apartment owners, and restored trust in good quality services of district heating solutions. However, the initial investments in district heating infrastructure is so large, commercial risk is so high and the organizational and financial issues so complicated that it is very difficult to establish district heating systems on purely commercial conditions.

The critical element in the success story of the Avan project is the reduction of commercial risk to a level that stimulates investment in the market. It was mainly achieved through public support scheme for promoting cogeneration based DH restoration. Such projects could be attractive for private investors if support mechanism is in place and investor has confidence, on the basis of regulations issued by public authorities, that he will get an adequate return on his investment. Thus, the governmental support for heating cogeneration is critical for its commercial replication and sustainability of reconstructed district heating schemes based on cogeneration.

It is important to emphasize the need for a stable economic and administrative environment for investments in new heating cogeneration installations. This need should be addressed by designing support schemes with a duration period of at least five years and by avoiding frequent changes in administrative procedures.