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# INTEGRATED HEATING USING NATURAL GAS AND GEOTHERMAL RESOURCES

**Giorgi Vardigoreli**
Geothermia Ltd.
P.O. Box 380060
Tbilisi
Georgia
*Vardigoreli_goga@hotmail.com*

## ABSTRACT

The general situation in the Georgian energy sector is serious. The whole energy sector was ruined with the collapse of the Soviet Union and today faces the reality of no central district heating or domestic hot tap water supply. Mostly, space heating changed to electric heating, which nowadays is quite expensive and inefficient. This also puts a heavy load on the electric power sector causing serious shortages in electricity during the winter. This project can thus be considered the very first step in rebuilding district heating.

After many surveys and analyses, during which several district heating alternatives were evaluated, a decision was made to opt for the following project. It is a two stage project: Tap water supply using geothermal hot water as a power source, and district heating based on individual natural gas boilers. Despite the higher prime cost of individual gas boilers, this alternative was chosen mainly due to the social-economical situation in the country and the flexibility it offers through stepwise development in phase with economic development and demand. It, moreover, avoids the bane of the industry, i.e. non-payment of energy bills. This is achieved by more controlled development than is possible with a centralised geothermal district heating system that requires a large up-front investment that may be out of phase with demand.

The current legal system in force in Georgia puts no constraints on the development of district heating systems or the utilisation of geothermal resources. The only constraints are commercial such as economic viability etc. In calculating the viability of the project, the energy price, upon which the project earnings are based, has a minimum level of 30 USD per MWh. Later this can and will be adjusted upwards in light of foreseen improvements in general purchasing power. The NPV for the combined version (geothermal domestic hot water plus space heating using individual gas boilers) is 15,787,000 USD giving an IRR of 12%. The same parameters for a geothermally heated domestic hot water supply is 11,718,000 USD and 13% for NPV and IRR, respectively. These values may be considered adequate in light of the social and environmental benefits the project brings, and its aims to help the Georgian nation gain a measure of energy independence.

# 1. INTRODUCTION

Georgia found itself in a very difficult position subsequent to the sudden disintegration of the Soviet Union and faced an unprecedented energy crisis. Traditional heating and hot water supply systems ceased operation in 1993 and the populace began to use electricity for this purpose. This has placed a heavy burden on the country's power system and caused serious problems.

## 1.1 General information

Georgia's territory is divided into two geographically different climatic regions near the Likhi mountain range. The West Georgia climatic belt comprises both humid subtropical and permafrost zones, while the climate of East Georgia is substantially of typical continental character. Mean annual temperature on the plains of Georgia varies between 11 and 15°C, whereas the total annual precipitation differs substantially, ranging from 1,500-2,500 mm in West Georgia down to 400-1,200 mm in its eastern part. The population of Georgia was 5.45 million in 1989. At present, however it is estimated to be 4.7 million, 3 million of which live in the cities.

From 1980 to 1990, annual carbon dioxide emission averaged 8.6 tons per capita. The annual $CO_2$ emission decreased to 2.6 tons per capita since 1991, as a result of economic decline.

Prior to the collapse of the Soviet Union, the Georgian industrial and agricultural sectors were well developed. The share of these sectors in the GNP was almost equal to that of the services sector, each comprising about one-third. After the collapse of the Union, industry's share fell to 18% in 1997 whereas the GNP share of services rose to 52%. The Georgian power system was part of the pan-Soviet power system. At the present, however, the country only receives some 20% of its primary energy requirements from Russia.

Georgia is very rich in renewable energy resources, especially in hydropower. The total energy capacity of surface runoff is calculated to be 219 billion kWh annually; technically it is only feasible to produce 40 billion kWh in some 300 electric plants of various production capacity. At present, only 25-30% of this technically feasible potential is utilized. Wind energy could potentially supply an additional 2-3 billion kWh of electricity. There is a great potential for biomass, geothermal and solar energy as well.

## 1.2 Geothermal heat supply history and present situation

Early in the 20th century, medical properties of Georgian thermal and mineral waters attracted special interest. Registered in the country at present are about 250 single and groups of natural springs and artificial wells with geothermal water at temperatures of 30-108°C. Their total yield equals 160 thousand $m^3$/day. Most of them are concentrated in the Tbilisi region and in Western Georgia. For technical and economic reasons, about 10 of these were selected for urgent rehabilitation and development, three of which are located in Tbilisi. Only 6 of the wells drilled into the Tbilisi geothermal reservoir could be used for heating purposes. Nowadays most of the wells are used for hot water supply to nearby small residential districts and some bathhouses.

The feasibility study project entitled "Removing the barriers to the energy efficiency in municipal heat and hot water supply systems in Georgia" was undertaken and resulted in several alternatives for a pilot project being developed. The main objective is the efficient rehabilitation of the heating and hot water supply system in the operating zones of Thermal Stations 1, 32 and 47, all of which are located in the administrative region of Saburtalo.

### 1.3 Heating systems past and present

Development of centralised heat supply systems (district heating systems) in Georgia started in the sixties with the building of medium and large capacity heating stations. In all, 78 cities had such systems, powered by 444 communal and 700 industrial thermal plants with a total thermal capacity of 3,006 MW (excluding Tbilisi). In Tbilisi heat generators were installed in a centralized heat supply system of about the same total capacity. The Tiblisi system received 80% of its supply from district thermal plants, 5% from CHP, 4.5% from industrial thermal stations and 10-11% from various heat sources.

By 1990, the district heat supply system of Tbilisi, comprising 47 thermal stations, provided about 7000 public and administrative buildings and 1 million residences with heating and hot water. Installed capacity of these stations ranged from 3.5 to 200 MW. The average specific thermal load for the city was 33 $MW/km^2$. The average specific heat consumption for heating of residential space was 68 $W/m^2$ and 0.29 kW per capita for the supply of hot water. Specific thermal load of public buildings was 100 $W/m^2$, whereof 83 $W/m^2$ were for heating and the remainder for providing hot water. The indoor design temperature for the residential buildings was taken to be 18˚C, and the duration of the heating season for Tbilisi 152 days, i.e. from November 15 to April 15. The tariff for thermal energy was 4.2 kopeks per $m^2$ of heating area and 60 kopeks/month per capita for domestic hot water.

The official estimates of energy system losses concluded that about 18% of the losses were due to the production of heat energy and 20% due to energy transportation. Tbilisi boiler plants are mainly powered by natural gas (NG). In 1990 the annual NG consumption was 1.1 billion $m^3$. Mazut served as reserve fuel. Hot water temperature regulation was performed manually in the boiler plants. The system was operated at constant flow in the distribution system. In 1993, after the disintegration of the Soviet Union, the heating supply system ceased operating in all the cities of Georgia.

To assess the existing state of heating and hot water supply in Tbilisi and other cities of Georgia, a survey was conducted during the winter months of 1990-2000. Special emphasis was on the pre-selected residential district of Saburtalo Region of Tbilisi. The study determined the share of different energy sources in space heating, the energy cost for space heating and the share of different fuels in $CO_2$ emissions.

In order to assess the contribution of the heating season duration to global warming, special examination was conducted for 6 different climatic zones in Georgia. Various thermal parameters were calculated for single – and multi-apartment residential buildings, public buildings and industrial objects. The total annual heat consumption was determined for all zones, taking into consideration the density of the population. The calculated quantity appeared to range from $2\times10^6$ to $29\times10^6$ GJ, giving a total of $97.5 \times 10^6$ GJ, of which $25.4 \times 10^6$ GJ were contributed by Tbilisi.

## 2. PROJECT OBJECTIVES

The national energy objective of the Georgian Authorities can be considered to supply the country with as much energy from indigenous resources as possible to ensure its energy independence to the greatest possible extent.

### 2.1 About the project itself

The present situation in the energy sector of Georgia is quite serious for several reasons. The country is today faced with a situation where there is no heating system, no tap water supply and even a shortage of electricity during the winter period in Tbilisi. This is mainly caused by the collapse of the economy after the disintegration of the Soviet Union. During Soviet times, the energy sector was an integral part of the enormous inter-Soviet energy system, financed by a large Soviet budget.

Currently, in the absence of a centralized heating system, the main sources for heating apartments are fossil fuels and electricity. The use of electricity for this purpose causes power peaks that are harmful to the energy sector as well as to the customers. Electric heating in wintertime increases the demand on electricity quite significantly. Bearing in mind that during the winter the generation of electricity is chiefly in thermal power stations, fuelled by imported NG from Russia. Besides being very expensive, reliance on imported energy also brings with it serious political problems and is counter to the main national energy objective of energy independence.

It is therefore evident that implementation of this project will work towards solving some of Georgia's energy problems, the most urgent of which are:

- Heating apartments
- Tap water supply (hot water)
- Decrease demand on electricity in winter during peak hours, which is very important to this sector in the present situation
- Decrease $CO_2$ emission

All of the above issues have significant bearing upon Georgia's main problem, which is virtually total unemployment.

### 2.2 Objectives

The principal objectives of this feasibility study are to evaluate the technical feasibility of two possible ways of supplying heating and hot tap water to the inhabitants of the Saburtalo district of Tiblisi.

- To heat apartment blocks in the district by means of individual natural gas fired boilers and hot tap water using geothermal energy
- To supply heat and hot tap water to the district using the district heating concept powered by a combination of natural gas and geothermal energy

Both possibilities will be evaluated and compared, applying strict viability criteria such as net present value and internal rate of return based upon commercial discount rates.

## 3. ENERGY RESOURCES

The following chapter gives an overview of the geological characteristics of the region with emphasis upon features important to the understanding of the region's geothermal potential, and typical geochemical characteristics of the fluid contained within the geothermal reservoirs.

### 3.1 Geological structures related to the Tbilisi deposit of thermal waters

Geo-tectonically, the Tbilisi deposit of thermal waters is located in the eastern subsidence zone of the Ajara-Trialeti folding system. Upper Cretaceous sediments and Quaternary ones, make up its geological stratigraphy. The main thermal aquifers are found in 300-800 m thick volcanic-sediment formations from the middle Eocene period, which are represented by tuffs of different composition. Dense rocks are heavily fractured. High porosity characterizes the rocks. Under the middle Eocene horizon, there is a thick (up to 3000 m) aquiclude made up of limestone plates, and from the top it is covered with upper Eocene age clay-sandstone sediments.

From the point of view of hydrogeology, the deposit represents a fractured integral pressure system where thermal water moves from west to east towards tectonic subsidence structures and has hydrodynamic connection with the Samgori-Sartichala oil deposit. In the north, the deposit is contiguous with the Georgian massif and in the south with the Artvin-Bolnisi massif. The borders between the deposit and the aforementioned massifs coincide with deep faults. A tectonic fault of meridian direction runs along the Mtkvari River.

The following tectonic structures go through the boundaries of the Tbilisi deposit from north to south:

- Lisi anticline
- Saburtalo syncline
- Mamadaviti anticline
- Krtsanisi syncline

Exposed areas on the surface of the middle Eocene rocks are the source of inflow to the geothermal field, and the tectonic fractures passing through the field and its borders represent the discharge zone of the geothermal field.

### 3.2 Geothermal exploration and utilisation to date

Here is presented a review of the present status and planned future utilization of Georgian thermal water. Contemporary conditions in South Caucasus and in Georgia particularly, maintain intensive use of geothermal energy. Confirmed total reserves are 90,000 $m^3$/day as of 1998, the heat potential of which equals some 500,000 tonnes of equivalent fuel (TEF) annually. Applying modern technology, i.e. construction of geothermal circulation systems (GCS), it is possible to save 2.5 million TEF annually. The Tbilisi geothermal field is described as an example of a project which, with efficient resource utilisation, proves that geothermal energy is cheaper, and environmentally friendly in the given conditions. Finally, it is possible to reduce the great amount of $CO_2$ released into the air by replacing traditional fuels with geothermal energy.

