Establishment of Hybrid Energy Station in Borjomi Municipality for Achievement of Green Status by the City

Feasibility Study

From Author

Feasibility study provides in depth analysis of potential to establish district heating system in Borjomi municipality. There are successful examples of such practices in a number of developed countries: 80-90% of urban areas of Germany, Denmark, Sweden, Finland, Norway and other countries are supplied with energy from local energy producers. Over the last years many other European countries are following the case and serve as good examples for developing countries. Based on the experience of these countries establishment of renewable energy operated system in municipalities of mountainous regions of Georgia promises to be efficient.

Document analyzes potential of establishing such a system in Borjomi municipality and discusses state/donor contributions required for such a business to be a successful case as well as environmental benefits that shall occur. In addition, potential of replication of such systems in other locations are considered.

Idea of development of pilot project into a revolving fund (as an energy cluster) is described. Cluster oriented relationship among stakeholders based on State-Private partnership (Private Public Partnership) can be an innovative solution for Georgia.

Study provides detailed master plan and technological concept of district heating system concept. Which is sufficient for detailed planning and design of project and is viable for the start of its implementation.

Hybrid financial instrument having grant, loan and in-kind contribution in the mix is offered as an efficient choice of project commercialization.

Study provides details on identification and analysis of risks used for development of final project proposal that serves as a corner stone for development of district heating system in Borjomi municipality. Given project proposal is defined as follows: **Hybrid district heating pilot project is considered to have high commercial risks with 67% deviation from full comfort. Additional are Unknown unknowns – the risks that cannot be identified at this stage.**

Project success is dependent on risk minimization and/or prevention. Expected risks are systematic for the country and study and analysis of these risks benefits commercialization, increase of business attractiveness and successful replication of pilot project in other locations.

Study provides results of analysis of financial factors and risks based on interviewing of hands-on and theoretical business experts (total of 5 interviews) and desk study of analogue pilot projects in 12 countries (in US-Canada, Europe, Asia and other developed and developing countries). Given results support the idea of full funding of project with a grant and financing operating expenditures by a business or considering 40% business capital vs. 60% in-kind contribution – grand financing. Specific terms can be identified after completion of detailed technical project and consideration of grant conditions.

Participants of the meeting were informed on the requirements of business development which involves a forecasted growth during the 4-6 years from start up. Forecasted financial outcomes are approximate and payback period is estimated at 8-11 years.

It is important to pay attention to environmental indicators of the project and factors having an impact on the environment. These factors can be successfully utilized in serving interests of Green Climate Fund and stimulate motivation for attracting such institutions to the project.

Given initiative is aimed to serve as basis for long-term (50 years and more) partnership between Georgian government and the project.

Author is grateful to USAID Energy Program and Deloitee and Touche LLC for practical support in reviewing of the given document.

Table of Contents

Introduction

Given report is provides results of research of ESCO operated 10 MW installed capacity hybrid energy station establishment opportunities in the town of Borjomi (densely populated resort town in the mountainous region of Georgia). Energy stations provides the supply of organized network of Borjomi's densely populated areas (population 33 people / km2) with heating, hot water, cold water, technical water.

According to the concept of the project, the utilized energy resources are sought from renewable sources (biomass, sun, geothermal energy, hydro, etc.) in the administrative territory of Borjomi municipality and beyond. The traditional fossil resource - gas is included in the system to ensure peak load and accidents.

The study was carried out by the group of authors:

Zaal Kheladze
Project Director
PhD in Geology and Geophysics. Has more than 25 years of technical expertise in sustainable construction, engineering and building physics, green building technologies including renewable energy generation and improvement of buildings' energy efficiency, project development, supervision and management, range of environmental subjects, business launch and operation executive. Was the coordinator and supervisor of environmental assessment of Trans Caucasian railway, Gali atomic power plant and Jhinvali power plant. Under his supervision establishment of infrastructures of Borjomi Kharagauli park, Mtatsminda amusement park, Kolkheti and Kobuleti national reserves and many other large-scale and challenging projects, that include the following were accomplished: Poultry Farm with annual production of 15 000 tons, 300-house settlement for IDP's in Gori and Aghmashenebeli Ave. reconstruction project. Under management of Mr. Kheladze New Technology Center implemented design stage of project of construction of sustainable settlements for 1500 families in Lebanon (architectural and engineering design, training of local population, construction supervision and logistics management). From 2015 was elected a President of Green Building Council, Georgia. From 2017 is a director of Biomass Association of Georgia.
Under his authorship the following documents were prepared Development of Engineering Project of Resource-Efficient (Energy- Efficient) Refurbishment and Management Concept for Tbilisi City Hall and District Administrations' Buildings; Detailed Feasibility Assessment of Pilot Biomass Plant

in Tbilisi And Complete Feasibility Study for Installing Biomass Boilers in Tbilisi Municipal Facilities; Architectural and Engineering project of energy-efficient restoration of Kindergarten #95 in Tbilisi; Preliminary Expert Study Of Feasibility of Nationally Appropriate Mitigation Actions (NAMA) for Georgian Construction Sector; The Project Proposal for the Full and Energy Efficient Restoration Programme of Municipal Buildings in Tbilisi City, etc. Has actively worked on development and implementation of state and donor funded projects in various municipalities of Georgia (Tbilisi, Telavi, Dusheti, Tianeti, Telavi, Bolnisi, Akhaltsikhe, etc.). Is currently managing EU funded project of Partnership for Entrepreneurship in Green building Sector.

Archil Papava

National Project Manager

More than 15 years of experience of project management at senior executive level in sustainable construction sector, energy-efficiency and renewable energy fields. Skilled in developing and executing business plans, marketing and sales strategies and campaigns involving innovative building products and services. Experienced in conducting economic, financial and environmental research and analysis, cost/benefit assessments and feasibility studies for new sustainable construction projects as well as retrofitting of existing buildings with energy-efficient technologies and equipment utilizing renewable energy sources. Over the last few year was involved in preparation of the following documents: Development of Engineering Project of Resource-Efficient (Energy-Efficient) Refurbishment and Management Concept for Tbilisi City Hall and District Administrations' Buildings; Detailed Feasibility Assessment of Pilot Biomass Plant in Tbilisi And Complete Feasibility Study for Installing Biomass Boilers in Tbilisi Municipal Facilities; Architectural and Engineering project of energy-efficient restoration of Kindergarten #95 in Tbilisi; Preliminary Expert Study Of Feasibility of Nationally Appropriate Mitigation Actions (NAMA) for Georgian Construction Sector; The Project Proposal for the Full and Energy Efficient Restoration Programme of Municipal Buildings in Tbilisi City, etc. Author and project manager of EU funded project of Partnership for Entrepreneurship in Green building Sector.

Tadas Lukoševičius

Technical Project Manager

Master of Business administration and management at Vytautas Magnus University of Kaunas, Lithuania. Has more than 10 years of experience in project management and coordination in the field of economics of energy, water management, logistics and engineering. From 2017 is Sales Director of UAB Enerstenos Projektavimas (UAB Enerstenos Grupe), Lithuania and is responsible for Sales of engineering services and serves as head of the consulting department.

Vaidas Mockevičius
Engineer Technologist
Has a practical experience of more than 5 years in the areas of heat production and supply, heating, ventilation, air conditioning. Is familiar with the technical regulations required for the design of the above systems and skilled in operating Openplant Modeler V8i. From 2016 is employed by Enerstenos projektavimas UAB on the position of Engineer Technologist and responsible for boiler design, project management for the design of boiler houses up to 30MW installed capacity. Has an extensive experience in design of biofuel boiler houses. Holds a Master degree in Thermal Engineering and a bachelor's degree in Building Engineering Systems from Kaunas University of Technology.

Vytautas Džiuvė
Engineer
Is a Master of Energy engineering and project management with a specialization in renewable energy technologies and Bachelor of energy engineering with a specialization in thermal energy and technology of Kaunas University of Technology. From 2017 works as an engineer for UAB „Enerstenos Projektavimas", Lithuania.

§ 1.0 Target Consumers

Target of the energy supply is the municipal (administrative building, kindergarten, public school, etc.), government (police and others) and private buildings (hotels, restaurants, residential housing, etc.) located on 1.5 square kilometers area adjacent to the energy station.

In the research process, the survey was carried out to research consumers with 100 kW and more installed capacity potential in the study area. In the area of feasible energy supply, the total potential installed capacity of such consumers amounts to 37.5 MW for heating and hot water, including 4 MW of municipal and government owned buildings, while the remaining 33.5 is under private ownership. The studied buildings are inefficient and are characterized by a high level of energy consumption (250-300 kW per sq.m / year). According to European energy directives, in case of achieving the targeted energy efficiency level, consumption of these buildings will become 50-70 kW. Per sq.m / year.

In such scenario, their energy consumption will decrease and the total demand of installed capacity will amount to 9-10 MW. Considering the potential of the region's economic growth and increased touristic potential, as well as the potential for development of neighboring ski resort Bakuriani, the estimated installed capacity demand in the studied area will be 50 MW in the next 10 years. Based on this data, we believe that the cumulative (heat, hot water, power) installed capacity of the energy stations is determined to be 10 megawatts.

Two potential consumers implied consent to connect their facilities to the networks. This are: Hotel Crowne Plaza and Borjomi Municipality City Hall. The total peak thermal load of these consumers considering conditions of existing thermal characteristics of the buildings (for the cold -8° C five-day period required by a standard in force) is identified as 6 MW. Based on the conditions of the potential demand, we consider that the cumulative installed capacity shall be estimated at the level of 10 MW. It should be noted that this capacity should be correlated with renewable energy resources.

§ 2.0 Feasibility of distribution of energy generated from renewable sources through system of district heating

Study involved assessment of potential renewable sources, including: solar, wind, biomass, heating pump, small capacity hydrogeneration and other. Based on analyzes of pilot projects[1] and various researches[2] through various regions of Georgia, as well as review of the strategic document of Georgia's renewable energy[3] and thorough analysis of Georgia's natural resources' cadasters it can

[1] Hybrid use of residual biomass and solar energy in the building of the kindergarten in Pshaveli village of in Telavi municipality; "Biomass Promotion in Georgia" - Biomass Pilot Projects in Dusheti and Tianeti Municipalities, 2018

[2] Field survey of biomass energy potential in Georgia, 2016; Evaluation of the potential waste of forest and agriculture residual biomass in Georgia, 2015; Residual Biomass Energy Potential in Georgia (Cadastre), 2013; Development of long-term (2030 years) energy-efficiency measures to be implemented in the construction sector of Georgia in order to achieve compliance with the requirements of the European Union 2016

[3] Georgia's Energy Development Strategy for 2016-2025

be concluded that for the given location it advised to use such heat generators that generate thermal and electrical energy using biomass, in a combination with low capacity hydropower generation and heat-pump connected to multilevel thermal energy buffer reservoirs[4].

Studies have identified background issues that will have negative impact on business development. These are:

- Shortage of modern technologies in the country - only low quality of Chinese origin or outdated equipment and locally developed technologies by private persons;

- Knowledge deficiency at academic and consumer level - education facilities do not provide enough education;

- Low awareness - absence of sectoral media outlets;

- Organizing collection of biomass and other types of waste does not occur, heat distribution – of municipal systems centralized heating are destroyed, there are issues with collection of waste fuel materials;

- Low level of state involvement - the lack of means of market stimulation;

- Subsidizing of natural gas and power supply – are hindering the development of renewable energy generators;

- The absence of adequate banking instruments - banks do not issue energy credits or loans;

- Unsatisfactory thermal qualities of the buildings - there is a significant overconsumption of energy – due to this renewable source consumers are inefficient;

- The absence of solid biomass collectors and distributors - there is no supplier of waste biomass and a heat distributor;

Undeveloped heat market - there are no systems of heat production, district distribution and municipal networks.

Due to these barriers, it may be uninteresting for business to operate an energy station. However, in the country there are also factors that support the initiative that provide risk minimization. There are methodologies in developed countries (Austria, Germany, Sweden, Lithuania) that can lead to positive results despite the existing barriers. The use of such approaches can ensure the profitable utilization of renewable energy technology in district heating station in the town of Borjomi.

---

http://www.energy.gov.ge/projects/pdf/pages/Sakartvelos%20Energetikis%20Ganvitarebis%20Strategia%2020172026%20Bunebrivi%20Gazis%20Natsili%201637%20geo.pdf and http://www.energy.gov.ge/projects/pdf/pages/Sakartvelos%20Energetikis%20Ganvitarebis%20Strategia%2020172026%20Bunebrivi%20Gazis%20Natsili%201637%20geo.pdf

[4] http://www.bdh-koeln.de/fileadmin/user_upload/Publikationen/Efficient%20systems%20and%20renewable%20energies%202015.pdf

The factors that would support the implementation of such a project are:

- Obligations of the Government of Georgia defined by EU directives;
- Demand of industrial and commercial business structures on upgrading their production to more cost-efficient cleaner production principles;
- State program on provision of population and public institutions with heating resources;
- Support of Global Climate Fund;
- Increased demand of household on fuel;
- Obligations of Government of Georgia defined by international conventions and agreements;
- Legislative initiatives adopted by the Parliament of Georgia in recent years (e.g. Law on State and Private Cooperation 04.04.2018, etc.);
- Significant potential energy of solid biomass waste (woody waste, agricultural residues, household and industrial waste).

§ 3.0 Potential of renewable energy in study area

As stated in §2 of this document, significant sources of renewable energy are identified in the researched region: biomass (mainly forest waste), small rivers hydropower. The use of solar and wind energy sources can only provide minor results (see Appendix # 1: Simulation Analysis). National Forestry Agency of Georgia invites interested parties to express interest in purchasing woody biomass. The price per cubic meter is 7 GEL. Such approach can be helpful to the project. However, it is important to note that biofuel shall be sold not by cubic meters but according to its thermal (calorific) value as approach currently used causes a number of uncertainties. The buyer may purchase fuel deficient of thermal potential only becoming aware of the fact after completion of procurement stages. This issue has to be solved and requires detailed analysis. There is also a possibility that seller may sell fuel of high calorific value and be unaware of the fact. This issue requires correction and represents the subject of discussion.

The feasible area of supply was identified - the optimal distance between the energy station and the delivery locations - the distance from which the supply of raw materials is effective was determined as 30 km. and covers forestry districts, agricultural and industrial units in the following locations: Borjomi, Bakuriani, Akhaldaba, partially Atskuri.

Based on these inputs and analysis of existing researches and data resources (biomass cadaster, feasibility studies, data from Ministry Environment Protection and Agriculture of Georgia) estimated installed capacity of biomass boiler was defined at the level of 2 MW. Its operation period based on thermal conditions equals 179 days and is characterized by 3025-degree days[5].

Surveying also showed that thermal demand in Borjomi is not active in heating consumption but also during summer holiday season due to hot water consumption. The total installed capacity for this type of consumers (hot water) is defined at the level of 1 MW. The decision was made fully satisfy this demand by energy produced by the heat pumps and stored in system connected 4 units of multi-level buffer tanks, each of 25 tons volume: two buffer tanks at the initial stage of the project and two more added on a later stage of operation.

[5] Mapping of Georgia according to Energy Efficient Technological Units, 2016

Information published on the web page of Ministry of Economy and Sustainable Development of Georgia that contains data on an investment project of small power hydropower plant located 3540 meters from the location of the energy station, allows us to assess the water availability required for the project this (see Table 1).

Table #1. Conditions of small power hydropower plant set-up on the river of Borjomula

Power station[6]

ID code of HPP: 13486621231040000
Object type: PPP
Length of water supply conductor: 200
Thrust: 41 meters
Average multiyear consumption: 3.08 m3/sec
Specified consumption: 6.07 m3/sec
Capacity kW: 1970 kW
Generation GWh: 7.3 GW.h
Total cost: 1.16 USD
Capital investment per kWh: 0.16 USD/kWh
Length of road to be built: 201 m
Distance to existing line : 19854 m
Distance of line to be built: 18565 m
Water reservoir No: 1348663
Cadaster code:
Region: Samtskhe-Javakheti
X -HPP building: 369689
Y -HPP building: 4629260
Level from HPP building: 1039 m from sea level
X-water receiver: 369855
Y-water receiver: 4629150
Water receiver level: 1080 m from sea level
Regular flow: no

Based on fact that, the estimated volume of supplied water to the planned energy station is 120 tons per hour, the old water reservoir is located at area and the town of Borjomi is not supplied with technical water, it is planned to add the distribution of technical water to the distribution system. This will bring extra income for the business.

The project does not plan installation of the solar power plant, since based on PV system simulation analysis (see Annex # 1) it is not reasonable to install such a station in Borjomi. However, from the new initiative of the GNERC, the project is ready to discuss the possibility of using the energy produced at other locations with higher solar activity (West Georgia) in the Borjomi project through net accounting or if government establishes a respective green rate.

[6] http://energy.gov.ge/map_geo.html

The potential utilization of the energy per year planned within the project is reflected in table #2.

Table #2. The potential utilization of the energy per year planned within the project

Resource	Unit	Energy produced
Biomass generated heat	kWh heating	7 261 800
Heat pump generated heat	kWh heating	6 726 000
Technical water	m3	63 702
Drinking water	m3	8 000.00
Biomass generated power	kWh power	3 112 200

§ 4.0 Masterplan and project development concept

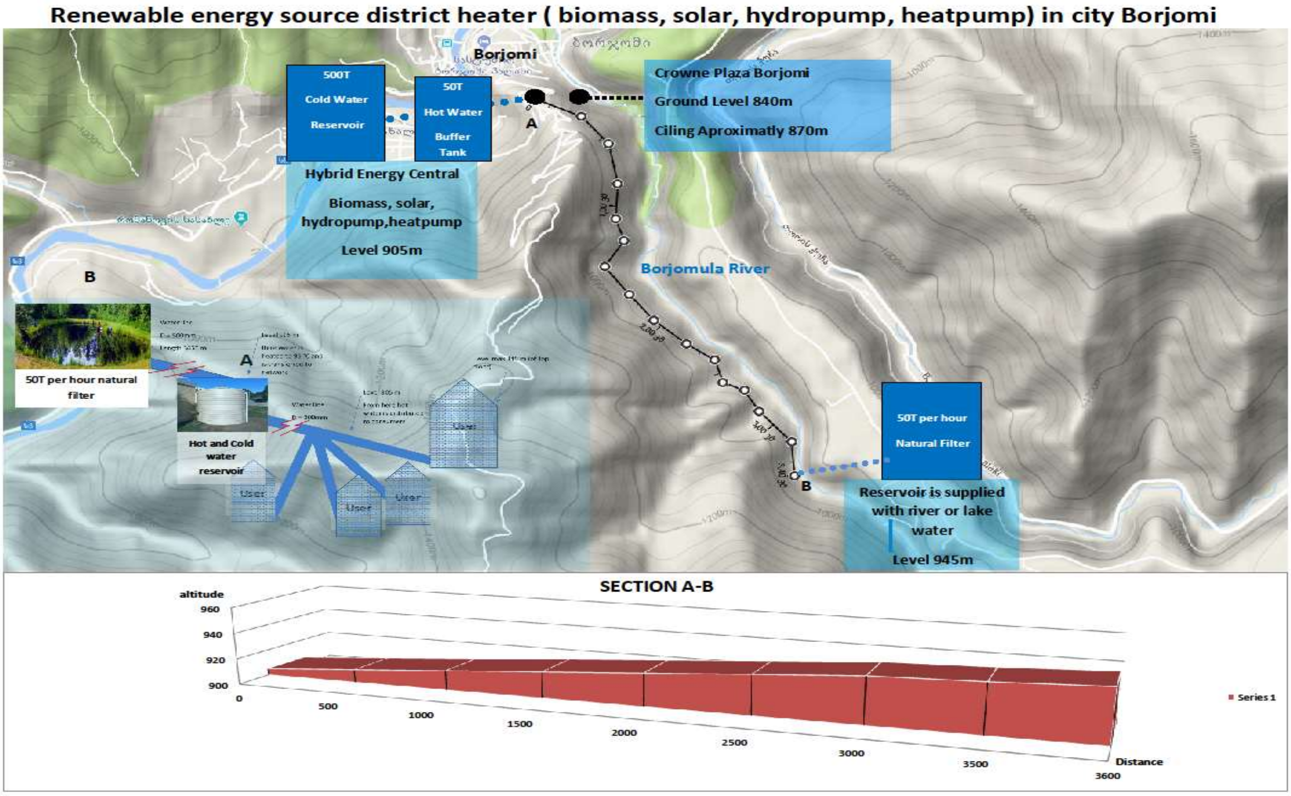
Considering issues discussed in §§1.0-3.0 and construction codes and regulations of Georgia concept of project development was prepared. Concept includes masterplan, respective engineering vision and a business models that involves establishment of the following operational units:

1. The residual biomass collector;
2. Hybrid (biomass cogeneration plant, heat pump system, gas condensing water heater) energy stations;
3. The system of accounting and monitoring of thermal energy distribution (heat tracks).

These three synchronically cycled units provide a successful business model. It is important to note that the two of the units: First and Third represent barriers and therefore in the pilot model, require involvement of state and / or donors to ensure the feasibility of the business.

As for the second unit, its funding and operation is partially accomplished via private investment. Unit 2 includes the following components:

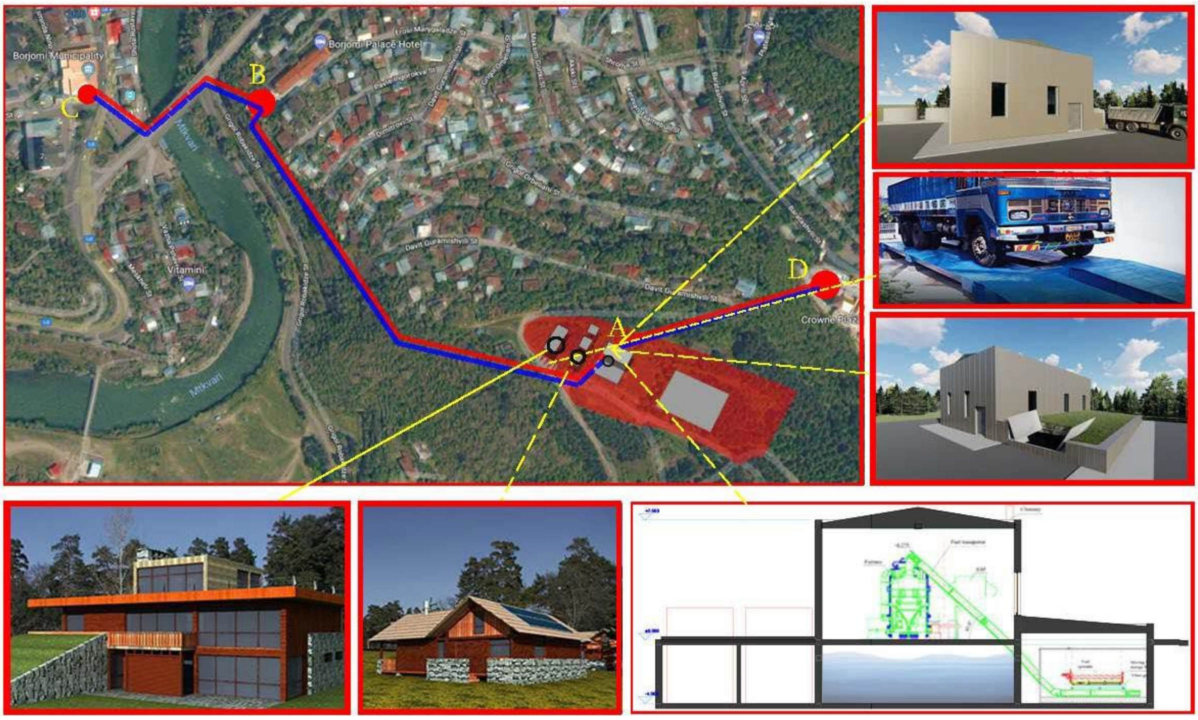
1. River water filter set up with bio-engineering technologies at the 1070 m level;
2. Water supply main with a length of 3.45 km;
3. The top reservoir at 945 m level;
4. Biomass boiler with 2 MW cogeneration equipment (70% - Turbine, 30%).
5. Warehouse for the storage of biomass, in order to ensure its air drying and shredding



Picture #1: Plan of locations of water filter, supply main and reservoir

The system is equipped with100 cubic meter hot water buffer tank to maintain its permanent operation regime, technical water reservoir of 850 cubic meters and drinking water preparation system with a total capacity of 50 tons.

Such a system provides supply of cold and hot water to intermediate B, C and D locators via distribution lines for their further supply. In turn, intermediate locations are equipped with 25 cubic meter trivalent heating storages, fitted with heat pumps and natural gas boilers to compensate for peak load and accidental black outs. Energy from the intermediate stations will be delivered to the final consumers and accounted by the special management and monitoring control module.



Picture #2. Plan of establishment of intermediary buffer tanks and energy station

§5.0 Raw Material Collection

Establishment of a raw material collection is a significant challenge for the project. Since there is no analogy to this day in Georgia, biomass collection should be organized considering the existing foreign experience. First of all, it is necessary to define the principles of collection, then it will be necessary to establish the necessary technical base for collection, which in turn will be associated with necessity to attract investment capital.

To provide solution for these issues it is necessary to employ public and private co-operation mechanisms. Public-Private Partnership (PPP) is an agreement between representatives of public and private sectors, which implies that the number of services that are obligation of state are being provided by the private sector. The state-private partnership is based on a contract that clearly defines the rights and obligations of the parties.
Its major properties are:

- Distribution of benefits, resources, risks and responsibilities between state and private organizations;
- Solving socially important problems in cooperation between state and private businesses;
- Long-term nature of cooperation between state and private business;
- Strengthening cooperation between state and private businesses;
- Voluntary participation in partnering cooperation.

The Georgian law which regulates this subject came into power on 1st July of this year and following partnership can be based on it:

• Providing Service. The State lacks capacity to provide high-quality specific production and organizational capacities, and therefore it is reasonable to conclude an agreement with private organizations. Private institutions are interested in such cooperation with the state because they allow them to benefit;

• Issuing lease of property. One of the means of state-private business partnership cooperation is lease of state property - the state is leasing out unused buildings and structures under its ownership to private business;

• Outsourcing. The state organization delegates certain activities (for example, network servicing, maintenance of the property, etc.) to the business;

• Free of charge transfer of property. The state organization based on specific terms transfers property of a certain type to a business free of charge;

• Setting special terms. State agencies impose special conditions for business for a certain period of time.

The project has a substantial potential to cooperate with Borjomi Municipality within this law.

On the other hand, there is a possibility to obtain a grant from donor organizations for establishing a biomass collector for Borjomi Municipality and the government of Georgia with the obligation to utilize the collector for the project tasks. In turn, the municipality will become obliged to use the earned revenue to improve the quality of energy efficiency of the Municipal buildings and to prepare additional thermal energy distribution networks. This approach ensures minimization of energy expenditures up to 70% and enables involvement of new consumers from the private sector through connection to the network, thus ensuring the achievement of planned level of load of installed capacity and increase of awareness of the community.