The history of using thermal water as thermal power goes back to 1951, when explorers for coal discovered water with temperature 80˚C in a well drilled in the village of Tsaishi not far from the Zugdidi region and, on the basis of which, a middle-size greenhouse was built. Currently, about 250 natural (springs) and water wells with temperature ranging from 30 to 108˚C have been registered in Georgia. Their total discharge amounts to about 160,000 $m^3$/day, but their potential is far greater. It has been established that indirect thermal water resources are 350-400 million $m^3$ per annum. As of January 1998, the confirmed thermal water reserves were 90,000 $m^3$/day, the heat potential of which is equal to 500,000 TEF annually. Using only a portion of this large quantity of energy has the potential to improve the present economic situation significantly (Buachidze et al., 2000).

The following example from Tbilisi, capital of Georgia, illustrates the importance geothermal energy can bring to bear on the solution to the country's energy problems. One should note here that the geothermal field is situated within the city and its environs. Since 1975 it has yielded above 20 million $m^3$ of thermal water. At present the flow of the wells amounts to only 4000 $m^3$ day. To ensure efficient utilisation, it is necessary to improve water extraction by employing suitable deep well pumps and to construct a GCS. Existing wells producing from Palaeocene formations present the possibility of installing a thermal power facility of 25 MWt, having an annual capacity of almost 25,000 MWh.

Another project plan is to use water from the upper Cretaceous aquifer. The anticipated well depth is 4.5 km, yielding a predicted temperature in excess of 150˚C. In order to build a new GCS in Tiblisi, it is necessary to drill new wells at a cost of 25-30 million USD. The prime heat cost will be not more than 8-10 USD per MWh at a payback rate of 5-8 years. The produced energy will suffice to satisfy district heating and hot water supply requirements (Buachidze, 1995) of one region populated by 100,000 families. This project is currently ready for investment and international firms are sought. After the successful construction of this GCS, it would be possible to plan 15-20 such systems for Tbilisi and the surrounding territory that would yield 7.0 million MWh annually.

The Tbilisi geothermal reservoir is administratively within eastern Kartly. It is located on both banks of the Mtkvari River, some 410-730 m a.s.l. To the east the territory is open, whereas mountains otherwise surround the field. The western part is characterised by eroded tectonic relief. Its elevations range is 2000-3000 m a.s.l. The eastern part is characterised by relatively lower elevations (300-1000 m), a worn-down plain and in some places with accumulated relief. Climatically, it belongs to a transition zone from a subtropical continental climate to sea climate. Being an extreme part of the Azerbaijani continental subtropical belt, it differs from the latter by relatively higher moisture and lesser amplitude of annual fluctuation in temperature. The average annual precipitation is 300-700 mm.

Thermal manifestations in Georgia and their therapeutic properties have been known since "ancient" times. They have been used mainly for hygienic purposes. Exploration of hot water manifestations, known as the "central district", began in 1932. From then to 1957, eight wells were drilled. They brought about an increase in the total discharge of 40-43°C water to 3,500 $m^3$/day. From 1953 to 1956, seven more wells were drilled on both banks of the Mtkvari River in order to enlarge the production areas and reveal additional resources of high-temperature water. The wells tapped water with temperatures of 45-50°C and of quite different type from the same aquifer. In the central part (the right bank of the Mtkvari River) the water was distributed between the wells. An additional quantity of thermal water of 1,500 $m^3$/day was produced on the left bank.

In 1969 water of relatively high temperature (57°C) of the same type was produced from the 2556 m deep oil well no. 1 in the central area of the Lisi anticline arch. From 1970 the "Sakburggeothermy" department carried out explorations especially for thermal water. Upto1982, eight 1867-3702 m deep wells were drilled in the city and its environs. Water of 52-74°C temperature was produced from the Lower and Middle Eocene volcanic thermal aquifers. The wells' discharge was 163-6000 $m^3$/day.

In 1984-85 the "Sakgeology" carried out explorations within the "central area" in order to reveal new thermal water resources. Eleven 400-3000 m deep wells were drilled in that period. Two of them (nos. 27 and 28) produced water of 39-40°C temperature. The Geological Department is still carrying out exploration in new areas of the Tbilisi deposit. During the explorations at the Tbilisi thermal water deposit, three areas wholly isolated from each other were discovered. These are

- The central area - old manifestations;
- The area adjacent to the health resort; and
- Lisi area - surroundings of the Lisi Lake and the Saburtalo district (the Vake-Saburtalo district).

There is a close hydro-dynamic interrelation between the wells within each area. Its nature, however, has not been determined yet. It is quite possible that further exploration may reveal more such areas.

Currently, the Tbilisi Baneological Health Resort and the hygienic bathhouses use the low- mineralization water produced in the central area. The higher-temperature water (57-74°C) tapped in the Lisi (wells 5-T, 7-T and 8-T) and the Saburtalo (1, 4-T and 6-T) areas with total discharge of 3800 $m^3$/day is used for hot-water supply and heating office buildings and the general population. It is worth noting that the thermal water in the three areas is of the same composition, of low mineralisation (0.19-0.26 g/l), with alkaline reaction. It is of sulphate-chloride-sodium type containing some hydrogen sulphide.

The 25-year exploitation of the Lisi area showed that direct utilisation of geothermal water without any regard for re-injection causes a gradual reduction of water discharge in production wells because the quantity produced exceeded the rate of natural recharge of the geothermal reservoir. This might eventually result in the water flow from the well ceasing. This can be prevented by closely monitored production with provision for significant re-injection, such as is depicted in the Lisi area's GCS concept.

All the conditions needed are present, i.e. production wells 5-T, 7-T and 8-T and wells for re-injection, wells l-Lisi and 9-T. The above-mentioned wells all intersect the Middle Eocene geothermal aquifer, which is overlain and underlain by impermeable layers (aquacludes), thus the re-injected water will circulate only in this aquifer. This is termed circulation cycle, circuit I.

A second possibility can also be considered, i.e. to install a second circulation circuit in the same area of the Upper Cretaceous thermal aquifer but at a deeper level (4000-4500 m). Consequently, water of higher temperature (95-100˚C) may be produced. Not a single well in the Lisi area has intersected this aquifer. To install the second circuit, it will be necessary to carry out additional drilling, which will require considerable expense.

It is possible to use the currently idle boilerhouse (after some reconstruction) as a heat central (GeoTS) for a Lisi GCS. This will allow using all the boilerhouse service lines (power and water supply, heating system, etc.).

### 3.3 Chemical composition of the geothermal fluid

The chemical composition of the water (from wells 5-T, and 7-T) that is earmarked for this project is given in Table 1. It should be pointed out, however, that the reliability of the analyses, adjudged by the net ionic balance of the sample analysis as is standard in Iceland, is not very high compared with that stipulated by our geothermal laboratories. The criterion adopted in Iceland is that the net ionic balance should be within +/- 5. The net ionic balance of the above sample analyses is about –32/-39.

TABLE 1: Chemical composition of the water in mg/l in wells 5-T and 7-T

| Component | Well 5-T | Well 7-T |
|---|---|---|
| pH | 10.0 | 9.85 |
| Temperature (˚C) | 60 | 60 |
| Carbon dioxide ($CO_2$) | 24.2 | 52.81 |
| Hydrogen sulphate ($H_2S$) | | |
| Silicon oxide ($SiO_2$) | 26.75 | 53.5 |
| Dissolved oxygen ($O_2$) | 14.0 | 11.8 |
| Lithium (Li) | 0.025 | 0.035 |
| Sodium (Na) | 69.6 | 91 |
| Potassium (K) | 0.77 | 2.1 |
| Magnesium (Mg) | 0.019 | 0.01 |
| Calcium (Ca) | 0.4 | 0.14 |
| Fluoride (F) | 0.999 | 2.4 |
| Chloride (Cl) | 35.5 | 43.665 |
| Bromide (Br) | 0.018 | |
| Nitrogen oxide ($NO_2$) | | 0.018 |
| Sulphate ($SO_4$) | 67.622 | 58.003 |
| Iron (Fe) | 0.09 | 0.03 |
| Copper (Cu) | | 0.01 |

The WATCH software was used to assess two compositions to try to determine their scaling potential with respect to anhydride and calcite, which are the most frequent scaling culprits in low temperature geothermal water as that under consideration here. The results are depicted in Figures 1 and 2.

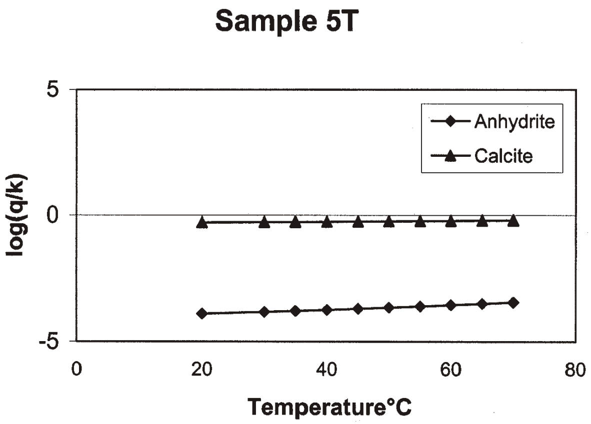


FIGURE 1: Scaling potential of well 5-T with respect to anhydrite and calcite

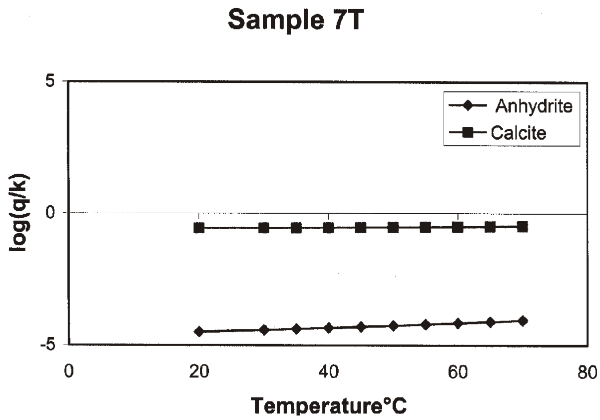


FIGURE 2: Scaling potential of well 7-T with respect to anhydrite and calcite

The scaling assessment of the water from the two geothermal wells indicates that there is little or no danger of calcite or anhydrite scaling in either well over the envisaged operating temperature range (30-65˚C). The inaccuracies inherent in the chemical compositions must, however, be borne in mind, and it is advised that more careful sampling and chemical analyses along with a new scaling potential assessment be carried out.

## 4. ENVIRONMENTAL ISSUES

The first inventory of greenhouse gas (GHG) emissions and sinks was performed during the preparation of Georgia's Initial National Communication in 1997-1998. According to the inventory, $CO_2$ emissions from the territory of Georgia amounted to 39.62 Tg in 1985, but declined to 5.34 Tg in 1995. Respective values for $CH_4$ were 0.41 and 0.15 Tg, and for $N_2O$ 8.60 and 3.27 Gg. Estimates of $CO_2$ sinks by forest ecosystems came to 12.39 Tg. The main share (about 70-90%) of $CO_2$ emission is due to fossil fuel combustion, both in stationary and mobile sources.

The estimation of the quantity of GHG and other air pollutants emitted using different kinds of fuel can be made: a) directly by measuring their average concentrations in the atmosphere, and b) indirectly by calculation using accepted methodologies. Whichever assessment method is used, it is also necessary to identify ways to mitigate deleterious environmental effects, and to determine to what degree it satisfies the project target which is reduction of GHG. To enable this, it is first necessary to determine the baseline emission, i.e. the emission quantity commensurate with the case of zero new development. Once a baseline (reference point) has been established, emissions caused by the study project can be estimated, to ascertain reductions or increases (Gzirishvili, 2000).