This is the solution to the identified barriers and means to increase the sustainability of business. In turn, the Government of Georgia and the Borjomi Municipality will ensure the implementation of the best pilot project, which will clearly demonstrate to the donor organizations and community the road to implementation of commitments under the Accession Agreement of Georgia to the Energy Community: May 19 2010 Directive 2010/31/EU on Energy Efficiency of Buildings (EPBD), 25 October 2012 Directive 2012/27/EU of the European Parliament and the Council on Energy Efficiency.

Employing such principles can be used to organize by a private revolving fund and replicate this pilot project in in other mountainous regions of Georgia where heat can be efficiently distributed: Mestia, Gudauri, Bakuriani, Akhaltsikhe, Goderdzi and other.

§6.0 Establishment of Thermal Network

Organizing the heat market is another important challenge and represents a tall barrier for the Georgian government in development of renewable energy.

By signing the Association Agreement with the European Union and joining the Energy Community, Georgia has taken the obligation to reflect the norms and requirements of the relevant EU Directives in the national legislative regulatory framework (*acquis communautaire)* and develop relevant policy and strategic documents. Among those obligations is the development and implementation of the National Energy Action Plan (NEAP). The deadline for approval of the first NEAP for government of Georgia was set by December 2018.

The Renewable Energy Action Plan (NREAP), with the relevant target indicators and the trajectories of their achievement have been prepared according to the methodology developed by the Directive on Renewable Energy (2009/28/EC) and the Secretariat of the Energy Community. The process of work on NREAP was undertaken in close coordination between the Ministry of Economy and Sustainable Development and the relevant departments Secretariat of the Energy Community.

The authors of this document had close cooperation with the Government of Georgia in the process of implementation of the NREAP and have access to information that the action plan that unequivocally considers and emphasizes the importance of establishment the district heating networks in the densely populated locations of the mountainous regions of Georgia, such as Mestia, Gudauri, Bakuriani, Akhaltsikhe, Goderdzi and other.

Within the framework of the project it is envisaged to provide grant funding to the municipality (based on the same principles as in the case of biomass collector) for energy distribution system (thermal tracks, drinking water and technical water supply, with further consideration of power supply). As was in the case of biomass collector, the municipality will generate the revenues with the purpose of improving the energy efficiency of municipal buildings and increase of thermal networks.

The micro-managed energy networks organized on such principles will provide the development of an efficient business model, and as a result the business operator will receive a commercially viable project, thus becoming a profitable ESCO unit.
The Government of Georgia and the Samtskhe-Javakheti Regional Administration will implement a pilot project in Borjomi municipality, which will be a successful example of the new law on state-private partnership initiative. As a result, a number of positive results will be achieved:

• Increased consciousness among local population and authorities;
• Reduced energy costs in pilot buildings;
• Strengthening touristic and recreational attractions;
• Increased energy independence;
• Accumulation of important statistical information;

• Reduction of illegal cutting of forests;
• Increase of economic potential of Borjomi Municipality;
• Accomplishment of existing environmental commitments, in particular reduction of carbon emissions;
• Providing professionals interested mastering innovative technologies with relevant capacity;
• Increase in employment and improvement of social conditions in Borjomi municipality;
• Demonstration of the production, use and capacity of renewable energy resources.

§7.0 Cost Structure Assessment (CAPEX / OPEX)

Based on the detailed project plan and respective cost assessment (see Annex #2) project investment expenditures (CAPEX) amount to 10 203 200 USD.

Table #3. Project's investment expenses

#	Investment	Cost in USD
1	Purchase of land	197 000
2	Establishment of road	612 500
3	Equipment for biomass collection and delivery and local carriers	1 025 000
4	Heat mains 1500 m long (60 wells)	925 000
5	Pumps and connection junctions	289 000
6	Natural gas boiler with 2 MW peak load capacity	712 000
7	Laboratory equipment	52 000
8	Cold water main of 4500 m	538 000
9	Awareness raising and capacity building	145 000
10	Network control and accounting system	309 000
11	Boiler building – 400 sq. m.	240 000
12	Plant site roads and biomass storage facility	755 000
13	Administrative and laboratory building 450 sq. m.	225 000
14	Technical water reservoir 1000 tons	145 000
15	Hot water buffer tank 100 tons	101 000
16	Cold water buffer tank 100 tons	148 000
17	2 MW Biomass boiler with feed in conveyor and transporter	1 937 000
18	Heat pumps with total installed capacity of 1 MW	603 000
19	2 hot water intermediate trivalent reservoirs (each 50 tons)	345 000
20	Management and monitoring system	193 000
21	Working capital	400 000
22	Unexpected expenses	306 700
	Total	**10 203 200**

It should also be noted that there are different opportunities of funding the above-mentioned investment positions, which will be necessary to achieve purpose of profitability, sustainability and therefore feasibility of the project.

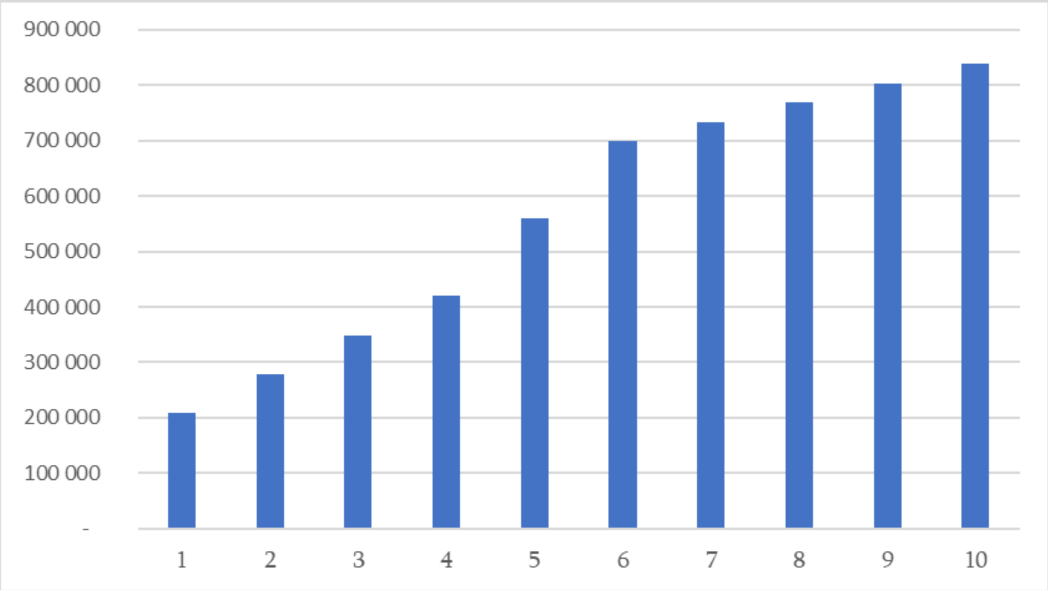
As for operational expenses and profit/loss estimates, the following inputs and assumptions (see annex #3 for OPEX) were used for the forecast:

- GEL/USD exchange rate - 2.45;
- Losses in heating main - 5%;
- Cost of drinking water - 1.489795918 USD;
- Sales price of technical water - 1.22449 USD;
- Sales price of technical water - 1.02041 USD;
- Calorific value of 1 m3 natural gas - 9.4 kWh;
- Cost of 1 m3 natural gas - 0.35 USD;
- Cost of 1 kWh thermal energy produced with natural gas - 0.037234043 USD;
- Sales price of 1 kWh energy produced by energy station - 0.02553191 USD (30% price reduction compared to natural gas produced energy);
- Cost of 1 kWh power - 0.08571 USD;
- Discount rate - 6%;
- Property tax - 1%;

It should also be noted that the selling price of thermal energy (1 kWh) is based on the analogy of production of 1 kWh of natural gas, provided that the energy supplied to consumers within the project is priced by 30% less than the current 1 kWh thermal energy price. As for the above-mentioned %, its selection at this level is based on a survey conducted within consumers having 100 kW and more installed capacity.

From the start of the operation of the plant particular time will be required to achieve full capacity: the annual income of the plant on the start of operation is only 20% of potential projected income. Graph # 1 reflects the growth of the first 10 years of income performance (maximum income level under existing network conditions).

Graph #1. Income forecast



Without the investment into expansion of the network from the 10th year of operation income will reach a maximum and freeze on the given level.

Considering the above assumptions and inputs, total income from sale of thermal energy, power, technical and drinking water for the 6th year from start of operation (achieving 70% of sales potential) is presented in Table #4.

Table #4. Annual volumes of sales of thermal energy, power and technical and drinking water

Resource	**Unit**	**Production**	**Sales price, $**	**Income, $**
Biomass generated heat	kWh heating	7 261 800	0.0369	268 021
Heat pump generated heat	kWh heating	6 726 000	0.0369	248 246
Technical water	m3	63 702	1.0204	65 002
Drinking water	m3	8 000	1.2245	9 796
Biomass generated power	kWh power	3 112 200	0.0857	266 760
Total				**698 693**

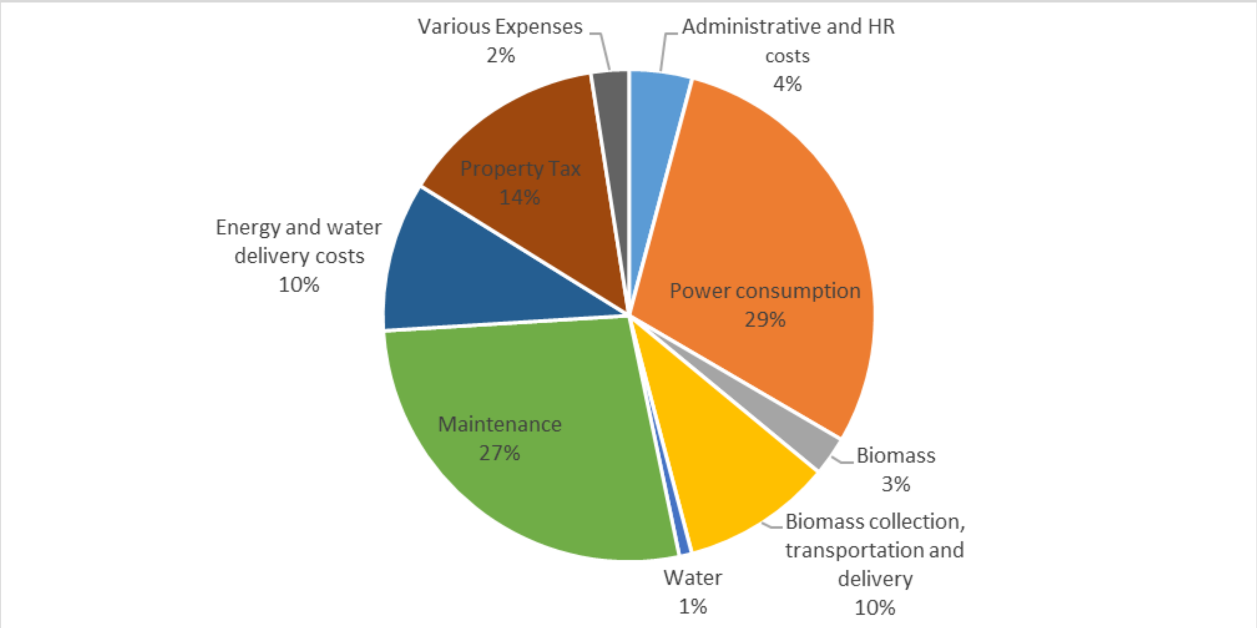
Cost structure for the same (6th) year is presented in the table #5.

Table #5. Operating Expenses

Expenses	USD
Staff and human resources	29 388
Power consumption	207 000
Biomass	18 200
Biomass collection, transportation and production	70 070
Water	5 853
Maintenance	193 164
Energy and water delivery expenses	69 600
Property tax	96 582
Various expenses	17 650
Total	**707 507**

Analysis of Operating Costs (see Figure # 2) shows that the significant portion of the expenses are spent on power consumption (29%), maintenance (27%) and property tax (14%).

Figure #2. Operating costs structure



Considering the operational costs exceed the income the project requires reduction of the operating expenses: only one of major operating expenses is not directly involved in plant operation while its share in total operating expenses equals 14%. This is property tax expenses that amounts to almost 100 000 USD per year. Based on this decision was made to request a special condition from the government of Georgia, that would enable the business profitability by excluding property tax from project operation.

§8.0 Financial Analysis

Preliminary financial analysis is based on various scenarios that involve variations of such inputs as energy sales prices, reinvestment options into network expansion, etc.

Scenario 1: Sales of thermal energy with a 30% discount on current price, property tax excluded from OPEX

Given scenario takes into consideration use of assumptions in §7 and is based on 30% cheaper sales price of energy compared to current thermal energy price.

Considering the investment capital required for the project (10 203 200 $), it won't pay back even with simple payback period. Projected income and annual operating expenses are given in table #6.

Table #6. Forecasted income and operating expenses

Year	Income USD	Operating expenses	Income before taxes USD
1	209 608	380 000	- 170 392
2	279 477	430 863	- 151 386
3	349 347	460 873	- 111 527
4	419 216	490 884	- 71 668
5	558 955	550 904	8 050
6	698 693	610 925	87 768
7	733 628	623 143	110 484
8	768 563	635 362	133 201
9	803 497	647 580	155 917
10	838 432	659 799	178 633
11	838 432	659 799	178 633
12	838 432	659 799	178 633
13	838 432	659 799	178 633
14	838 432	659 799	178 633
15	838 432	659 799	178 633

16	838 432	659 799	178 633
17	838 432	659 799	178 633
18	838 432	659 799	178 633
19	838 432	659 799	178 633
20	838 432	659 799	178 633
21	838 432	659 799	178 633
22	838 432	659 799	178 633
23	838 432	659 799	178 633
24	838 432	659 799	178 633
25	838 432	659 799	178 633
26	838 432	659 799	178 633
27	838 432	659 799	178 633
28	838 432	659 799	178 633
29	838 432	659 799	178 633
30	838 432	659 799	178 633
31	838 432	659 799	178 633
32	838 432	659 799	178 633
33	838 432	659 799	178 633
34	838 432	659 799	178 633
35	838 432	659 799	178 633
36	838 432	659 799	178 633
37	838 432	659 799	178 633
38	838 432	659 799	178 633
39	838 432	659 799	178 633
40	838 432	659 799	178 633
41	838 432	659 799	178 633
42	838 432	659 799	178 633
43	838 432	659 799	178 633

44	838 432	659 799	178 633
45	838 432	659 799	178 633
46	838 432	659 799	178 633
47	838 432	659 799	178 633
48	838 432	659 799	178 633
49	838 432	659 799	178 633
50	838 432	659 799	178 633

Profit before taxes reaches its maximum level in the 10^h year from the start of the operation. Considering this fact payback of investment capital is impossible (even with a simple payback the period equals 74 years).

Due to this fact it is necessary to obtain co-financing for the project that will enable funding of the project components that represent barriers or can be contributed to the project by in-kind contribution. Project funding is planned with the following sources: Private investment – 1 ml USD, the 70% of remaining investment (6 442 240 USD) with grant capital, while 30% with 10-year grace period 50 years term loan of 1% annual interest rate (see annex #4 for loan amortization schedule).

Scenario 2: Sales of thermal energy with a 30% discount on current price, property tax excluded from OPEX, Project funding is planned with the following sources: Private investment – 1 ml USD, the 70% of remaining investment with grant capital, while 30% with 10-year grace period 50 years term loan of 1% annual interest rate.

Investment components and potential sources of their financing are given in table #7.

Table #7. Investment components and potential sources of their financing

#	Investment	Cost in USD	Potential sources of financing and operation
1	Purchase of land	197 000	Granting of land to the project for free of charge by state and municipality
2	Establishment of road	612 500	Development of necessary infrastructure for transport by the Ministry of Infrastructure
3	Equipment for biomass collection and delivery and local carriers	1 025 000	Obtaining grant funding for municipality from international donor organizations for establishment of operation of biomass collection and delivery
4	Heat mains 1500 m long (60 wells)	925 000	Obtaining grant funding for municipality from international donor organizations for development of heating networks and water supply with further renting out of operation by municipality
5	Pumps and connection junctions	289 000	Similar to #4
6	Natural gas boiler with 2 MW peak load capacity	712 000	Employment of existing boiler house of LTD Park Place is considered
7	Laboratory equipment	52 000	Grant funding for establishment of laboratory
8	Cold water main of 4500 m	538 000	Obtaining grant funding for municipality from international donor organizations for development of water main with further renting out of operation by municipality
9	Awareness raising and capacity building	145 000	With the support of donor organizations
10	Network control and accounting system	309 000	Obtaining grant funding for municipality for development of network control and accounting system for further renting out of operation by municipality
11	Boiler building – 400 sq. m.	240 000	Low interest rate loan with grace period from international financial institutions

12	Plant site roads and biomass storage facility	755 000	With the support of donor organizations
13	Administrative and laboratory building 450 sq. m.	225 000	Low interest rate loan with grace period from international financial institutions
14	Technical water reservoir 1000 tons	145 000	Low interest rate loan with grace period from international financial institutions
15	Hot water buffer tank 100 tons	101 000	Low interest rate loan with grace period from international financial institutions
16	Cold water buffer tank 100 tons	148 000	Low interest rate loan with grace period from international financial institutions
17	2 MW Biomass boiler with feed in conveyor and transporter	1 937 000	Technical grant support by donor organizations
18	Heat pumps with total installed capacity of 1 MW	603 000	Technical grant support by donor organizations
19	2 hot water intermediate trivalent reservoirs (each 50 tons)	345 000	Technical grant support by donor organizations
20	Management and monitoring system	193 000	Technical grant support by donor organizations
21	Working capital	400 000	Private investment
22	Unexpected expenses	306 700	Private investment

Discounted financial cash flows in the case of such co-financing are given in Table # 8.

Table #8. Discounted financial cash flows for the second scenario

	Cash Flow	**Net Cash Flow**	**Discounted Cash Flow**	**Net Discounted Cash Flow**
Year 0	- 1 000 000	- 1 000 000	- 1 000 000	- 1 000 000
Year 1	- 170 392	- 1 170 392	- 160 747	- 1 160 747
Year 2	- 151 386	- 1 321 778	- 134 733	- 1 295 480
Year 3	- 111 527	- 1 433 305	- 93 640	- 1 389 120
Year 4	- 71 668	- 1 504 973	- 56 768	- 1 445 888
Year 5	8 050	- 1 496 923	6 015	- 1 439 873
Year 6	87 768	- 1 409 155	61 873	- 1 378 000
Year 7	110 484	- 1 298 671	73 478	- 1 304 522
Year 8	133 201	- 1 165 470	83 572	- 1 220 950

Year 9	155 917	- 1 009 553	92 287	- 1 128 663
Year 10	178 633	- 830 920	99 748	- 1 028 915
Year 11	94 546	- 736 374	49 806	- 979 109
Year 12	94 546	- 641 828	46 986	- 932 123
Year 13	94 546	- 547 282	44 327	- 887 796
Year 14	94 546	- 452 736	41 818	- 845 978
Year 15	94 546	- 358 190	39 451	- 806 527
Year 16	94 546	- 263 644	37 218	- 769 310
Year 17	94 546	- 169 098	35 111	- 734 199
Year 18	94 546	- 74 552	33 124	- 701 075
Year 19	94 546	19 994	31 249	- 669 826
Year 20	94 546	114 540	29 480	- 640 346
Year 21	94 546	209 086	27 811	- 612 535
Year 22	94 546	303 632	26 237	- 586 298
Year 23	94 546	398 178	24 752	- 561 546
Year 24	94 546	492 724	23 351	- 538 196
Year 25	94 546	587 270	22 029	- 516 166
Year 26	94 546	681 816	20 782	- 495 384
Year 27	94 546	776 362	19 606	- 475 778
Year 28	94 546	870 908	18 496	- 457 282
Year 29	94 546	965 454	17 449	- 439 833
Year 30	94 546	1 060 000	16 461	- 423 372
Year 31	94 546	1 154 546	15 530	- 407 842
Year 32	94 546	1 249 092	14 651	- 393 192
Year 33	94 546	1 343 638	13 821	- 379 370
Year 34	94 546	1 438 184	13 039	- 366 331
Year 35	94 546	1 532 730	12 301	- 354 030
Year 36	94 546	1 627 276	11 605	- 342 426
Year 37	94 546	1 721 822	10 948	- 331 478
Year 38	94 546	1 816 368	10 328	- 321 150
Year 39	94 546	1 910 914	9 743	- 311 406
Year 40	94 546	2 005 460	9 192	- 302 214
Year 41	94 546	2 100 006	8 672	- 293 543
Year 42	94 546	2 194 552	8 181	- 285 362
Year 43	94 546	2 289 098	7 718	- 277 644
Year 44	94 546	2 383 644	7 281	- 270 363
Year 45	94 546	2 478 190	6 869	- 263 495
Year 46	94 546	2 572 736	6 480	- 257 015
Year 47	94 546	2 667 282	6 113	- 250 901

Year 48	94 546	2 761 828	5 767	- 245 134
Year 49	94 546	2 856 374	5 441	- 239 694
Year 50	94 546	2 950 920	5 133	- 234 561

Payback Period: **18.789 years**

Discounted Payback Period: **65.322 years**

Cash Flow Return Rate: **4.97% per year**

With the discount rate of 6%, the Investment won't pay back in 50 years. Average discounted payback is $15,308.78/year in the first 50 years. If continues, the discounted payback period is **65.322 years**.

Based on analysis of this scenario it is of low interest business-wise, as investment payback period is extensively long. Despite this fact given scenario has an advantage of increased demand among potential consumers due to comparatively cheaper price of thermal energy. However, profitability level of the plant does enable for expansion of network and installed capacity and increase in income is coming to a stop after 11 years from start of operation.

Scenario 3: Thermal energy prices equal existing market prices, property tax excluded from OPEX, **Project funding is planned with the following sources: Private investment – 1 ml USD, the 70% of remaining investment with grant capital, while 30% with 10-year grace period 50 years term loan of 1% annual interest rate.:**

Given scenario implies the sales of energy for the existing market price. In the given conditions, the project will have the opportunity to increase the number of consumers connected to the network, through capacity and network expansion.

In contrast to the second scenario reinvestment of generated income enables the business to sustain income growth rate and reaches full operational capacity on 17th year from the start of operation.

Discounted cash flow of this scenario is given in the table #9.

Table #9. Discounted cash flow for the third scenario

	Cash Flow	Net Cash Flow	Discounted Cash Flow	Net Discounted Cash Flow
Year 0	- 1 000 000	- 1 000 000	- 1 000 000	- 1 000 000
Year 1	- 122 652	- 1 122 652	- 115 709	- 1 115 709
Year 2	- 87 733	- 1 210 385	- 78 082	- 1 193 791
Year 3	- 31 961	- 1 242 346	- 26 835	- 1 220 627
Year 4	87 048	- 1 155 298	68 950	- 1 151 676
Year 5	197 520	- 957 778	147 598	- 1 004 078
Year 6	246 900	- 710 878	174 055	- 830 023
Year 7	277 573	- 433 305	184 602	- 645 421

Year 8	308 246	- 125 059	193 397	- 452 024
Year 9	338 918	213 859	200 605	- 251 419
Year 10	369 591	583 450	206 378	- 45 041
Year 11	216 177	799 627	113 879	68 838
Year 12	228 522	1 028 149	113 568	182 407
Year 13	240 867	1 269 016	112 928	295 334
Year 14	253 212	1 522 228	111 996	407 330
Year 15	265 557	1 787 785	110 808	518 138
Year 16	277 902	2 065 687	109 395	627 533
Year 17	390 247	2 455 934	144 924	772 457
Year 18	390 247	2 846 181	136 721	909 178
Year 19	390 247	3 236 428	128 982	1 038 159
Year 20	390 247	3 626 675	121 681	1 159 840
Year 21	390 247	4 016 922	114 793	1 274 633
Year 22	390 247	4 407 169	108 296	1 382 929
Year 23	390 247	4 797 416	102 166	1 485 094
Year 24	390 247	5 187 663	96 383	1 581 477
Year 25	390 247	5 577 910	90 927	1 672 404
Year 26	390 247	5 968 157	85 780	1 758 184
Year 27	390 247	6 358 404	80 925	1 839 109
Year 28	390 247	6 748 651	76 344	1 915 453
Year 29	390 247	7 138 898	72 023	1 987 476
Year 30	390 247	7 529 145	67 946	2 055 422
Year 31	390 247	7 919 392	64 100	2 119 522
Year 32	390 247	8 309 639	60 472	2 179 993
Year 33	390 247	8 699 886	57 049	2 237 042
Year 34	390 247	9 090 133	53 820	2 290 862
Year 35	390 247	9 480 380	50 773	2 341 635
Year 36	390 247	9 870 627	47 899	2 389 534
Year 37	390 247	10 260 874	45 188	2 434 722
Year 38	390 247	10 651 121	42 630	2 477 352
Year 39	390 247	11 041 368	40 217	2 517 569
Year 40	390 247	11 431 615	37 941	2 555 510
Year 41	390 247	11 821 862	35 793	2 591 303
Year 42	390 247	12 212 109	33 767	2 625 070
Year 43	390 247	12 602 356	31 856	2 656 926
Year 44	390 247	12 992 603	30 053	2 686 978
Year 45	390 247	13 382 850	28 351	2 715 330
Year 46	390 247	13 773 097	26 747	2 742 077

Year 47	390 247	14 163 344	25 233	2 767 309
Year 48	390 247	14 553 591	23 804	2 791 114
Year 49	390 247	14 943 838	22 457	2 813 571
Year 50	390 247	15 334 085	21 186	2 834 757

Payback Period: **8.369 years**

Discounted Payback Period: **10.396 years**

Cash Flow Return Rate: **14.64% per year**

Given positive cash flow enables private investor to establish a revolving fund that will enable further expansion of the project for the next 30 years.

§9.0 Project action plan development

Implementation of the project is being accomplished by the involvement of Georgian and foreign specialists within 36 months, the process includes several stages of development. These are:

a) Conceptual design, identification of possible partners and stakeholders. Creation and agreement of regulatory documentation between partners.

Conceptual design will be completed at this stage, initiative group will identify project partners and determine the relationships between partners. This will be documented in the regulatory documents. The initiative group will initiate fundraising to identify financial and donor institutions and provide necessary arrangements. At this stage, the project management will be implemented by the initiative group with the involvement of management from New Technology Center, Park Hotel Ltd, Enerstena, Borjomi Municipality, Ministry of Economy and Sustainable Development.