The baseline atmospheric pollution describes the situation, as it would be in the absence of any energy project implementation. The environmental objectives of this project are to raise energy efficiency in the field of heating and hot water supply and thereby abate deleterious atmospheric emissions. In particular, fuel consumption will be reduced, thereby abating the main parameter in global warming – greenhouse gas emissions to the atmosphere. Besides the global environmental impact, fossil fuel consumption leads to negative regional and local impacts by emitting other atmospheric pollutants such as carbon monoxide, nitrogen oxides, sulphur dioxide, fly ash, vanadium pentoxide, etc.

The fuel consumption of the pilot project and corresponding $CO_2$ emissions are presented in Table 2 and Figure 3 (for total fuel consumption and corresponding emission see tables and figures in Appendix I).

TABLE 2: Fuel consumption and $CO_2$ emissions for the pilot project in Saburtalo

| **Year** | **Annual energy production, GWh** | **Annual consumption** | | **Annual $CO_2$ emissions, thousand tons** | | |
|---|---|---|---|---|---|---|
| | | **Natural gas, million $m^3$** | **Electricity, MWh** | **Natural Gas** | **Electricity** | **Total** |
| 2001 | 18.016 | 1.360 | 3600 | 2.666 | 0.993 | 6.61 |
| 2002 | 17.920 | 1.817 | 26 | 3.561 | 0.155 | 3.734 |
| 2003 | 35.841 | 3.633 | 53 | 7.121 | 0.309 | 7.475 |
| 2004 | 36.992 | 3.750 | 54 | 7.350 | 0.310 | 7.710 |
| 2005 | 37.979 | 3.850 | 56 | 7.546 | 0.321 | 7.919 |
| 2006 | 39.130 | 3.967 | 58 | 7.775 | 0.333 | 8.161 |
| 2007 | 40.116 | 4.067 | 59 | 7.971 | 0.338 | 8.364 |
| 2008 | 41.267 | 4.183 | 61 | 8.199 | 0.350 | 8.606 |
| 2009 | 42.253 | 4.283 | 62 | 8.395 | 0.355 | 8.809 |
| 2010 | 43.404 | 4.4 | 64 | 8.624 | 0.367 | 9.051 |
| 2011 | 44.555 | 4.517 | 66 | 8.853 | 0.378 | 9.293 |
| 2012 | 47.186 | 4.783 | 70 | 9.375 | 0.401 | 9.842 |
| 2013 | 48.500 | 4.917 | 71 | 9.637 | 0.407 | 10.110 |
| 2014 | 49.816 | 5.05 | 73 | 9.898 | 0.419 | 10.385 |
| 2015 | 51.131 | 5.183 | 75 | 10.159 | 0.430 | 10.659 |
| 2016 | 52.446 | 5.317 | 77 | 10.421 | 0.441 | 10.934 |
| 2017 | 53.762 | 5.45 | 79 | 10.682 | 0.453 | 11.209 |
| 2018 | 55.241 | 5.6 | 81 | 10.976 | 0.464 | 11.516 |
| 2019 | 55.241 | 5.6 | 81 | 10.976 | 0.464 | 11.516 |
| 2020 | 55.241 | 5.6 | 81 | 10.976 | 0.464 | 11.516 |
| **Total** | 866.035 | 87.327 | 4847 | 171.161 | 9.306 | 182.265 |
| | | Baseline emissions | | | | 513.890 |
| | | Emission reduction | | | | 331.625 |

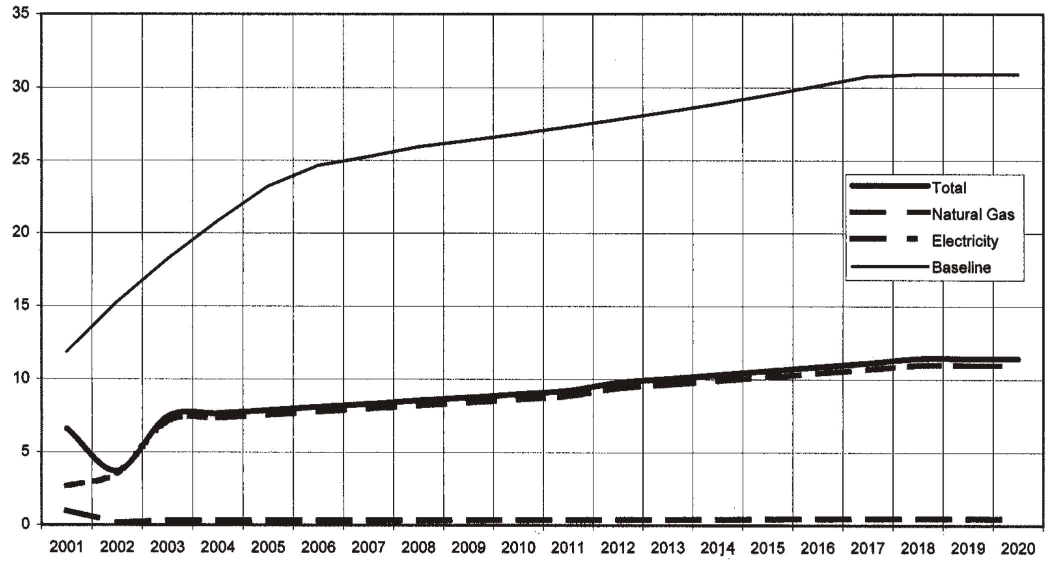


FIGURE 3: $CO_2$ emmisions for the pilot project in Saburtalo, thousand tons

## 5. TECHNICAL DESCRIPTION

This chapter describes the essential technical features of the project and outlines its planned implementation, envisioned being carried out in discrete stages, planned to suit the local demand for heat and hot tap water, and the prevailing financial situation both nationally and locally.

### 5.1 Implementation of the project

The project will be implemented in carefully planned discrete stages. This stepwise implementation is depicted in Figure 4. Some steps foreseen in the implementation are:

1. Domestic hot tap water supply completed with construction of a GTS and network, laying the re-injection pipeline and ancillaries, etc.;
2. Provision of the commercial and legal background for the project (building of a service centre, billing system, legal directives etc.);
3. Installment of individual boilers for apartment block heating at a rate that suits customer heating demands.

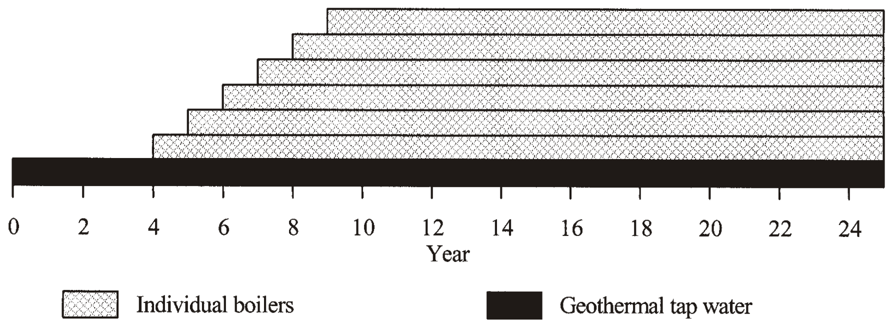


FIGURE 4: Schematic implementation schedule of project

Each implementation step will begin at a different time. It was deemed prudent not to start the installment of individual gas boilers until after 3 to 4 years so as not to overtax project financing. Heating is several times more expensive for customers and the current affordability low. It was thus decided to use the intervening period for preparing the political background and to build up the heating market.

According to our project estimates, 1kWh of geothermal energy will cost 0.07 GEL. Based upon a daily per capita consumption of 30 l/day of hot water (we estimate that 1.6 kWh of geothermal energy is necessary to produce 30 l/day of hot water), daily DHW cost will amount to 0.112 GEL. Correspondingly, the per capita outlay for geothermally produced domestic hot water will come to 3.36 GEL per month.

Natural gas heating of a space equivalent to 1 $m^2$ of floor area will require a minimum of 35 kWh and cost 0.07 GEL = 3.36 GEL per month. On the basis of an average per capita floor area of 18 $m^2$ heating costs a minimum of 37.8 GEL per month. Calculating for an average heating season of 6 months, the annual cost will come to a minimum of 227 GEL.

### 5.2 The principal layout of the geothermal hot water supply

#### 5.2.1 Geothermal production system (GPS)

There are two main ways to increase the geothermal yield (potential energy yield) from the Lisi district of Tbilisi's geothermal reservoir.

I. Select a Geothermal production system (GPS) that produces from the Middle-Eotcen thermal aquifers using existing wells, installing deep well pumps in the production wells to increase production by pumping, and simultaneously re-inject the spent geothermal water to maintain pressure in the reservoir.

II. Producing from aquifers located at greater depths from Upper Cretaceous by drilling new and deeper wells. It is anticipated that fluids of 100-170°C may be obtained at this depth. Drilling new deep wells means using larger drill rigs and more expensive drilling techniques, which in turn increases the initial investment. Thus, this alternative can, at this stage, only be considered for the future.

For the purpose of this project we choose the Geothermal production system based upon existing wells producing from the Middle-Eocen geothermal aquifer (GPS-I).

The principal process diagram of GPS-I, using 4 existing wells, is presented in Figure 5. The production wells are wells 5-T and 7-T. Their mechanical conditions are better than that of other wells, so they don't need significant rehabilitation work. Well 1-Lisi and well 9 will be used for re-injection. At present these wells are under conservation and, thus, national experts cannot exactly determine the necessary repair work required at this stage.

The diagram presented in Figure 5 envisages the thermal water being pumped using electrically driven line shaft type deep well pumps with one installed in each production well. The geothermal water pumped to the surface passes through individual de-aerators mounted close to the wells, where gases are removed from the geothermal water. After that, the main stream of thermal water from wells 5-T and 7-T is pumped to the collective de-aerator at the Geothermal Station (GeoTS). The existing Tbilisi wells can each sustain pumping at a rate of 150 $m^3$/h. If used for supplying hot tap water, it will be sufficient to install 150 $m^3$/h and 50 $m^3$/h capacity pumps in wells 5-T and 7-T, respectively.

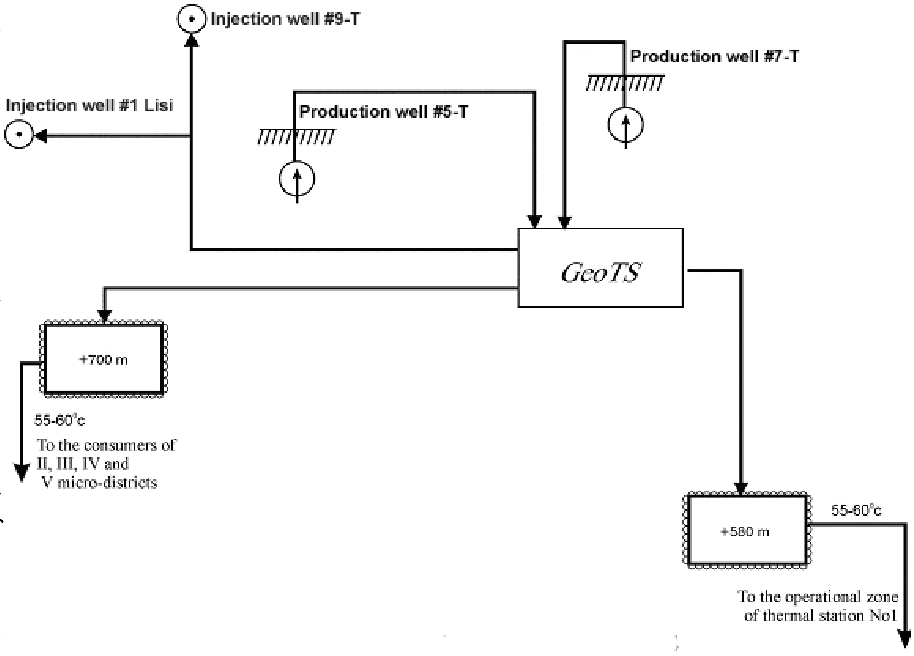


FIGURE 5: Schematic diagram of the selected geothermal production and injection area relative to the GeoTS

Figure 6 depicts the principal flow diagram for the Geothermal Station (GeoTS) utilising the GPS-I arrangement described above. The production wells 5-T and 7-T are located relatively close to the GeoTS (GeoTS will be erected in the building of thermal station 47).