The activities will commence in October 2018 and will end in May 2019

b) Project management team development

On this stage the following activities will be implemented: Selection of staff members to form project management team, assignment of managers. Define management policy and team mobilization strategy. Delegating authority from the initiative group to the management. Permission and licensing processes required for the start will be completed at this stage.

The phase will commence in April 2019 and will end by June 2019

c) Detailed designing, fundraising, obtaining necessary permits and licenses, accreditation of property forms.

At this stage the detailed technical project will be developed, the details of the organizing of the construction works will be agreed, the necessary construction permits will be obtained.

The exact budget of construction works will be developed and agreed.

Project management will present a detailed construction strategy.

Agreement on the plans and schedules required for financing will be formed and construction organizations will be selected, contracts will be prepared. Mobilization activities for construction works will be carried out. Organizing temporary roads and contracts with suppliers will be formed.

The stage will commence in July 2019 and will end in January 2020

d) Organizing construction and installation works

The phase involves organizing construction and installation works and completing them according to approved work plans and schedules. The complete cycle of works and commissioning will be implemented.

The stage will commence in January 2020 and will end in September 2020

e) Operating of energy station in test mode and implementation of procedures to connect the consumers to the network. Implementing marketing activities and promotion to increase awareness raising.

This stage will start parallel to the D stage, and will cover the municipal as well as the national and regional level. Visits will be made to potential consumers through a campaign type promotion. Selection of personnel and their training abroad will be carried out. Startup of the plant in test mode and organization of biomass collector will be implemented. Contracts with suppliers will be organized for collection of residual biomass.

This phase will commence in January 2020 and will end in December 2020.

f) Reaching a full projected capacity level of energy station and its transfer to the operating team.

This stage implies transitioning from testing mode to operating mode, organization of distribution network and establishment of so-called Revolving Fund (Energy Cluster). At this stage, analysis of results of the pilot project to demonstrate the positive outcomes of the project for replication in other locations will be accomplished. Work will start with financial institutions to obtain investments into the revolving fund (energy cluster). Promotion campaign will aim to increase awareness on used technologies, promotion of possibilities of replication of successful example onto other densely populated locations. Fundraising will be initiated to obtain support for the fund (Cluster) from private sector, government institutions and foreign donor organizations. In additions, measures will be taken to eliminate the barriers identified in the pilot phase.

This phase of the project will commence in October 2020 and will end in September 2021

§10.0 Environmental Benefits of the project

Implementation of the project results in replacement of fossil fuel with renewable resources that will reduce CO2 emissions. The reduction is reflected in the following table:

Energy source	**Consumption**	**Generation**	**Difference**	**Emission factor (kg/kWh)**	**Emission reduction ton/year**
Fuel (L)	6 900	-	- 6 900	0.247	- 1.7
Power (kWh)	2 100 000	10 576 000	8 476 000	0.104	881.5
Thermal energy/ Natural gas (kWh)	104 712	14 724 000	14 619 288	0.202	2 953.1
Total					**3 833**

§11.0 Conclusions and recommendations

Conclusions of feasibility study can be formed into 5 key points that will serve as an important postulate of an action strategy:

1. Densely populated areas of mountainous regions of Georgia, especially resorts in the mountains, have great potential in terms of renewable energy-based district heating systems. It is possible to commercialize the district heating systems operating on renewable energy through specific activities for each location;

2. Borjomi pilot project on Establishment of Hybrid Energy Station in Borjomi Municipality can be commercialized in case of 45% grant co-financing and / or ensuring proportionate support measures undertaken within the framework of public co-operation;

3. Overcoming of barriers identified during the pilot phase of the project will eliminate the hindering conditions of commercialization and provide development of a successful business model for other locations;

4. To facilitate commercialization of the given business model, it is necessary to ensure the high engagement of the Government of Georgia on the legislative and executive levels to address the problems through:

- Providing support to the development of modern technologies in the country;
- Elimination of knowledge deficiency at academic and consumer levels;
- Increase of awareness through development of sectoral media outlets;
- Implementation of measures to facilitate the organization of heat and biomass fuel market generated by renewable sources;

- Organization of solid biomass collectors and heat distribution networks at municipal levels.

5. It is important to establish a Revolving fund (energy cluster) that provides: establishment of a single platform for supporting renewable energy systems operated district heating systems through advocacy, lobbying, awareness raising campaigns, increasing the commercial attractiveness and other facilitating activities as well as development of efficient business models and horizontal relationships between businesses, non-profit organizations and institutions.

Annex #1: Simulation analysis for solar power farms in various locations

1. Tbilisi

PVSYST V6.70 Page 1/3

Grid-Connected System: Simulation parameters

Project : **12LG_2_Tbilisi_100KWt**

Geographical Site Tbilisi — Country: Georgia

Situation — Latitude: 41.71° N — Longitude: 44.83° E

Time defined as — Legal Time: Time zone UT+4 — Altitude: 633 m

Albedo: 0.20

Meteo data: Tbilisi — Meteonorm 7.1 (2003-2013), Sat=100% - Synthetic

Simulation variant : **Longi285_SMA50**

Simulation date: 06/06/18 11h04

Simulation parameters — System type: **No 3D scene defined**

Collector Plane Orientation — Tilt: 30° — Azimuth: 0°

Models used — Transposition: Perez — Diffuse: Perez, Meteonorm

Horizon — Free Horizon

Near Shadings — No Shadings

PV Array Characteristics

PV module — Si-mono — Model: **LR-60-285M**

Custom parameters definition — Manufacturer: Longi Solar

Number of PV modules — In series: 20 modules — In parallel: 20 strings

Total number of PV modules — Nb. modules: 400 — Unit Nom. Power: 285 Wp

Array global power — Nominal (STC): **114 kWp** — At operating cond.: 102 kWp (50°C)

Array operating characteristics (50°C) — U mpp: 559 V — I mpp: 182 A

Total area — Module area: 654 m² — Cell area: 584 m²

Inverter — Model: **Sunny Tripower_Core1_PRELIM_MOW**

Custom parameters definition — Manufacturer: SMA

Characteristics — Operating Voltage: 150-1000 V — Unit Nom. Power: 50.0 kWac

Inverter pack — Nb. of inverters: 2 units — Total Power: 100 kWac

Pnom ratio: 1.14

PV Array loss factors

Thermal Loss factor — Uc (const): 20.0 W/m²K — Uv (wind): 0.0 W/m²K / m/s

Wiring Ohmic Loss — Global array res.: 52 mOhm — Loss Fraction: 1.5 % at STC

LID - Light Induced Degradation — Loss Fraction: 1.3 %

Module Quality Loss — Loss Fraction: -0.5 %

Module Mismatch Losses — Loss Fraction: 1.0 % at MPP

Strings Mismatch loss — Loss Fraction: 0.10 %

Incidence effect (IAM): User defined IAM profile

0°	20°	40°	60°	70°	75°	80°	85°	90°
1.000	1.000	1.000	0.960	0.880	0.800	0.670	0.430	0.000

User's needs : Unlimited load (grid)

HELIOS strategia	PVSYST V6.70		Page 2/3

Grid-Connected System: Main results

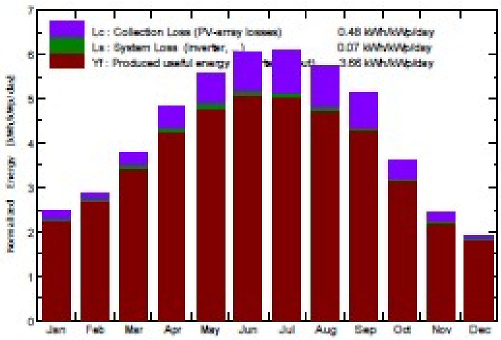
Project : **12LG_2_Tbilisi_100KWt**

Simulation variant : **Longi285_SMA50**

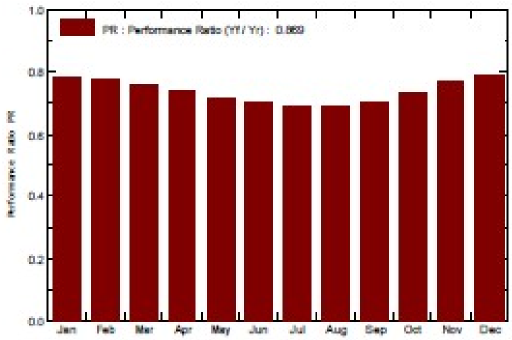
Main system parameters				
	System type	Grid-Connected		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	Produced Energy	152.3 MWh/year	Specific prod.	1336 kWh/kWp/year
	Performance Ratio PR	86.92 %		

Normalized productions (per installed kWp): Nominal power 114 kWp



Performance Ratio PR



Longi285_SMA50

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	48.9	25.04	-1.35	75.7	73.9	8.23	8.08	0.937
February	60.9	34.14	-0.02	80.9	78.9	8.74	8.58	0.930
March	98.3	54.36	4.89	118.1	114.8	12.45	12.23	0.908
April	135.4	77.04	9.43	144.6	140.2	14.89	14.63	0.887
May	174.6	82.69	14.50	172.8	167.4	17.26	16.95	0.860
June	190.0	76.33	18.15	181.7	176.1	17.70	17.36	0.838
July	194.8	76.27	21.46	189.6	184.1	18.17	17.82	0.825
August	168.5	72.01	21.31	177.8	172.7	17.08	16.75	0.826
September	128.1	48.00	16.25	153.1	149.1	14.97	14.69	0.842
October	84.1	42.34	10.85	110.9	108.3	11.40	11.19	0.885
November	50.3	28.17	4.64	72.2	70.5	7.73	7.59	0.922
December	38.7	24.24	-0.61	59.3	57.7	6.51	6.39	0.946
Year	1372.5	640.63	10.02	1536.6	1493.9	155.13	152.26	0.869

Legends:				
	GlobHor	Horizontal global irradiation	GlobEff	Effective Global, corr. for IAM and shadings
	DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	PR	Performance Ratio

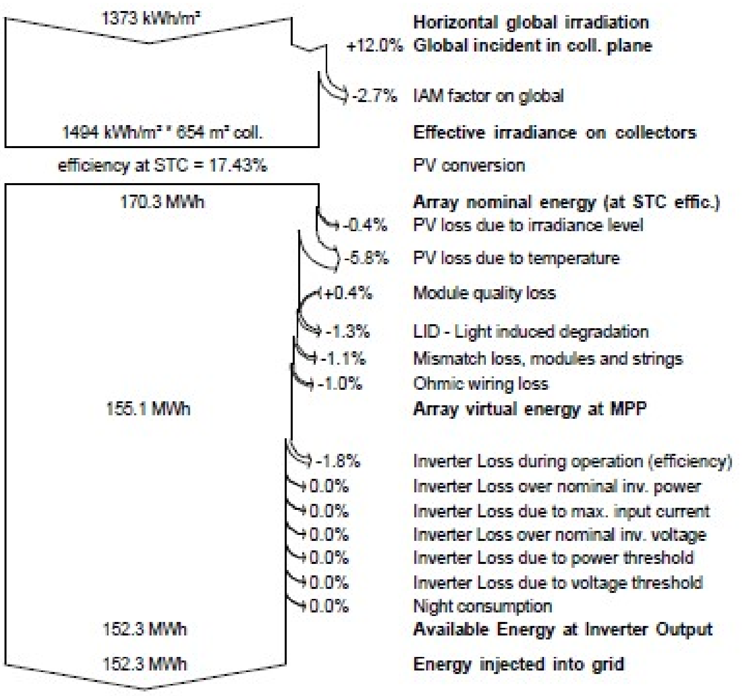
Grid-Connected System: Loss diagram

Project : **12LG_2_Tbilisi_100KWt**

Simulation variant : **Longi285_SMA50**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



2. Terjola

HELIOS strategia | PVSYST V6.70 | Page 1/3

Grid-Connected System: Simulation parameters

Project :	**11LG_2_Terjola_100KWt**			
Geographical Site	**Terjola**		Country	**Georgia**
Situation	Latitude	42.18° N	Longitude	42.97° E
Time defined as	Legal Time	Time zone UT+4	Altitude	185 m
	Albedo	0.20		
Meteo data:	**Terjola**	Meteonorm 7.1 (2003-2013), Sat=100% - Synthetic		

Simulation variant : **Longi285_SMA50**

Simulation date 06/06/18 11h04

Simulation parameters	System type	**No 3D scene defined**		
Collector Plane Orientation	Tilt	30°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module	Si-mono	Model	**LR-60-285M**		
Custom parameters definition		Manufacturer	Longi Solar		
Number of PV modules		In series	20 modules	In parallel	20 strings
Total number of PV modules		Nb. modules	400	Unit Nom. Power	285 Wp
Array global power		Nominal (STC)	**114 kWp**	At operating cond.	102 kWp (50°C)
Array operating characteristics (50°C)		U mpp	559 V	I mpp	182 A
Total area		Module area	**654 m²**	Cell area	584 m²

Inverter	Model	**Sunny Tripower_Core1_PRELIM_MOW**		
Custom parameters definition	Manufacturer	SMA		
Characteristics	Operating Voltage	150-1000 V	Unit Nom. Power	50.0 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	100 kWac
			Pnom ratio	1.14

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	52 mOhm	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	1.3 %
Module Quality Loss			Loss Fraction	-0.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Incidence effect (IAM): User defined IAM profile

0°	20°	40°	60°	70°	75°	80°	85°	90°
1.000	1.000	1.000	0.960	0.880	0.800	0.670	0.430	0.000

User's needs : Unlimited load (grid)

HELIOS strategia	PVSYST V6.70		Page 2/3

Grid-Connected System: Main results

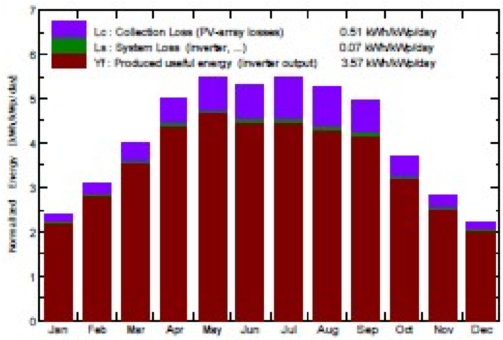
Project : **11LG_2_Terjola_100KWt**

Simulation variant : **Longi285_SMA50**

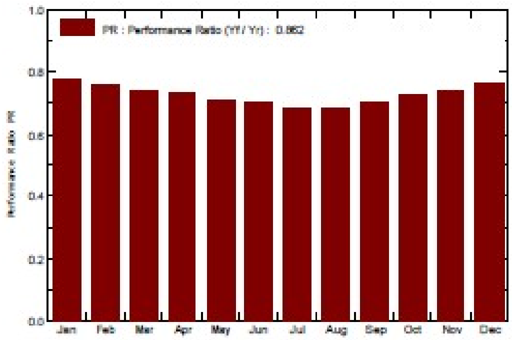
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	Produced Energy	**148.6 MWh/year**	Specific prod.	1303 kWh/kWp/year
	Performance Ratio PR	86.17 %		

Normalized productions (per installed kWp): Nominal power 114 kWp



Performance Ratio PR



Longi285_SMA50

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	48.6	28.31	5.41	73.9	72.0	7.95	7.82	0.928
February	64.4	36.96	6.35	87.1	84.9	9.22	9.06	0.913
March	103.3	56.11	9.37	124.1	120.7	12.77	12.54	0.887
April	139.1	75.12	11.93	150.1	145.6	15.28	15.01	0.877
May	171.3	77.61	16.20	170.0	164.9	16.82	16.50	0.851
June	168.2	90.42	20.28	160.2	155.0	15.64	15.35	0.841
July	174.5	80.08	23.94	168.8	163.6	16.06	15.75	0.818
August	154.9	83.65	24.69	162.3	157.5	15.54	15.24	0.824
September	125.3	57.37	20.46	149.2	145.3	14.53	14.25	0.838
October	87.7	49.14	16.23	114.2	111.2	11.54	11.34	0.871
November	54.9	27.27	10.76	84.6	82.7	8.75	8.59	0.891
December	42.6	24.61	6.97	68.0	66.4	7.27	7.14	0.920
Year	1334.7	686.66	14.43	1512.5	1469.9	151.37	148.59	0.862

Legends:			
GlobHor	Horizontal global irradiation	GlobEff	Effective Global, corr. for IAM and shadings
DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
T Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	PR	Performance Ratio

PVSYST V6.70		Page 3/3

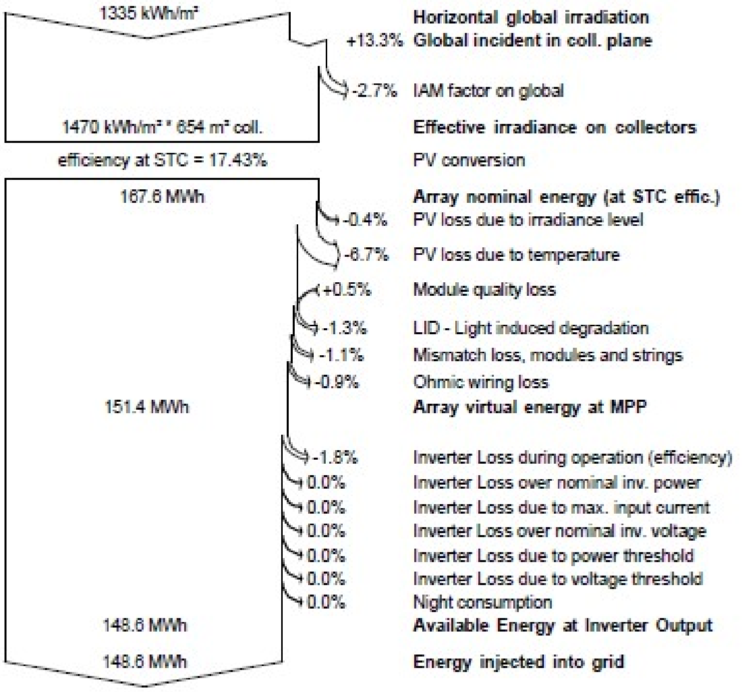
Grid-Connected System: Loss diagram

Project : **11LG_2_Terjola_100KWt**

Simulation variant : **Longi285_SMA50**

Main system parameters	System type	Grid-Connected		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



3. Zugdidi

PVSYST V6.70 | Page 1/3

Grid-Connected System: Simulation parameters

Project : **10LG_2_Zugdidi_100KWt**

Geographical Site	**Zugdidi**		Country	Georgia
Situation	Latitude	42.50° N	Longitude	41.87° E
Time defined as	Legal Time	Time zone UT+4	Altitude	109 m
	Albedo	0.20		
Meteo data:	**Zugdidi**	Meteonorm 7.1 (2003-2013), Sat=100% - Synthetic		

Simulation variant : **Longi285_SMA50**

Simulation date 06/06/18 11h02

Simulation parameters	System type	**No 3D scene defined**		
Collector Plane Orientation	Tilt	30°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module	Si-mono	Model	**LR-60-285M**		
Custom parameters definition		Manufacturer	Longi Solar		
Number of PV modules		In series	20 modules	In parallel	20 strings
Total number of PV modules		Nb. modules	400	Unit Nom. Power	285 Wp
Array global power		Nominal (STC)	**114 kWp**	At operating cond.	102 kWp (50°C)
Array operating characteristics (50°C)		U mpp	559 V	I mpp	182 A
Total area		Module area	**654 m²**	Cell area	584 m²

Inverter	Model	**Sunny Tripower_Core1_PRELIM_MOW**		
Custom parameters definition	Manufacturer	SMA		
Characteristics	Operating Voltage	150-1000 V	Unit Nom. Power	50.0 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	100 kWac
			Pnom ratio	1.14

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	52 mOhm	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	1.3 %
Module Quality Loss			Loss Fraction	-0.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Incidence effect (IAM): User defined IAM profile

0°	20°	40°	60°	70°	75°	80°	85°	90°
1.000	1.000	1.000	0.960	0.880	0.800	0.670	0.430	0.000

User's needs : Unlimited load (grid)

Grid-Connected System: Main results

Project : 10LG_2_Zugdidi_100KWt

Simulation variant : Longi285_SMA50

Main system parameters — System type: Grid-Connected

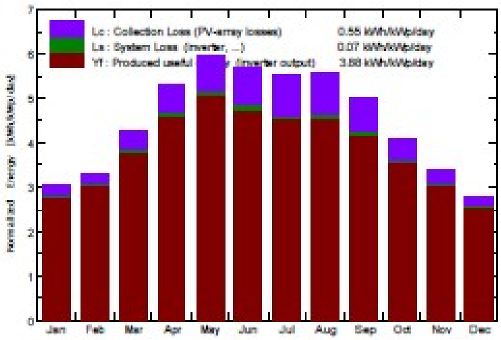
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results

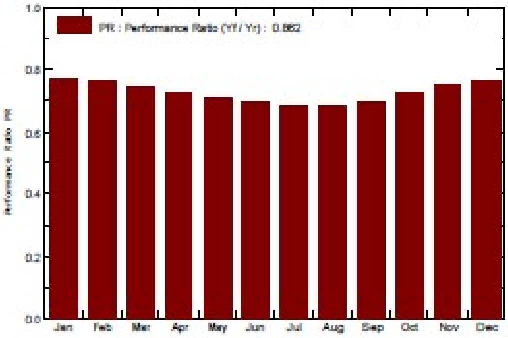
System Production — Produced Energy **161.4 MWh/year** — Specific prod. 1416 kWh/kWp/year

Performance Ratio PR 86.23 %

Normalized productions (per installed kWp): Nominal power 114 kWp



Performance Ratio PR



Longi285_SMA50

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	55.3	25.14	5.80	93.2	91.2	10.01	9.83	0.925
February	66.5	36.19	6.56	92.8	90.6	9.90	9.73	0.919
March	107.1	56.60	9.45	131.7	128.1	13.64	13.40	0.892
April	145.4	69.19	12.04	159.1	154.7	16.08	15.78	0.870
May	184.9	84.71	16.32	185.0	179.4	18.31	17.98	0.852
June	179.5	84.99	20.37	171.3	165.9	16.64	16.32	0.836
July	174.8	82.68	24.03	171.3	166.1	16.34	16.02	0.820
August	163.3	77.89	24.79	172.5	167.6	16.43	16.11	0.819
September	126.7	53.34	20.55	150.4	146.5	14.55	14.27	0.832
October	92.6	45.17	16.50	126.8	123.7	12.77	12.54	0.868
November	63.7	29.44	11.03	101.5	99.4	10.59	10.41	0.899
December	49.1	22.55	7.37	86.1	84.2	9.16	9.00	0.917
Year	1409.0	667.89	14.62	1641.7	1597.4	164.40	161.39	0.862

Legends:

GlobHor	Horizontal global irradiation	GlobEff	Effective Global, corr. for IAM and shadings
DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
T Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	PR	Performance Ratio

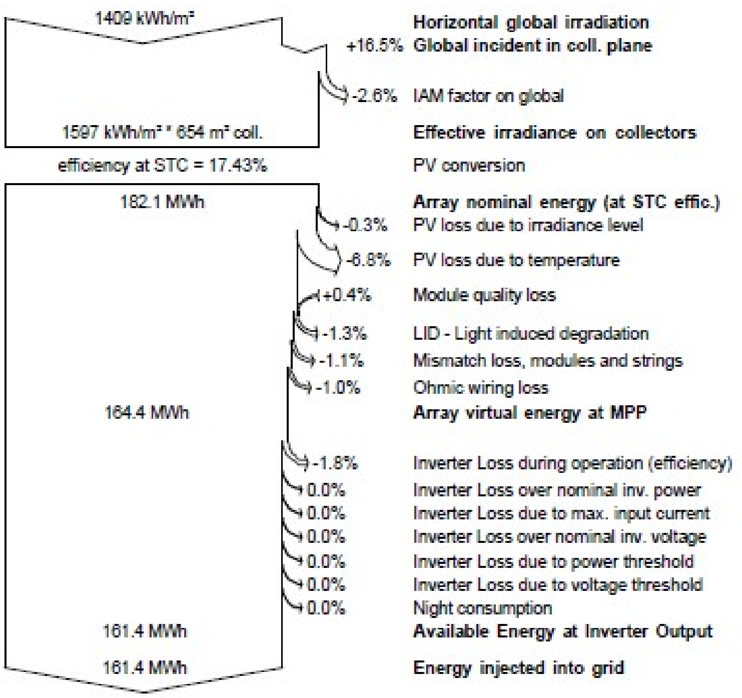
Grid-Connected System: Loss diagram

Project : **10LG_2_Zugdidi_100KWt**

Simulation variant : **Longi285_SMA50**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



4. Gudauri

HELIOS strategia	PVSYST V6.70		Page 1/3

Grid-Connected System: Simulation parameters

Project : **9LG_2_Gudauri_100Kwt**

Geographical Site	**Gudauri**		Country	Georgia
Situation	Latitude	42.47° N	Longitude	44.48° E
Time defined as	Legal Time	Time zone UT+4	Altitude	2111 m
	Albedo	0.20		
Meteo data:	**Gudauri**	Meteonorm 7.1 (2003-2013), Sat=100% - Synthetic		

Simulation variant : **Longi285_SMA50**

Simulation date 06/06/18 10h58

Simulation parameters	System type	**No 3D scene defined**		
Collector Plane Orientation	Tilt	30°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module	Si-mono	Model	**LR-60-285M**		
Custom parameters definition		Manufacturer	Longi Solar		
Number of PV modules		In series	20 modules	In parallel	20 strings
Total number of PV modules		Nb. modules	400	Unit Nom. Power	285 Wp
Array global power		Nominal (STC)	**114 kWp**	At operating cond.	102 kWp (50°C)
Array operating characteristics (50°C)		U mpp	559 V	I mpp	182 A
Total area		Module area	**654 m²**	Cell area	584 m²

Inverter	Model	**Sunny Tripower_Core1_PRELIM_MOW**		
Custom parameters definition	Manufacturer	SMA		
Characteristics	Operating Voltage	150-1000 V	Unit Nom. Power	50.0 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	100 kWac
			Pnom ratio	1.14

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	52 mOhm	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	1.3 %
Module Quality Loss			Loss Fraction	-0.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Incidence effect (IAM): User defined IAM profile

0°	20°	40°	60°	70°	75°	80°	85°	90°
1.000	1.000	1.000	0.960	0.880	0.800	0.670	0.430	0.000

User's needs : Unlimited load (grid)