The total capacity of GPS-I utilizing these two wells equals 200$m^3$/h of 65°C thermal water. The installed thermal capacity would thus be equivalent to 10.6 MWt, according to the following and based upon re-injecting used geothermal water at 20°C into the injection wells, $N = \Delta t \times L \times 1.16$ MWt, where N is the installed capacity in MWt, $\Delta t$ is the difference between the temperatures of pumped and re-injected geothermal water, L the quantity of geothermal water in $m^3$, and 1.16 a coefficient for expressing the capacity in Mwt).

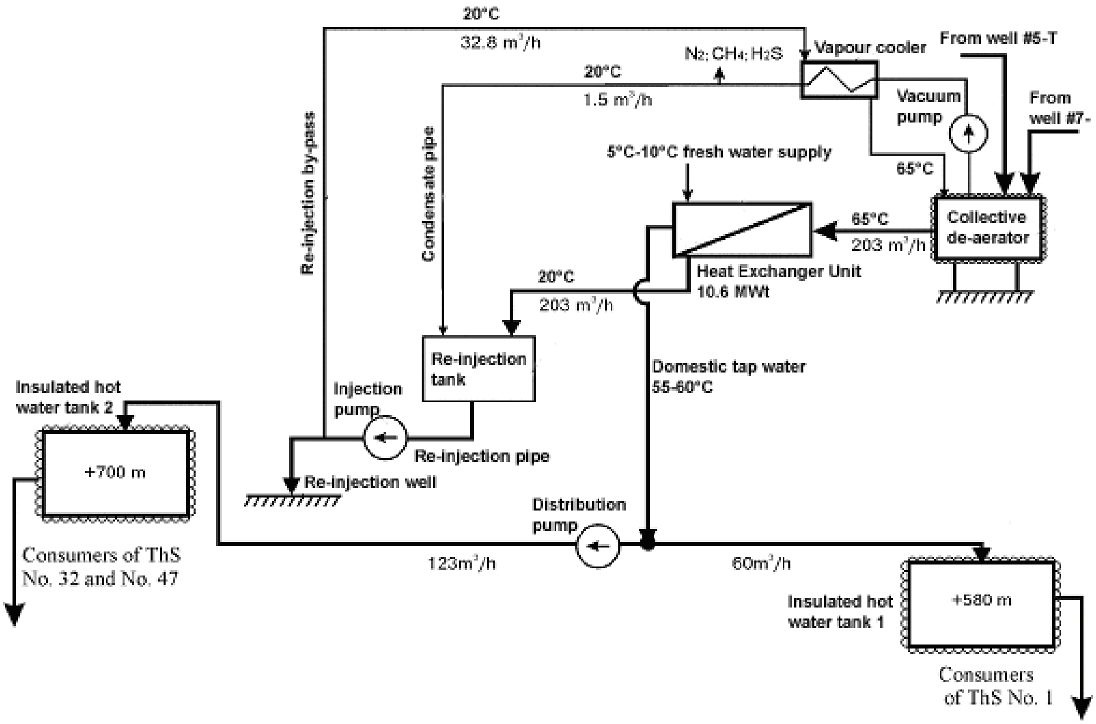


FIGURE 6: Principal layout for the Geothermal Station (GeoTS)

### 5.2.2 Technical layout of the geothermal station (GeoTS)

The principal technical layout of the geothermal hot water central GeoTS is depicted in Figure 6. It is based upon the water being pumped from production wells 5-T and 7-T, using line shaft type deep well pumps, as previously described.

For the implementation of the pilot project and realization of its first step, the supply of domestic hot tap water to the district, 183 m$^3$/h of 55-60˚C temperature water is necessary. To heat this amount of cold fresh water (5–10˚C), some 203 m$^3$/h of 65˚C geothermal water are needed. For this task two deep well pumps will be installed in wells 5-T and 7-T with 50 m$^3$/h and 150 m$^3$/h capacity, respectively. The geothermal water from the wells is collected in the collective de-aerator, where all gas is removed via a vacuum pump. The associated vapour is condensed in the vapour cooler. This requires some 32.8 m$^3$/h by-passed from the re-injection pipeline (Figure 6). About 1.5 m$^3$/h of condensed vapour at 20-30˚C is returned to the re-injection tank. The de-aerated geothermal water passes through the plate heat exchanger unit, where it heats fresh water from 5-10˚C up to 55-60˚C, thereby cooling the geothermal water to about 20˚C. The cooled geothermal water is collected in the re-injection tank, whence pumped to the re-injection well. All the 183 m$^3$/h of heated water is pumped to the insulated hot water tank 2, located at +700 m elevation. From the tank, 123 m$^3$/h flows by gravity to the residents of II, III, IV and V micro-districts of Nutsubidze Plateau (total heat load is 5.67 MW). The remainder (60 m$^3$/h) flows by gravity into hot water tank 1 located at +580 m elevation, from where it is distributed by gravity to the consumers of thermal station No.1 (with heat load 2.83 MW).

### 5.2.3 The system for geothermal hot water supply to Saburtalo district

As already mentioned the realization of hot domestic water requires the selection of a production aquifer and construction of a heat central facility. Necessary capital investment and potential earnings were estimated, based on the technical layout described above.

The construction of a GeoTS based upon the shallower aquifer requires the following:

1. Rehabilitation of Lisi well 5-T and wells 9, 7-T and 1;
2. Establishment of sanitary-protection areas close to the wells;
3. Arrangement of electricity supply to the field;
4. Construction of geothermal pipelines;
5. Reconstruction of the building of thermal station 47 as a geothermal heat central; purchase and installation of appropriate equipment;
6. Installation of insulated hot water tanks.

After dismantling existing equipment in thermal station 47, the roof of the building, the windows, and the laboratory and maintenance workshops must be restored and sanitary units installed. The reconstruction will also include the installation of the following capital equipment:

1. Plate heat exchangers for hot water (172 plates) – 9 packages;
2. Re-injection pumps CNS (Russian) 180-180 – 160 kW – 2 units;
3. The secondary hot water pumps KC 125-110 – 60 kW – 2 units

It is also necessary to install other associated minor equipment – a vacuum pump, an evaporation cooler, the geothermal water collective de-aerator reservoir and insulated hot water tanks at elevations 580 m and 700 m.

### 5.3 Space heating using natural gas boilers in individual buildings

For various reasons, of which the prevailing economic situation in Georgia and the affordability of the general population weigh most strongly, it has been decided to start re-establishing an effective heating system for the area by utilising decentralised natural gas boilers each for heating one block of apartments. These will hereafter be called individual gas boilers for simplicity.

The main advantages of an individual gas boiler heating system are:

- High efficiency, (here, modern high efficiency boilers are considered with an efficiency of more than 09; readily available on the Georgian market;
- Easy and quick to install;
- Quickly put into operation to suit heat demands;
- Low initial investment (low cost gas boilers are readily available on the Georgian market);
- Possible to include facilities of consumers in construction;
- Possibility of independent local regulation;
- Low consumption of electric power;
- Comparatively low level of greenhouse gas emission due to high efficiency;
- $NO_2$ emission is also low;
- Two-stage burning process in modern gas boilers, promotexs low emission levels.

Natural gas is considered an ideal fuel for individual boilers, as it is a convenient, cheap and relatively benign fuel in an environmental sense. The main basis for this consideration is the initiation of an intensive rehabilitation of Tbilisi's natural gas supply system. A programme of stepwise rehabilitation of the natural gas supply system is under discussion. The privatisation problem besetting the Joint Stock Company "Tbilgasi" will be solved in the near future. It should be mentioned that the main condition of privatisation is that the city's low-pressure gas network, currently mainly covering the demand for cooking gas and a part of the hot tap water supply needs, should after the rehabilitation also cover gas needed for heating.

The Saburtalo district is already supplied with gas (we understand that rehabilitation of the gas supply in this region should be completed by the time our project is implemented). The project cost estimates only include the construction of the pipe from the gas main to the building's boiler plant. Construction of a cabin to house the pressure reduction and metering gear are included in the estimate of total investment for heat supply to each building. The distance from the gas mains to each building's boiler plant is not more than 100 m. According to "Tbilgasi" data, construction of each running meter of gas pipeline, 50 mm in diameter, costs 15 USD, but 65mm and 80 mm cost 20 USD.

## 5.4 Description of autonomous boiler plants

A visual examination of the buildings, led to the conclusion that the best placement for the individual gas boiler plant would be the roof of the buildings. This solution is quite common in Central and Eastern Europe, and the former Soviet Union.

Some work is needed in order to install the gas boiler plant on the roof of the building. Most commonly these buildings (3, 4 and 5-story buildings) have garrets on the roof and are of wooden construction. Partial reconstruction of the garret will be necessary. The roof would be removed from the area necessary for the boiler equipment (14-20 $m^2$) and an enclosure built from fire-proof materials (concrete, brick, etc.). The floor of the boiler enclosure is built over the metal constructions mounted on the carrying walls. The floor is made of concrete with a waterproof system connected to the sewage system of the building. The removed part of the roof will then be restored after the installation of the boiler equipment. According to construction experience, the average building cost of 1 $m^2$ of such construction is about 200 USD. The installation of the boilers in 8 or more story buildings is relatively simple. In some cases, simple fencing of the boiler area is enough.

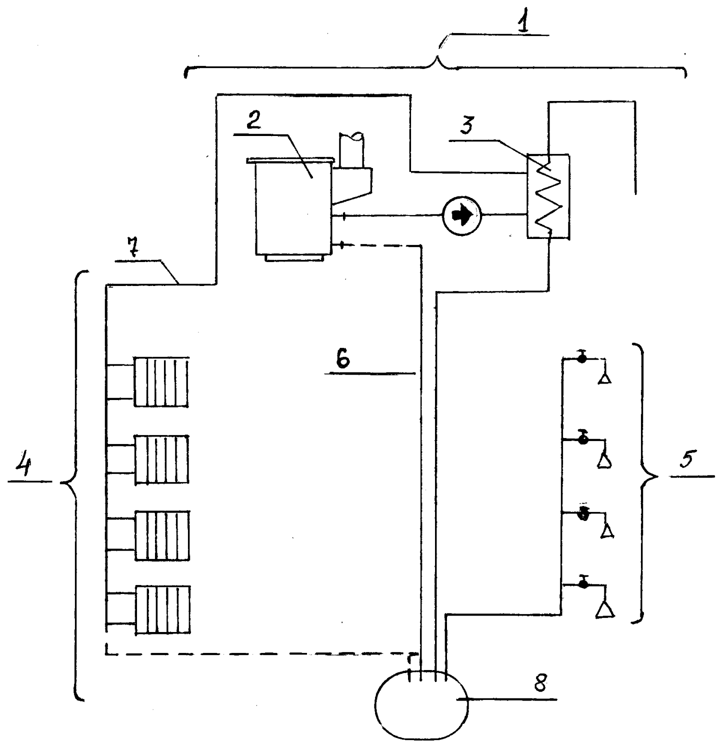

FIGURE 7: Schematic view of an individual gas boiler; 1) Boiler, 2) Chimney stack, 3) Protecting valve of the boiler, 4) Water temperature regulator in the system, 5) Circulation pump of heating system, 6) Heating system (with radiators), 7) Settling tank, and 8) Locking valve

The boiler will be equipped with all necessary devices for the protection and regulation of the system. Among them are water softener, regulator for temperature of the water delivered to the heating system, which will be controlled relative to the outdoor temperature, the regulators of natural gas and water pressure, etc. The elements of the boilers used for space heating only are given in Figure 7.

The outlined initial investments and annual expenses for the installation and functioning of individual gas boilers and geothermal hot water supply are presented in Table 1 in Appendix II. The summary table of the initial investments for geothermal hot water supply specially, is presented in Table 2 in Appendix II.

## 6. LEGAL ASPECTS

### 6.1 Legal basis for using thermal water

To understand the legislative base for utilisation of thermal water in Georgia, one should start with the laws on enterprise and then stipulate economic, organizational and legal foundations for business activities, regulate economic relationships between enterprises, promote their contacts, and establish their duties and responsibilities (liabilities). Currently the 1994 law "On enterprise" is in force in Georgia. It became active on March 1, 1995. Under this law, the following organizational and legal forms of enterprise were established:

I. *A private enterprise*. The private enterprise's owner bears sole responsibility before creditors for assumed liabilities. Only a natural born citizen may be a founder of such an enterprise.
II. A joint liability company. Owners bear joint responsibility before creditors for all assumed liabilities without restrictions on all their property. Only a natural born citizen may be a founder of such a company.
III. *A commanditor company.* Here the responsibility of several members before creditors is confined to a share of the common stock (commandits), while other liability of the members is unlimited (complementaries). Only a natural born citizen may be a complementary.
IV. *A limited liability company.* It bears responsibility before creditors for all its property, while its members - have shares in the authorized capital. The amount of the authorized capital is 2000 GEL. Both natural and legal persons may be founders of such a company.
V. *A joint stock company.* Here the authorized capital is divided into stocks. The minimal amount of the authorized capital is 15,000 GEL. The nominal cost of a share is 1 GEL or its equivalent.

A production becomes a subject of activity on the date of its being entered into the Enterprise Register. The registration is performed by the district courts where a company is located, or under a legal address according to an application (claim) of one of the founders. The application includes: the title of a firm, organizational-legal form, legal address, subject of activities, the amount of the authorized capital and other information concerning the enterprise. It is noteworthy that the so-called joint ventures are to be established either as a joint stock company or as a limited liability company. Provided a foreign founder is a legal person, it is necessary to additionally attach an extract from the Enterprise Register, the charter of the firm to be translated into Georgian and legalized, (for an enterprise registered within CIS, legalization is not needed). And if a foreign founder is a naturalized person, then his legalized biographical particulars are to be attached, too.

To carry out the investments policy in 1991, the government passed a law on foreign investments, which in 1995 was replaced by a new law. The latter was annulled in November 12, 1996 and replaced by the law "On investment activities incentives and guarantees". Currently there is no special law on investments, thus local and foreign investors are in equal conditions (the abrogated law "On foreign investments" created more favourable fiscal conditions for foreign investors than for local ones; which was the reason for its abrogation). The law "On investment activities incentives and guarantees" establishes the legal base for realization of both foreign and local investments in Georgia and guarantees their protection. Under the law, all kinds of material and intellectual values invested in business activities for a profit are considered investments. Under the law a foreign investor is granted such important rights as: to export profit without any restrictions, to export his own property, to open current and other kinds of accounts in any currency, to buy personal and real estate (except land which may only be rented to a foreigner), etc. Apart from the above mentioned, the Georgian government ensures and guarantees an investor from any non-commercial risks, namely, nationalization of property is prohibited; disputes may be settled through the international arbitration court and if a respondent is a state body then state sovereign immunity may be deprived.

To promote business activities in Georgia and create a legal base for the concrete sphere, the law "On monopoly business and competition" was passed in 1996. The law determines the responsibility of a business for monopoly abuse, unfair competition and other similar violations which affect market competition. The law prohibits monopoly activities and such unfair competition as using a competitor's or a third person's trademark and a firm's title without his permission, or spread such information that harms a competitor, etc. The antimonopoly service to the Ministry of Economy controls compliance with the antimonopoly law. It is invested with full powers to suspend or ban the activities of an enterprise which violates the antimonopoly law, examine documents connected with the business activities of a subject on the basis of the court decision, to raise the question of administrative and criminal responsibility of a law breaker, etc.

The law "On failure of enterprise activities" passed in 1996 plays an important role in harmonization of business legislation. The law regulates financial problems of a business entity by its liquidation through a court. The court will examine the failure case on the location of a debtor. One of the most important details of a failure is the fact that the court may refuse to set in motion the failure procedure if the debtor's property is so small that it is unable to cover, first of all, basic requirements.

The fiscal legislation is one of the most important for business activities. The law "On customs duty" and the "Tax code" are of importance. The law "On customs duty" determines the amount of a mandatory contribution to the state budget for transporting import goods through the Georgian customs border. A person who imports goods is a payer while customs value of goods transported through the customs border is the object for taxation. The duty rate is 5-12%. A detailed list of goods with a 5% duty rate is provided in the law upon the other imported goods is imposed a 12% duty rate. Transit, re-export, raw materials needed for production of export products, semi-products, import of goods financed by a grant or a soft credit which includes elements of a grant not less than 25% are duty-free.

As to the "Tax code", it controls the tax system and interrelations connected with it. The code imposes such state taxes as:

- Income tax;
- Profit tax;
- VAT;
- Excise tax;
- Property tax;
- Land tax;
- Conveyance tax;
- Transfer tax;
- Social tax;
- Mineral resources use tax;
- Pollution tax;
- Motor entrance tax.

For a subject interested in natural thermal waters taxes such as income tax (paid by persons engaged in business) and pollution tax (no harmful emissions are associated with utilizing thermal water) are of minor importance. The most important taxes for businessmen are the value added tax (VAT), profit and property taxes.

Profit taxes are to be paid by enterprises while profit is a taxable object. Profit is imposed by a 20% tax. It is noteworthy that the costs incurred for geological studies and preparatory work for development of natural resources are deducted from the total gain as depreciation charges (the amortization quota is 15%) and are not taxable. The expenses on research, design and development aimed at gaining profit are also deducted.

A person who is engaged in economic business and performs VAT imposed operations, the total amount of which exceeds 3000 GEL, pays VAT. The VAT rate is 20% of the amount of taxable turnover or import. VAT-free is import of power-generating plants and power-saving installations, production lines, power meters, monitoring equipment and their spare parts. The VAT is paid monthly.

Property tax is also of importance. Fixed and intangible assets registered in the balance of an enterprise are also taxable. The value of property is taxed at 1%, paid once a year.

For those interested in thermal waters, the law "On mineral resources" is the basic one. Under the law, thermal waters are considered a natural formation in-situ like other mineral resources. Some of the law provisions are of a declarative character. For example a provision saying that "mineral resources are state-owned and may be handed over only for a temporary use", "utilization of minerals is payable", etc. The important part of the law is material-procedural requirements. Of them the following forms of using minerals are of interest:

- Scientific study of minerals;
- Development and processing of minerals;
- Usage of underground natural reservoirs;
- Collection of geologic and mineralogical samples.

At the same time mineral resources are handed over for a certain period only under a relevant permission - on the basis of a license issued by the interdepartmental board operating at the Ministry for Protection of Environment and Natural Resources. The validity of a license depends on the objectives of activities:

- For studies - 5 years;
- For mining and processing minerals - up to 20 years;
- For studies and mining - up to 25 years.

It is noteworthy that minerals may be used as a production subject regardless of the form of property. A license for using minerals is granted through a tender or an auction. The amount of use tax and validity of license are indicated. Under the "Tax code", taxes for using minerals are differentiated in accordance with the kinds of mineral resources. For thermal waters it is 1-15%. A taxable object is the amount of produced thermal water. To carry out business activities in the territory of Georgia, including usage of mineral resources, it is necessary to obtain a permit at the Ministry for Protection of Environment and Natural Resources.

The activities influencing environment are divided into four categories. Deep drilling for thermal waters belongs to the activities of the first category. Generally, mining of mineral resources belongs to the activities of the second category. Establishing norms of environmental protection is aimed at maintaining an ecological balance. The process of giving permission for using minerals implies execution of ecological examination. It allows establishing acceptable norms of effecting the environment. The charges needed for ecological examination are paid by subject business activities.

The “Law on minerals” and the “Law on waters” govern protection, study and use of underground waters. The latter establishes a procedure of formation of a water state foundation and its usage, measures to prevent water depletion, procedure for allotting areas for sanitary protection of water reservoirs, requirements for land cultivation in the water catchment’s area, etc.

The above-mentioned laws were published in the press, issued as brochures and are accessible for everyone concerned (Tsersvadze,1998).

## 7. COST ESTIMATION

This chapter deals with the estimation of capital investment costs associated with the project. It also addresses issues related to the estimation of operating costs of the energy production facilities involved.

### 7.1 Demand for heating and hot domestic water in Saburtalo 2001-2020 (baseline energy scenario)

The projection of energy demand depends, to a significant extent, upon the initial values of energy consumption and reliable statistical data. The forecast of energy demand for space heating in Saburtalo district was based on results obtained from a public opinion poll made in 1999-2000 during the heating season, that gave quite a clear picture of the existing state of space heating.

The state of the domestic hot water (DHW) demand was, however, not quite clear from the results of the poll. For the purpose of this study, the forecast of DHW energy demand was based on additional assumptions. It was assumed that during the cold period of the year (during the heating season) the population would consume 100 l, and during the warm period 40 l of 60˚C hot water per person per week. For water heating during the heating season mostly electricity and natural gas are used, and to a small extent kerosene, firewood and liquid gas. During the warm period of the year, however, only electricity and natural gas are used. The categorisation of DHW energy demand according to the income of the residents was, however, not possible because of the absence of actual statistical data. Annual growth rates of energy demand were determined for each type of fuel. The results are given in Table 3.

The forecast on energy demand for heating and domestic hot water in the Saburtalo pilot region 2001-2020 was made in three stages.

- First, the energy demand was projected according to the growth rates presented in Table 3;

- Second, the effect of fuel price and convenience was taken into account. It was assumed that during the forecasted period, residents would gradually switch from inconvenient fuel (kerosene, liquid gas, firewood, electricity) to the cheapest and most convenient (natural gas). The speed of fuel replacement was selected according to a resident's income level. For space heating it was assumed that:
  - In year one, some 5% of the total energy is generated from natural gas instead of expensive fuel by the poor residents (income group 1);
  - In the following years, it is equal to 10%.
    - ✓ For income group 2 some 7.5% and 15%;
    - ✓ For income group 3 some 10% and 20%;
    - ✓ For income group 4 some 12.5% and 25%.
  - As regards domestic hot water, the change of fuel (switching to natural gas) was assumed to be 15% per year.
  - According to these assumptions, only natural gas will be used both for space heating and domestic hot water after the year 2008. Calculations showed that an annual increase of 5% in income level against 1% increase in fuel cost was not sufficient to bring the consumption level up to normal (or standard levels).

- Third, it was assumed that people will continue to spend the same amount on energy for heating and DHW after switching to the cheapest fuel. More energy would be purchased and energy demands would reach normal levels.

TABLE 3: Annual growth rates for Saburtalo district of energy demand on heating and hot water according to fuels

| Fuel | For space heating | | | | | For hot water | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Share in energy production % | Growth rate for heating, % | | | | Share in energy production | | | Growth rate for hot water (%) |
| | | Income group | | | | Cold period | Warm period | Total | |
| | | 1 | 2 | 3 | 4 | | | | |
| Electricity | 25.72 | 5.3 | 4.9 | 3.9 | 3.5 | 60.00 | 80.00 | 75.67 | 5.7 |
| Kerosene | 27.89 | 5.2 | 4.8 | 3.9 | 3.4 | 11.05 | | 2.39 | 5.5 |
| Natural gas | 34.89 | 5.4 | 5.0 | 4.0 | 3.5 | 20.00 | 20.00 | 20.00 | 5.9 |
| Liquid gas | 0.79 | 5.1 | 4.7 | 3.8 | 3.4 | 0.35 | | 0.08 | 5.7 |
| Firewood | 10.72 | 0.5 | 0.0 | -1.0 | -1.5 | 8.61 | | 1.86 | 1.0 |

The energy demand for 2001-2020, as regards heating and domestic hot water, is presented in Table 4. As was mentioned above, significant changes have taken place in space heating during the current year. This development is expected to continue. Thus, it will be necessary to correct the basic scenario to reflect real conditions in the future.