Helios strategia	PVSYST V6.70		Page 2/3

Grid-Connected System: Main results

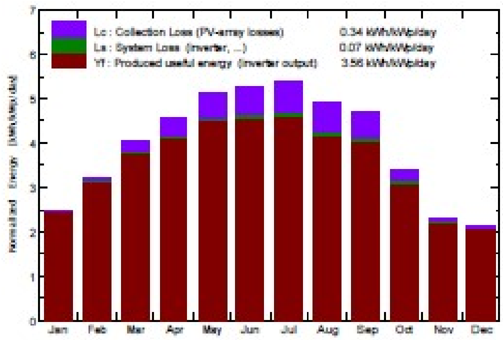
Project : 9LG_2_Gudauri_100Kwt

Simulation variant : Longi285_SMA50

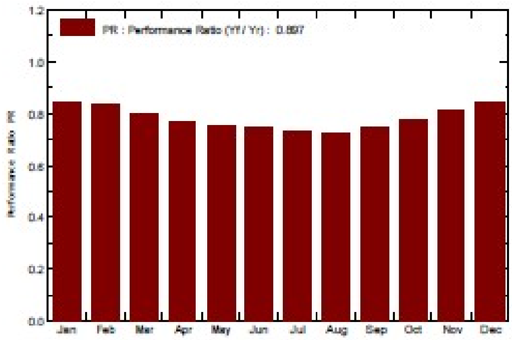
Main system parameters	System type	Grid-Connected		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	Produced Energy	**148.2 MWh/year**	Specific prod.	1300 kWh/kWp/year
	Performance Ratio PR	89.73 %		

Normalized productions (per installed kWp): Nominal power 114 kWp



Performance Ratio PR



Longi285_SMA50

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	48.2	23.34	-12.55	77.2	75.5	8.78	8.62	0.980
February	64.8	34.25	-9.74	89.9	87.8	10.12	9.94	0.970
March	104.2	57.52	-2.39	125.3	121.8	13.55	13.32	0.932
April	129.3	74.49	3.60	137.8	133.4	14.31	14.06	0.895
May	161.3	83.35	8.19	158.6	153.3	16.24	15.95	0.882
June	167.1	86.89	12.04	157.3	152.0	15.85	15.56	0.868
July	173.0	88.35	15.68	167.2	161.8	16.59	16.29	0.855
August	147.4	72.49	16.12	153.0	148.3	15.04	14.75	0.845
September	120.1	58.97	11.64	140.6	136.5	14.14	13.88	0.866
October	81.6	45.18	6.18	106.2	103.4	11.15	10.96	0.905
November	48.3	29.38	-1.35	69.8	68.0	7.67	7.53	0.946
December	39.6	21.17	-8.98	65.8	64.1	7.46	7.32	0.977
Year	1284.9	675.38	3.27	1448.7	1405.9	150.90	148.19	0.897

Legends:				
	GlobHor	Horizontal global irradiation	GlobEff	Effective Global, corr. for IAM and shadings
	DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	PR	Performance Ratio

HELIOS strategia	PVSYST V6.70		Page 3/3

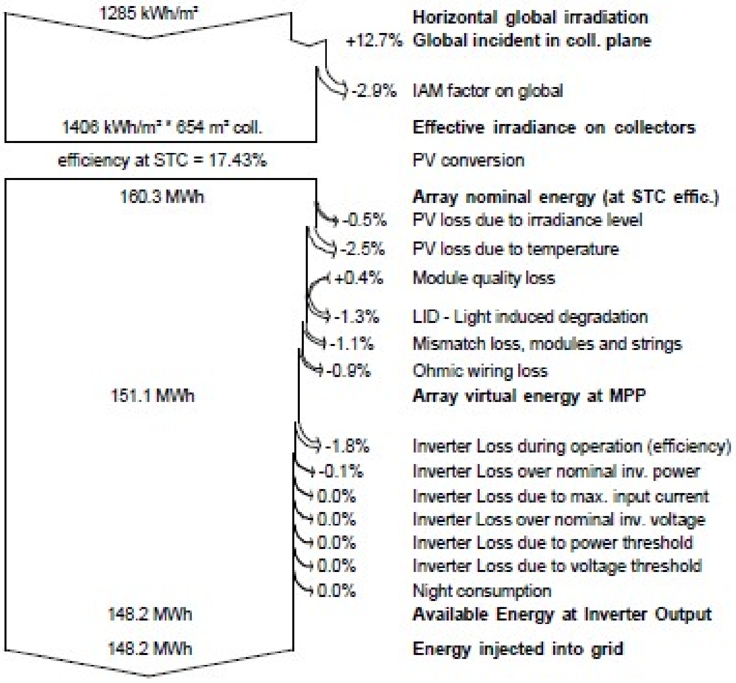
Grid-Connected System: Loss diagram

Project : 9LG_2_Gudauri_100Kwt

Simulation variant : Longi285_SMA50

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



5. Kvareli

PVSYST V6.70		Page 1/3

Grid-Connected System: Simulation parameters

Project : 8LG_2_Kvareli_100KWt

Geographical Site		Kvareli	Country	Georgia
Situation	Latitude	41.94° N	Longitude	45.81° E
Time defined as	Legal Time	Time zone UT+4	Altitude	390 m
	Albedo	0.20		
Meteo data:	Kvareli	Meteonorm 7.1 (2003-2013), Sat=100% - Synthetic		

Simulation variant : Longi285_SMA50

Simulation date 06/06/18 10h58

Simulation parameters	System type	No 3D scene defined		
Collector Plane Orientation	Tilt	30°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module	Si-mono	Model	**LR-60-285M**		
Custom parameters definition		Manufacturer	Longi Solar		
Number of PV modules		In series	20 modules	In parallel	20 strings
Total number of PV modules		Nb. modules	400	Unit Nom. Power	285 Wp
Array global power		Nominal (STC)	**114 kWp**	At operating cond.	102 kWp (50°C)
Array operating characteristics (50°C)		U mpp	559 V	I mpp	182 A
Total area		Module area	**654 m²**	Cell area	584 m²

Inverter	Model	**Sunny Tripower_Core1_PRELIM_MOW**		
Custom parameters definition	Manufacturer	SMA		
Characteristics	Operating Voltage	150-1000 V	Unit Nom. Power	50.0 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	100 kWac
			Pnom ratio	1.14

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	52 mOhm	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	1.3 %
Module Quality Loss			Loss Fraction	-0.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Incidence effect (IAM): User defined IAM profile

0°	20°	40°	60°	70°	75°	80°	85°	90°
1.000	1.000	1.000	0.960	0.880	0.800	0.670	0.430	0.000

User's needs : Unlimited load (grid)

PVSYST V6.70		Page 2/3

Grid-Connected System: Main results

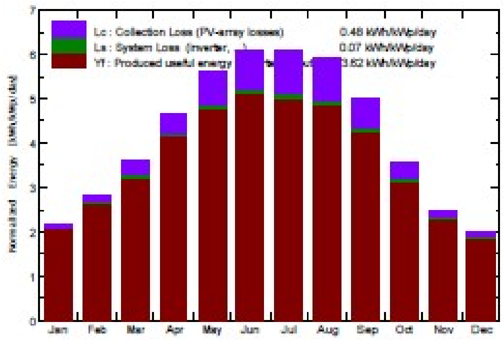
Project : **8LG_2_Kvareli_100KWt**

Simulation variant : **Longi285_SMA50**

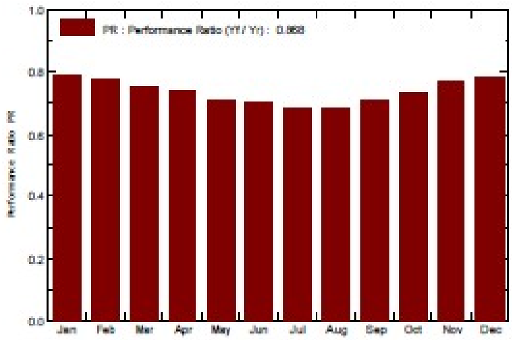
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	Produced Energy	**150.8 MWh/year**	Specific prod.	1323 kWh/kWp/year
	Performance Ratio PR	86.78 %		

Normalized productions (per installed kWp): Nominal power 114 kWp



Performance Ratio PR



Longi285_SMA50

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	46.9	30.22	-0.73	67.0	65.2	7.38	7.25	0.950
February	59.1	33.18	0.46	79.8	77.8	8.63	8.48	0.932
March	95.2	52.19	5.07	111.7	108.6	11.69	11.48	0.902
April	131.0	73.37	9.61	139.9	135.7	14.41	14.15	0.887
May	174.8	79.17	15.01	173.3	168.0	17.19	16.87	0.854
June	190.7	81.56	18.93	182.6	177.1	17.80	17.47	0.839
July	195.6	74.78	22.38	189.0	183.3	18.03	17.68	0.821
August	173.2	73.11	22.40	183.9	178.8	17.57	17.23	0.822
September	128.1	59.75	17.43	150.3	146.2	14.84	14.56	0.850
October	83.2	43.03	11.93	110.4	107.7	11.32	11.12	0.883
November	51.1	30.31	5.50	74.7	72.8	8.02	7.88	0.925
December	39.4	23.32	0.31	61.6	60.0	6.73	6.61	0.942
Year	1368.3	653.99	10.75	1524.2	1481.3	153.62	150.78	0.868

Legends:				
	GlobHor	Horizontal global irradiation	GlobEff	Effective Global, corr. for IAM and shadings
	DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	PR	Performance Ratio

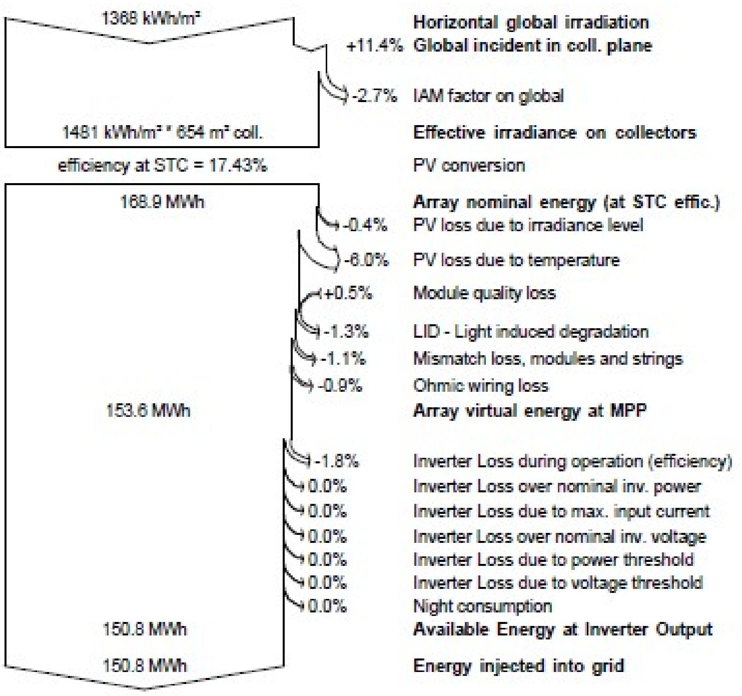
Grid-Connected System: Loss diagram

Project : **8LG_2_Kvareli_100KWt**

Simulation variant : **Longi285_SMA50**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs		Unlimited load (grid)		

Loss diagram over the whole year



6. Borjomi

PVSYST V6.70		Page 1/3

Grid-Connected System: Simulation parameters

Project : **7LG_2_Borjomi_100KWt**

Geographical Site		Borjomi	Country	Georgia
Situation	Latitude	41.84° N	Longitude	43.39° E
Time defined as	Legal Time	Time zone UT+4	Altitude	923 m
	Albedo	0.20		
Meteo data:	Borjomi	Meteonorm 7.1 (2003-2013), Sat=100% - Synthetic		

Simulation variant : **Longi285_SMA50**

Simulation date 06/06/18 10h41

Simulation parameters	System type	**No 3D scene defined**		
Collector Plane Orientation	Tilt	30°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module	Si-mono	Model	**LR6-60-285M**		
Custom parameters definition		Manufacturer	Longi Solar		
Number of PV modules		In series	20 modules	In parallel	20 strings
Total number of PV modules		Nb. modules	400	Unit Nom. Power	285 Wp
Array global power		Nominal (STC)	**114 kWp**	At operating cond.	102 kWp (50°C)
Array operating characteristics (50°C)		U mpp	561 V	I mpp	182 A
Total area		Module area	654 m²	Cell area	590 m²

Inverter	Model	**Sunny Tripower_Core1_PRELIM_MOW**		
Custom parameters definition	Manufacturer	SMA		
Characteristics	Operating Voltage	150-1000 V	Unit Nom. Power	50.0 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	100 kWac
			Pnom ratio	1.14

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	52 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	-0.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Incidence effect (IAM): User defined IAM profile

0°	20°	30°	40°	50°	60°	70°	80°	90°
1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.760	0.000

User's needs : Unlimited load (grid)

HELIOS strategia | PVSYST V6.70 | Page 2/3

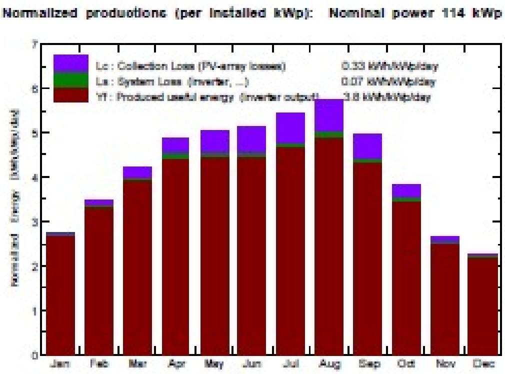
Grid-Connected System: Main results

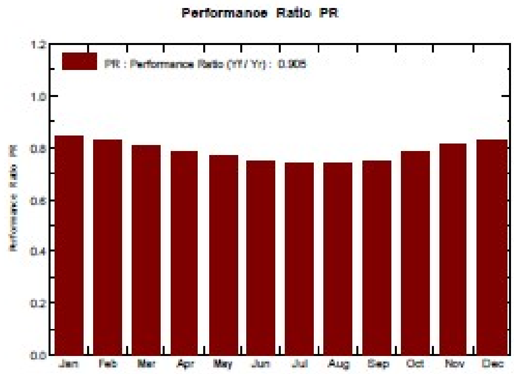
Project : **7LG_2_Borjomi_100KWt**

Simulation variant : **Longi285_SMA50**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR6-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	Produced Energy	**158.1 MWh/year**	Specific prod.	1387 kWh/kWp/year
	Performance Ratio PR	90.46 %		