TABLE 4: Annual energy demand on heating and hot water in Saburtalo district, GWh

| Year | Electricity | Kerosene | Natural gas | Liquid gas | Firewood | Total |
|---|---|---|---|---|---|---|
| 2001 | 16.8 | 3.08 | 14.3 | 0.13 | 1.61 | 35.91 |
| 2002 | 15.68 | 1.12 | 35.23 | 0.08 | 1.23 | 53.34 |
| 2003 | 13.26 | 0.31 | 54.88 | 0.06 | 0.81 | 69.31 |
| 2004 | 10.35 | | 72.64 | | 0.47 | 83.45 |
| 2005 | 7.42 | | 89.18 | | | 96.6 |
| 2006 | 4.22 | | 99.65 | | | 103.87 |
| 2007 | 0.89 | | 106.52 | | | 107.4 |
| 2008 | | | 110.61 | | | 110.61 |
| 2009 | | | 112.36 | | | 112.36 |
| 2010 | | | 114.2 | | | 114.2 |
| 2011 | | | 116.13 | | | 116.13 |
| 2012 | | | 118.16 | | | 118.16 |
| 2013 | | | 120.3 | | | 120.3 |
| 2014 | | | 122.55 | | | 122.55 |
| 2015 | | | 124.92 | | | 124.92 |
| 2016 | | | 127.42 | | | 127.42 |
| 2017 | | | 130.04 | | | 130.04 |
| 2018 | | | 130.56 | | | 130.56 |
| 2019 | | | 130.56 | | | 130.56 |
| 2020 | | | 130.56 | | | 130.56 |

## 7.2 Tariff policy

### 7.2.1 Purchasing power and tariffs

The determination of a tariff policy (whether variable or fixed) for geothermal energy with regard to existing conditions in Georgia is a rather difficult problem that is dependent upon numerous economic, social and environmental factors. The fact that existing heat supply systems have not been operated since 1993 creates a particular problem in establishing a tariff. It must be borne in mind that, as a rule, the population uses individual devices for heat and hot water supply. Tariffs under the old Soviet system were very low. The heating tariff was fixed relative to the number of square metres of floor area occupied by each family. DHW tariff was determined on the basis of the number of family members.

In determining tariffs, the financial viability of the project should first of all be considered because it is very important to the potential investor. The USA based Global Environment Facility (GEF) co-finances investments made for environmental protection measures. This improves attainable economic viability and promotes possibilities for financing the project.

Project earnings used in the financial analysis of the project are based upon the heat energy consumed (in kWh). However, since it is impossible to record the precise amount of heat energy consumed by each family in an apartment house, tariffs adopted will have to be combined (heat and DHW rates). The total consumption by a whole apartment block can be accurately measured and recorded. The charges levied on the apartment block must then be divided between the residents on the basis of square metres inhabited by each family or according to the share of consumed heat recorded by thermal meters installed on the radiators. The payment for hot water is possible to determine from the meters.

### 7.2.2 Family expenditures on heating and domestic hot tap water

Approximately 50% of Georgian residents earn less than the minimum national monthly subsistence wage (102 GEL). According to statistics, the situation is most serious in Tbilisi where the percentage is 57%. The number of people earning less than 100 GEL a month increased from 24 to 27% in the past year. The number of families earning less than 300 GEL per month (a family income below the poverty line), increased by 1% in the past year. Such families still constitute a staggering 74% of the country's total number of households. In the past year, the number of families earning between 300 and 800 GEL a month dropped from 19 to 17.5%. While poverty seems to have increased, so has the number of relatively prosperous Georgians. Currently 7.4% of households in Georgia earn between 800 and 1,500 GEL per month, up from last year's 6.9 percent. The stratum of relatively wealthy families with a monthly income of over 1,500 GEL accounts for 1.2% of the total number of households (data from Georgian Centre for Strategic Research and Development, Human Development Report, in 1999)

A typical family's annual expenditure on heating was calculated to analyse the viability of the project. Comparison of these expenditures with the family's income was expected to make it possible to estimate approximately the purchasing power of the family.

The following parameters were used in the calculations:

- Heat load on space heating 64 - 68 $W/m^2$
- Norm of hot water 100 l/capita;
- Cost of thermal energy 30 USD/MWh

Expenditures on domestic hot water and space heating were calculated separately. The dwelling area of single-, double- and three-room flats used for the calculations are typical for the mentioned micro-district. The number of residents in identical flats may be unequal. Taking into consideration the most realistic distribution, we assume that from 1 to 4 residents live in a single-room apartment, from 2 to 5 - in a double-roomed flat and from 3 to 6 in a three-roomed flat. The results of calculations are given in Tables 5-7.

TABLE 5: Dynamics of per capita monthly expenditures on hot water with time

| Year | Daily consumption of hot water | | Monthly consumption of hot water | Hot water cost |
|---|---|---|---|---|
| | (l) | (kWh) | (kWh) | (USD) |
| 1 | 0 | 0 | 0 | 0 |
| 2 | 30 | 1.59 | 48.3 | 1.45 |
| 3 | 38 | 2.05 | 62.4 | 1.87 |
| 4 | 50 | 2.69 | 81.9 | 2.46 |
| 5 | 62 | 3.26 | 99.2 | 2.98 |
| 6 | 72 | 3.82 | 116.1 | 3.48 |
| 7 | 82 | 4.39 | 133.6 | 4.01 |
| 8 | 85 | 4.54 | 137.9 | 4.14 |
| 9 | 88 | 4.68 | 142.4 | 4.27 |
| 10 | 90 | 4.80 | 146 | 4.38 |
| 11 | 92 | 4.88 | 148.5 | 4.45 |
| 12 | 93 | 4.97 | 151.1 | 4.53 |
| 13 | 95 | 5.06 | 153.9 | 4.62 |
| 14 | 97 | 5.15 | 156.8 | 4.70 |
| 15 | 99 | 5.25 | 159.8 | 4.79 |
| 16-25 | 100 | 5.32 | 161.9 | 4.86 |

TABLE 6: Dynamics of average monthly expenditures for space heating of single-, double- and three-roomed flats with time

| Year | Consumed heat for $1m^2$ space heating during the season, (kWh) | Average cost for space heating per month, (USD/month) | | | |
|---|---|---|---|---|---|
| | | $1m^2$ space | Single-room flat (30 $m^2$) | Double-room flat (50 $m^2$) | Flat with three rooms (70 $m^2$) |
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 35 | 0.09 | 2.7 | 4.4 | 6.2 |
| 3 | 46 | 0.11 | 3.4 | 5.7 | 8.0 |
| 4 | 60 | 0.15 | 4.5 | 7.5 | 10.5 |
| 5 | 73 | 0.18 | 5.5 | 9.1 | 12.7 |
| 6 | 85 | 0.21 | 6.4 | 10.6 | 14.9 |
| 7 | 98 | 0.25 | 7.4 | 12.3 | 17.2 |
| 8 | 101 | 0.25 | 7.6 | 12.7 | 17.7 |
| 9 | 104 | 0.26 | 7.8 | 13.1 | 18.3 |
| 10 | 107 | 0.27 | 8.0 | 13.4 | 18.7 |
| 11 | 109 | 0.27 | 8.2 | 13.6 | 19.1 |
| 12 | 111 | 0.28 | 8.3 | 13.9 | 19.4 |
| 13 | 113 | 0.28 | 8.5 | 14.1 | 19.8 |
| 14 | 115 | 0.29 | 8.6 | 14.4 | 20.1 |
| 15 | 117 | 0.29 | 8.8 | 14.7 | 20.5 |
| 16-25 | 119 | 0.30 | 8.9 | 14.9 | 20.8 |

TABLE 7: Dynamics of family monthly expenditures for heating and domestic hot water with time

| Year | Expenses (USD) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Single-room flat Residents | | | | Double-room flat Residents | | | | Flat with three rooms Residents | | | |
| | One | Two | Three | Four | Two | Three | Four | Five | Three | Four | Five | Six |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 4.1 | 5.6 | 7.0 | 8.5 | 7.3 | 8.8 | 10.2 | 11.7 | 10.6 | 12.0 | 13.5 | 14.9 |
| 3 | 5.3 | 7.2 | 9.0 | 10.9 | 9.5 | 11.3 | 13.2 | 15.1 | 13.6 | 15.5 | 17.4 | 19.2 |
| 4 | 6.9 | 9.4 | 11.9 | 14.3 | 12.4 | 14.9 | 17.3 | 19.8 | 17.9 | 20.3 | 22.8 | 25.3 |
| 5 | 8.4 | 11.4 | 14.4 | 17.4 | 15.1 | 18.0 | 21.0 | 24.0 | 21.7 | 24.7 | 27.6 | 30.6 |
| 6 | 9.8 | 13.4 | 16.8 | 20.3 | 17.6 | 21.1 | 24.6 | 28.1 | 25.4 | 28.8 | 32.3 | 35.8 |
| 7 | 11.4 | 15.4 | 19.4 | 23.4 | 20.3 | 24.3 | 28.3 | 32.3 | 29.2 | 33.2 | 37.2 | 41.2 |
| 8 | 11.7 | 15.9 | 20.0 | 24.1 | 20.9 | 25.1 | 29.2 | 33.3 | 30.1 | 34.3 | 38.4 | 42.5 |
| 9 | 12.1 | 16.4 | 20.6 | 24.9 | 21.6 | 25.9 | 30.1 | 34.4 | 31.1 | 35.4 | 39.6 | 43.9 |
| 10 | 12.4 | 16.8 | 21.2 | 25.5 | 22.1 | 26.5 | 30.9 | 35.3 | 31.9 | 36.3 | 40.6 | 45.0 |
| 11 | 12.6 | 17.1 | 21.5 | 26.0 | 22.5 | 27.0 | 31.4 | 35.9 | 32.4 | 36.9 | 41.3 | 45.8 |
| 12 | 12.8 | 17.4 | 21.9 | 26.4 | 22.9 | 27.5 | 32.0 | 36.5 | 33.0 | 37.5 | 42.1 | 46.6 |
| 13 | 13.1 | 17.7 | 22.3 | 26.9 | 23.3 | 28.0 | 32.6 | 37.2 | 33.6 | 38.2 | 42.8 | 47.5 |
| 14 | 13.3 | 18.0 | 22.7 | 27.4 | 23.8 | 28.5 | 33.2 | 37.9 | 34.2 | 38.9 | 43.6 | 48.3 |
| 15 | 13.6 | 18.4 | 23.2 | 28.0 | 24.2 | 29.0 | 33.8 | 38.6 | 34.9 | 39.7 | 44.5 | 49.3 |
| 16-25 | 13.8 | 18.6 | 23.5 | 28.3 | 24.6 | 29.4 | 34.3 | 39.1 | 35.4 | 40.2 | 45.1 | 49.9 |

### 7.3 Operating costs

Main costs are electricity (for tap water), fuel (for heating), overhead costs and salary. The estimate is shown in Table 8.

TABLE 8: Operating costs

| | Electricity | Fuel (gas) | Salary | Maintenance | Water | Other | Total |
|---|---|---|---|---|---|---|---|
| Geothermal | 1,624,000 | - | 2,016,000 | 1,128,000 | 354,000 | 1,880,000 | 7,002,000 |
| Combined | 1,624,000 | 6,730,000 | 2,400,000 | 1,693,000 | 354,000 | 2,821,000 | 15,622,000 |

## 8. ECONOMIC VIABILITY

In this chapter the financial viability of the project is addressed using economic criteria acceptable to international financing institutions the world over. The most important of these are the Internal Rate of Return (IRR) and the Present Value (PV) of the investment.

Calculations are based upon a 25-year operating time and the following premises:

- Discount rate 12%
- NPV for combined natural gas/geothermal alternative is USD15,787,000 (Appendix II, Table 1)
- IRR=12%
- Financing schedule:
  1. Geothermal tap water system installation 3,937,000 at the beginning of project;
  2. Individual boiler installations 4,665,000 begins from 4th year of project, finishing at the end of 9th year.

The results are given in Appendix II, Tables 1-2. They show that NPV for only geothermal tap water supply is USD 11,718,000 and that the IRR for geothermally heated domestic hot tap water is 13%.

## 9. DISCUSSION AND CONCLUSIONS

The main advantages of choosing the combined geothermal and natural gas option may be summarised as follows:

- Payment ability of the customer is an important criterion bearing in mind existing social conditions. This calls for a system that is very flexible in implementation. Individual boilers for heating and DHW supply from a geothermal source best fulfill this criterion. Such boilers can be installed in phase with heating demand, thus minimising capital investment and financial risks.
- Purchasing power is another important criterion. It is, therefore, not considered prudent to opt for a centralized geothermal heating plus DHW alternative in the beginning, even though the economic prime cost per MWh of geothermal energy is quite low, because it requires more initial capital investment and thus carries more risk in light of the current financial situation in Georgia.
- This agrees with the result of a technical-economic assessment carried out by the World Bank (WB) for 6 different Georgian cities. According to the WB estimate, the cost of heat supply from individual gas-fired boilers would be 11% less per MWh than the cost of heat supply from a new geothermal district heating system, even with zero fuel price (for example geothermal heat supply in our project).
- Also, an important factor is the ratio between the length and spread of the network and heat loads. A comparison between centralised and individual heating systems was specially addressed in the World Bank Report using special software. The results revealed that decentralised heating systems are viable, if the heating density per km of network length is less than 2 MW. Centralised heating systems are, on the other hand, preferable if the heat density is greater than 5 MW/km. Heat density in between these two limits needs special investigation. In the Saburtalo Pilot Region the total length of the net of the No. 1, 32 and 47 ThS operational zone is about 14 km and the total heat load is 49.39 MW. Specific load per km of the network is, thus, more than 3 MW. This case, therefore, falls in

the last mentioned category. Improvements of the socio-economic conditions prevailing in the country will change the picture and make a combined natural gas geothermal heating system feasible.

- Operation of individual boilers for space heating only during the heating season decreases viability and increases the prime cost per MWh heating energy up to 25 USD. In the pilot project, which is the combination of a geothermal hot water supply and individual gas boiler heating, the prime cost of energy per MWh is increased up to 20 USD (see Table 7). Simultaneously, the initial capital cost increases by 4 million USD. The total annual cost of geothermal DHW and individual gas boiler space heating equals 652 thousand USD. This is brought about by reducing natural gas use by 50% and is also less than what the cost would be using natural gas only, i.e 804,000 USD. Another benefit is a reduction in annual $CO_2$ emission by 8,387 tonnes.
- Benefits for the Georgian Government will be twofold: a reduction in $CO_2$ emission, part of which may be used as $CO_2$ credits, and increased use of indigenous geothermal resources instead of imported natural gas.

Today's situation in the Georgian energy sector is very serious. Steps must be taken for improvement. This treatise deems the project technically feasible and economically viable, and that it should be implemented. The implementation of this project will be the first step in restoring district heating and supplying domestic hot water to Tbilisi.

## ACKNOWLEDGMENTS

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**APPENDIX I: Fuel consumption and total $CO_2$ emissions for the Saburtalo project**

TABLE 1: Baseline fuel consumption for heat and hot water supply

| | Electricity, MWh | | | Kerosene, tons | | | Natural gas, million m$^3$ | | | Liquid gas, tons | | | Wood, tons | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Heating | Hot water | Total | Heating | Hot water | Total | Heating | Hot water | Total | Heating | Hot water | Total | Heating | Hot water | Total |
| Saburtalo pilot district | | | | | | | | | | | | | | | |
| 2001 | 3.61 | 15.05 | 18.67 | 552.56 | 39.55 | 592.11 | 1.36 | 0.40 | 1.77 | 13.18 | 1.19 | 14.37 | 870.14 | 128.73 | 998.86 |
| 2002 | 3.79 | 13.64 | 17.42 | 232.62 | | 232.62 | 2.79 | 1.50 | 4.28 | 10.45 | | 10.45 | 829.01 | | 829.01 |
| 2003 | 3.49 | 11.25 | 14.73 | 63.90 | | 63.90 | 3.90 | 2.72 | 6.62 | 7.86 | | 7.86 | 545.46 | | 545.46 |
| 2004 | 2.78 | 8.72 | 11.50 | | | | 4.70 | 4.02 | 8.72 | | | | 314.22 | | 314.22 |
| 2005 | 2.20 | 6.05 | 8.25 | | | | 5.26 | 5.38 | 10.64 | | | | | | |
| 2006 | 1.45 | 3.23 | 4.68 | | | | 5.79 | 6.10 | 11.88 | | | | | | |
| 2007 | 0.73 | 0.25 | 0.99 | | | | 6.32 | 6.40 | 12.72 | | | | | | |
| 2008 | | | | | | | 6.81 | 6.42 | 13.23 | | | | | | |
| 2009 | | | | | | | 7.03 | 6.42 | 13.46 | | | | | | |
| 2010 | | | | | | | 7.26 | 6.42 | 13.69 | | | | | | |
| 2011 | | | | | | | 7.51 | 6.42 | 13.93 | | | | | | |
| 2012 | | | | | | | 7.77 | 6.42 | 14.19 | | | | | | |
| 2013 | | | | | | | 8.04 | 6.42 | 14.46 | | | | | | |
| 2014 | | | | | | | 8.32 | 6.42 | 14.75 | | | | | | |
| 2015 | | | | | | | 8.63 | 6.42 | 15.05 | | | | | | |
| 2016 | | | | | | | 8.94 | 6.42 | 15.37 | | | | | | |
| 2017 | | | | | | | 9.27 | 6.42 | 15.70 | | | | | | |
| 2018 | | | | | | | 9.34 | 6.42 | 15.77 | | | | | | |
| 2019 | | | | | | | 9.34 | 6.42 | 15.77 | | | | | | |
| 2020 | | | | | | | 9.34 | 6.42 | 15.77 | | | | | | |

TABLE 2: $CO_2$ baseline emissions, 1000 tons

| | Electricity | | | Kerosene | | | Natural gas | | | Liquid gas | | | Wood | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Heat-ing | Hot water | Total | Heat-ing | Hot water | Total | Heat-ing | Hot water | Total | Heat-ing | Hot water | Total | Heat-ing | Hot water | Total | Heat-ing | Hot water | Total |
| Saburtalo pilot district | | | | | | | | | | | | | | | | | | |
| 2001 | 1.25 | 4.14 | 5.39 | 1.41 | 0.10 | 1.51 | 2.67 | 0.79 | 3.46 | 0.02 | 0.00 | 0.02 | 1.28 | 0.19 | 1.47 | 6.63 | 5.23 | 11.85 |
| 2002 | 1.40 | 3.65 | 5.05 | 0.59 | | 0.59 | 5.46 | 2.94 | 8.40 | 0.02 | | 0.02 | 1.22 | | 1.22 | 8.68 | 6.59 | 15.28 |
| 2003 | 1.29 | 2.95 | 4.24 | 0.16 | | 0.16 | 7.65 | 5.34 | 12.9 | 0.01 | | 0.01 | 0.80 | | 0.80 | 9.92 | 8.28 | 18.20 |
| 2004 | 1.02 | 2.25 | 3.27 | | | | 9.21 | 7.87 | 17.0 | | | | 0.46 | | 0.46 | 10.69 | 10.12 | 20.82 |
| 2005 | 0.80 | 1.56 | 2.36 | | | | 10.3 | 10.5 | 20.8 | | | | | | | 11.11 | 12.11 | 23.23 |
| 2006 | 0.53 | 0.83 | 1.36 | | | | 11.3 | 11.9 | 23.2 | | | | | | | 11.87 | 12.78 | 24.66 |
| 2007 | 0.27 | 0.07 | 0.33 | | | | 12.3 | 12.5 | 24.9 | | | | | | | 12.65 | 12.61 | 25.26 |
| 2008 | | | | | | | 13.3 | 12.5 | 25.9 | | | | | | | 13.35 | 12.59 | 25.94 |
| 2009 | | | | | | | 13.7 | 12.5 | 26.3 | | | | | | | 13.78 | 12.59 | 26.37 |
| 2010 | | | | | | | 14.2 | 12.5 | 26.8 | | | | | | | 14.24 | 12.59 | 26.83 |
| 2011 | | | | | | | 14.7 | 12.5 | 27.3 | | | | | | | 14.72 | 12.59 | 27.31 |
| 2012 | | | | | | | 15.2 | 12.5 | 27.8 | | | | | | | 15.22 | 12.59 | 27.82 |
| 2013 | | | | | | | 15.7 | 12.5 | 28.3 | | | | | | | 15.76 | 12.59 | 28.35 |
| 2014 | | | | | | | 16.3 | 12.5 | 28.9 | | | | | | | 16.32 | 12.59 | 28.91 |
| 2015 | | | | | | | 16.9 | 12.5 | 29.5 | | | | | | | 16.91 | 12.59 | 29.50 |
| 2016 | | | | | | | 17.5 | 12.5 | 30.1 | | | | | | | 17.53 | 12.59 | 30.12 |
| 2017 | | | | | | | 18.1 | 12.5 | 30.7 | | | | | | | 18.18 | 12.59 | 30.77 |
| 2018 | | | | | | | 18.3 | 12.5 | 30.9 | | | | | | | 18.31 | 12.59 | 30.90 |
| 2019 | | | | | | | 18.3 | 12.5 | 30.9 | | | | | | | 18.31 | 12.59 | 30.90 |
| 2020 | | | | | | | 18.3 | 12.5 | 30.9 | | | | | | | 18.31 | 12.59 | 30.90 |
| Total in 2001-2020 | | | | | | | | | | | | | | | | 282.46 | 231.43 | 513.89 |

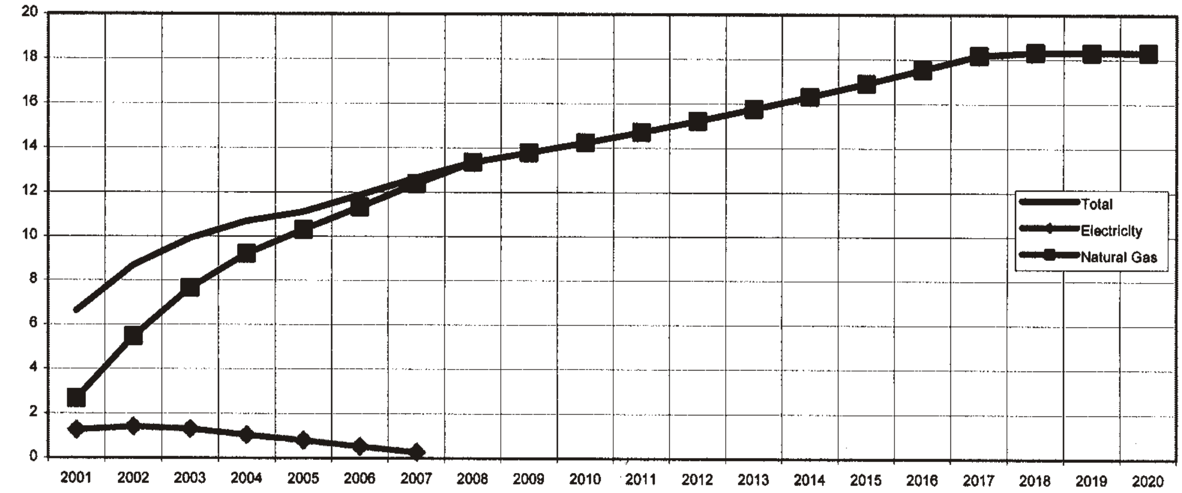


FIGURE 1: Annual $CO_2$ baseline emissions in Saburtalo (heating), in thousand tons

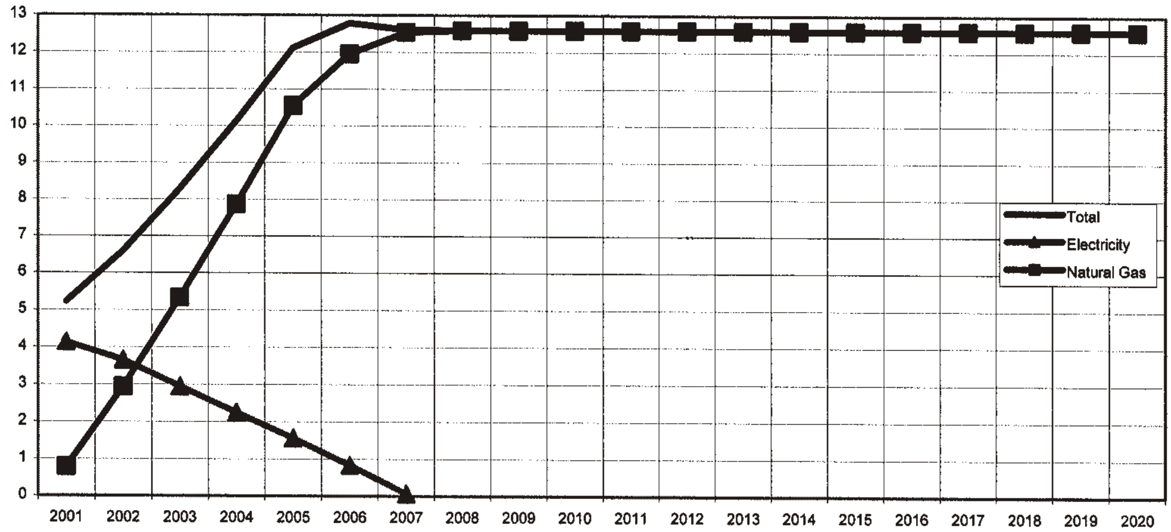


FIGURE 2: Annual $CO_2$ baseline emissions in Saburtalo (hot water), in thousand tons

## APPENDIX II: NPV and IRR calculations for the Saburtalo project

TABLE 1: Financial calculations for the combined version of the Subartalo project

| Year | Consump MWh | Revenue | Invest-ment | VAT | Electricity | Fuel (gas) | Mainte-nance | Salary | Water | Other | Total costs | EBIT (income before interest & taxes) | Interest | EBT | Road tax | Tax on profite | Net income | Acumulated cash flow | Cash inflow-outflow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 3937 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -3937 | -3937 |
| 2 | 12248 | 367 | 0 | 61 | 37 | 0 | 11 | 100 | 9 | 18 | 175 | 192 | 680 | -488 | 4 | -97.6 | -387 | -4324 | -387 |
| 3 | 35942 | 1078 | 0 | 180 | 69 | 0 | 32 | 100 | 15 | 54 | 270 | 808 | 661 | 147 | 11 | 29 | 129 | -4195 | 129 |
| 4 | 48270 | 1448 | 1540 | 242 | 69 | 180 | 43 | 100 | 15 | 72 | 480 | 968 | 642 | 327 | 14 | 65 | 276 | -3919 | -264 |
| 5 | 59521 | 1786 | 816 | 298 | 69 | 248 | 54 | 100 | 15 | 89 | 575 | 1211 | 622 | 588 | 18 | 118 | 489 | -3431 | -327 |
| 6 | 71019 | 2131 | 885 | 356 | 69 | 262 | 64 | 100 | 15 | 107 | 616 | 1514 | 603 | 911 | 21 | 182 | 750 | -2681 | -135 |
| 7 | 75628 | 2269 | 428 | 379 | 69 | 276 | 68 | 100 | 15 | 113 | 642 | 1627 | 584 | 1043 | 23 | 209 | 857 | -1823 | 429 |
| 8 | 77888 | 2337 | 718 | 390 | 69 | 284 | 70 | 100 | 15 | 117 | 655 | 1682 | 565 | 1117 | 23 | 223 | 917 | -906 | 199 |
| 9 | 79120 | 2374 | 278 | 396 | 69 | 289 | 71 | 100 | 15 | 119 | 663 | 1711 | 546 | 1165 | 24 | 233 | 956 | 49 | 678 |
| 10 | 80416 | 2412 | 0 | 403 | 69 | 294 | 72 | 100 | 15 | 121 | 671 | 1741 | 526 | 1215 | 24 | 243 | 996 | 1046 | 996 |
| 11 | 81775 | 2453 | 0 | 409 | 69 | 298 | 74 | 100 | 15 | 123 | 678 | 1775 | 507 | 1268 | 25 | 254 | 1039 | 2084 | 1039 |
| 12 | 83204 | 2496 | 0 | 417 | 69 | 304 | 75 | 100 | 15 | 125 | 688 | 1808 | 488 | 1320 | 25 | 264 | 1081 | 3166 | 1081 |
| 13 | 84711 | 2541 | 0 | 424 | 69 | 309 | 76 | 100 | 15 | 127 | 696 | 1845 | 469 | 1376 | 25 | 275 | 1126 | 4292 | 1126 |
| 14 | 86296 | 2589 | 0 | 432 | 69 | 315 | 78 | 100 | 15 | 129 | 706 | 1883 | 450 | 1433 | 26 | 287 | 1172 | 5464 | 1172 |
| 15 | 87965 | 2639 | 0 | 440 | 69 | 321 | 79 | 100 | 15 | 132 | 716 | 1923 | 430 | 1492 | 26 | 298 | 1220 | 6685 | 1220 |
| 16 | 89725 | 2692 | 0 | 449 | 69 | 328 | 81 | 100 | 15 | 135 | 727 | 1964 | 411 | 1553 | 27 | 311 | 1269 | 7954 | 1269 |
| 17 | 91570 | 2747 | 0 | 458 | 69 | 334 | 82 | 100 | 15 | 137 | 738 | 2009 | 392 | 1617 | 27 | 323 | 1321 | 9276 | 1321 |
| 18 | 91936 | 2758 | 0 | 460 | 69 | 336 | 83 | 100 | 15 | 138 | 741 | 2017 | 373 | 1645 | 28 | 329 | 1343 | 10619 | 1343 |
| 19 | 91936 | 2758 | 0 | 460 | 69 | 336 | 83 | 100 | 15 | 138 | 741 | 2017 | 354 | 1664 | 28 | 333 | 1359 | 11978 | 1359 |
| 20 | 91936 | 2758 | 0 | 460 | 69 | 336 | 83 | 100 | 15 | 138 | 741 | 2017 | 334 | 1683 | 28 | 337 | 1374 | 13352 | 1374 |
| 21 | 91936 | 2758 | 0 | 460 | 69 | 336 | 83 | 100 | 15 | 138 | 741 | 2017 | 315 | 1702 | 28 | 340 | 1389 | 14741 | 1389 |
| 22 | 91936 | 2758 | 0 | 460 | 69 | 336 | 83 | 100 | 15 | 138 | 741 | 2017 | 296 | 1721 | 28 | 344 | 1405 | 16146 | 1405 |
| 23 | 91936 | 2758 | 0 | 460 | 69 | 336 | 83 | 100 | 15 | 138 | 741 | 2017 | 277 | 1741 | 28 | 348 | 1420 | 17566 | 1420 |
| 24 | 91936 | 2758 | 0 | 460 | 69 | 336 | 83 | 100 | 15 | 138 | 741 | 2017 | 258 | 1760 | 28 | 352 | 1435 | 19001 | 1435 |
| 25 | 91936 | 2758 | 0 | 460 | 69 | 336 | 83 | 100 | 15 | 138 | 741 | 2017 | 238 | 1779 | 28 | 356 | 1451 | 20452 | 1451 |
| Sum | 1880786 | 56424 | 8602 | 9417 | 1624 | 6730 | 1693 | 2400 | 354 | 2821 | 15622 | 40802 | 11021 | 29781 | 564 | 5956 | 24389 | | |

| | | | | | |
|---|---|---|---|---|---|
| Price | 30 USD | VAT | 16.69% | Interest | 12% |
| Discount rate | 10 % | Other expences | 5% | **IRR** | **12%** |
| Maintenance | 3% | Road tax | 1% | **NPV** | **15787** |

TABLE 2: Financial calculations for the combined version of the Subartalo project

| Year | Consump MWh | Revenue | Investment | VAT | Electricity | Mainte-nance | Salary | Water | Other | Total costs | EBIT(income before interest &taxes) | Interest | EBT | Road tax | Tax on profited | Net income | Accumulated cash flow | Cash inflow-outflow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 3937 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -3937 | -3937 |
| 2 | 40000 | 1200 | 0 | 200 | 37 | 36 | 84 | 9 | 60 | 226 | 974 | 680 | 294 | 12 | 59 | 235 | -3702 | 235 |
| 3 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 661 | 627 | 16 | 125 | 501 | -3200 | 501 |
| 4 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 642 | 646 | 16 | 129 | 517 | -2684 | 517 |
| 5 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 622 | 665 | 16 | 133 | 532 | -2151 | 532 |
| 6 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 603 | 684 | 16 | 137 | 548 | -1604 | 548 |
| 7 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 584 | 704 | 16 | 141 | 563 | -1041 | 563 |
| 8 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 565 | 723 | 16 | 145 | 578 | -463 | 578 |
| 9 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 546 | 742 | 16 | 148 | 594 | 131 | 594 |
| 10 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 526 | 761 | 16 | 152 | 609 | 740 | 609 |
| 11 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 507 | 780 | 16 | 156 | 624 | 1364 | 624 |
| 12 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 488 | 800 | 16 | 160 | 640 | 2004 | 640 |
| 13 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 469 | 819 | 16 | 164 | 655 | 2659 | 655 |
| 14 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 450 | 838 | 16 | 168 | 670 | 3329 | 670 |
| 15 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 430 | 857 | 16 | 171 | 686 | 4015 | 686 |
| 16 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 411 | 876 | 16 | 175 | 701 | 4716 | 701 |
| 17 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 392 | 896 | 16 | 179 | 716 | 5433 | 716 |
| 18 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 373 | 915 | 16 | 183 | 732 | 6165 | 732 |
| 19 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 354 | 934 | 16 | 187 | 747 | 6912 | 747 |
| 20 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 334 | 953 | 16 | 191 | 763 | 7675 | 763 |
| 21 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 315 | 972 | 16 | 194 | 778 | 8452 | 778 |
| 22 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 296 | 992 | 16 | 198 | 793 | 9246 | 793 |
| 23 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 277 | 1011 | 16 | 202 | 809 | 10054 | 809 |
| 24 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 258 | 1030 | 16 | 206 | 824 | 10878 | 824 |
| 25 | 52740 | 1582.2 | 0 | 264 | 69 | 47 | 84 | 15 | 79 | 295 | 1288 | 238 | 1049 | 16 | 210 | 839 | 11718 | 839 |
| Sum | 1253020 | 37591 | 3937 | 6274 | 1624 | 1128 | 2016 | 354 | 1880 | 7001 | 30589 | 11021 | 19569 | 376 | 3914 | 15655 | | |

| | | | | | |
|---|---|---|---|---|---|
| Price | 30 USD | VAT | 16.69% | Interest | 12% |
| Discount rate | 10 % | Other expences | 5% | **IRR** | **13%** |
| Maintenance | 3% | Road tax | 1% | **NPV** | **11718** |