Longi285_SMA50

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	52.8	25.28	-2.74	85.2	84.5	9.69	9.52	0.980
February	69.9	35.20	-1.46	97.5	96.7	10.89	10.70	0.962
March	108.1	54.98	3.39	130.6	129.2	14.16	13.91	0.934
April	134.6	74.69	8.06	146.2	144.2	15.50	15.23	0.914
May	158.7	78.59	13.10	156.0	153.8	16.15	15.86	0.892
June	161.9	77.10	16.76	153.8	151.7	15.61	15.32	0.874
July	175.3	80.72	20.05	168.4	166.0	16.88	16.56	0.863
August	169.3	69.37	19.92	178.3	176.2	17.74	17.40	0.856
September	125.7	51.11	14.75	148.8	146.9	15.14	14.86	0.876
October	89.3	43.92	9.34	118.5	117.4	12.59	12.36	0.915
November	54.6	31.87	3.28	79.1	78.4	8.76	8.61	0.954
December	42.7	22.14	-2.02	70.2	69.6	7.89	7.75	0.969
Year	1342.9	644.97	8.59	1532.7	1514.4	161.01	158.07	0.905

Legends:				
	GlobHor	Horizontal global irradiation	GlobEff	Effective Global, corr. for IAM and shadings
	DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	PR	Performance Ratio

HELIOS strategia	PVSYST V6.70	Page 3/3

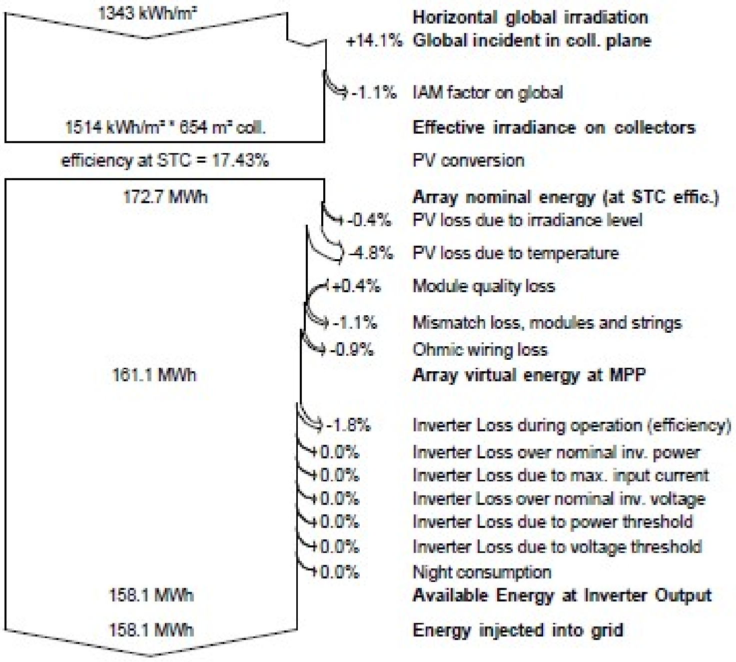
Grid-Connected System: Loss diagram

Project : **7LG_2_Borjomi_100KWt**

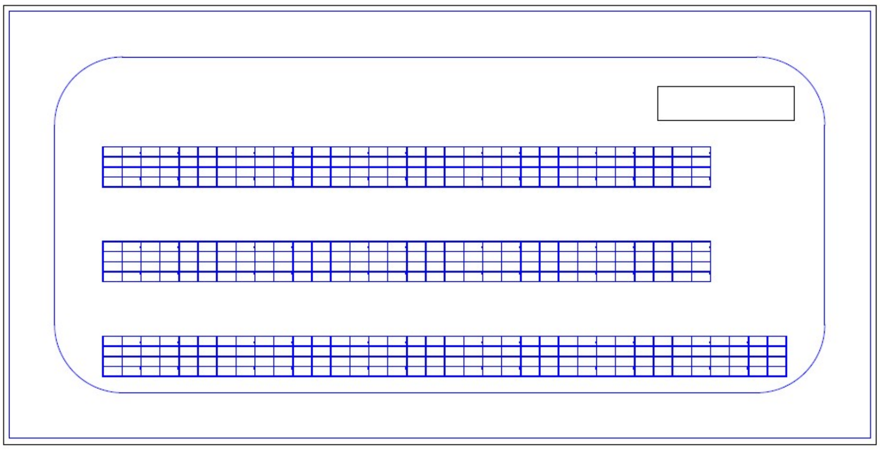
Simulation variant : **Longi285_SMA50**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	LR6-60-285M	Pnom	285 Wp
PV Array	Nb. of modules	400	Pnom total	**114 kWp**
Inverter		Sunny Tripower_Core1_PRELIM_MOW	Pnom	50.0 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Детальна інформація		
Встановлена потужність ФЕС	114	кВт-пік
Електрична потужність ФЕС	100	кВт
Кількість ФЕМ	400	шт
Тип ФЕМ	Longi Solar LR6-60-285M	
Тип інверторів	Sunny Tripower Core 1	
Кількість інверторів	2	шт
Кут нахилу	30	°

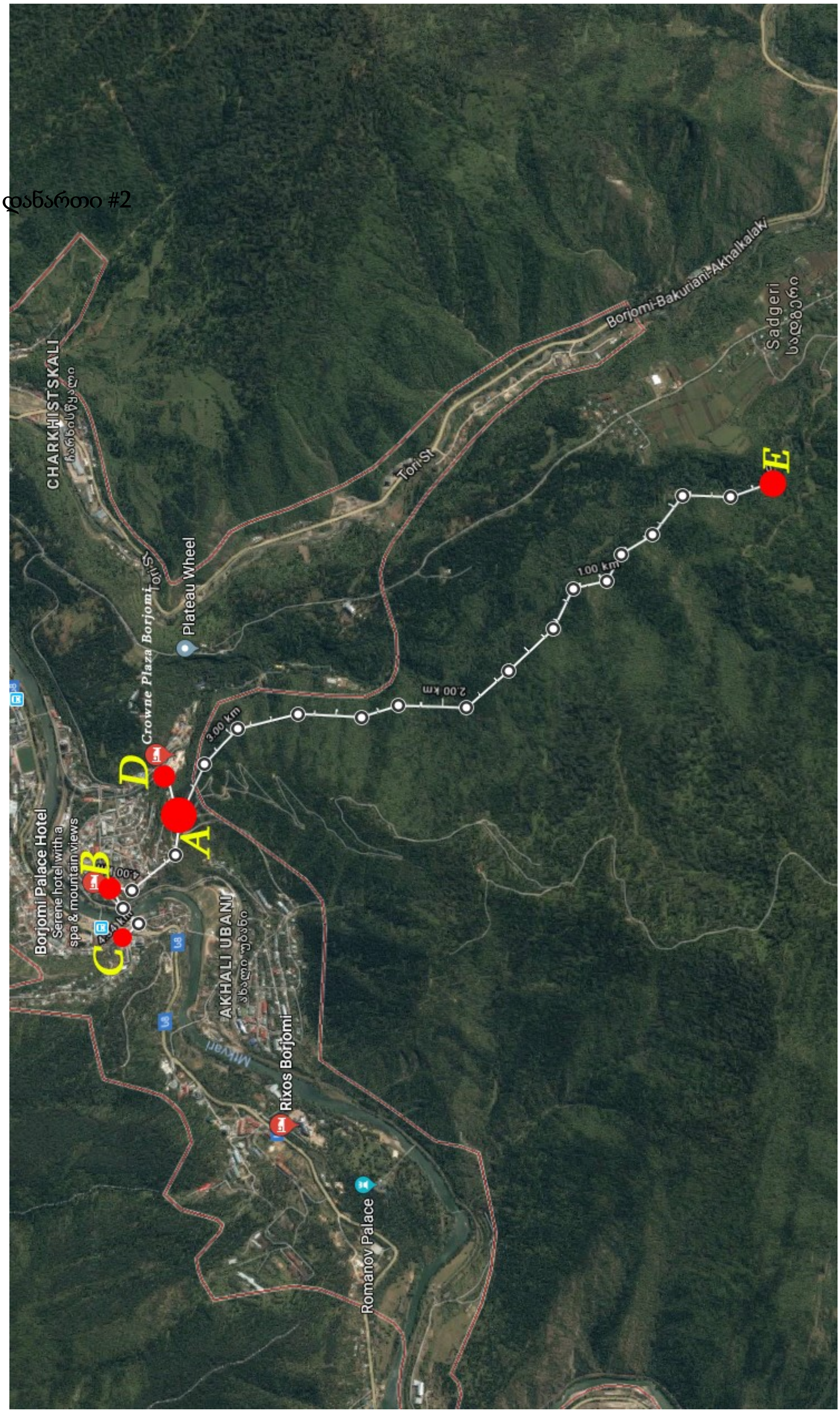


Умовні позначення	
▭	Адміністративно-побутова будівля
▦	Стіл на 16 ФЕМ

Розроблено HELIOS strategia

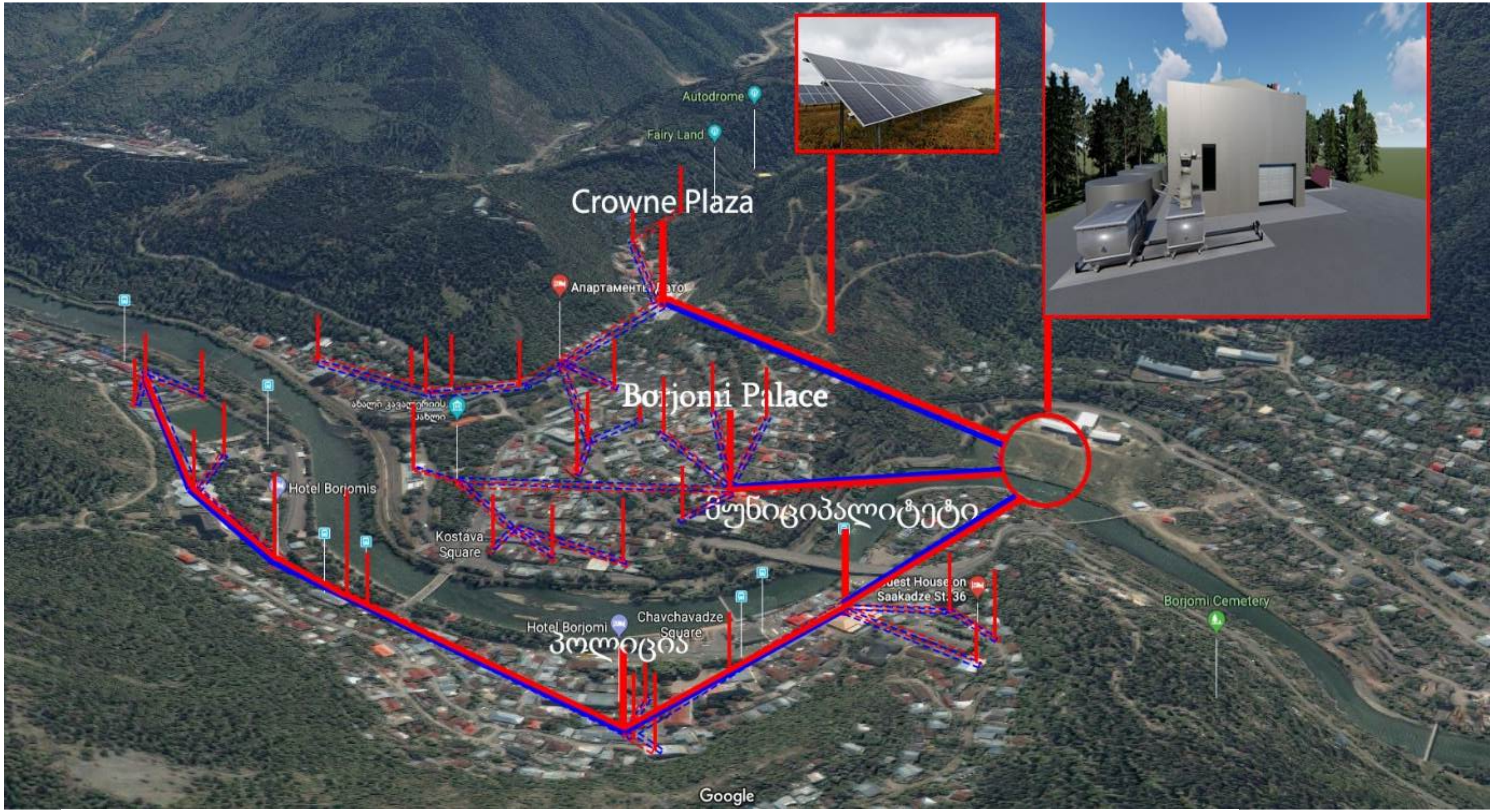
Annex #2: Detailed project

დანართი #2



RENEWABLE ENERGY SOURCE DISTRICT HEATER (biomass, solar, hydropump,heatpump)IN CITY BORJOMI

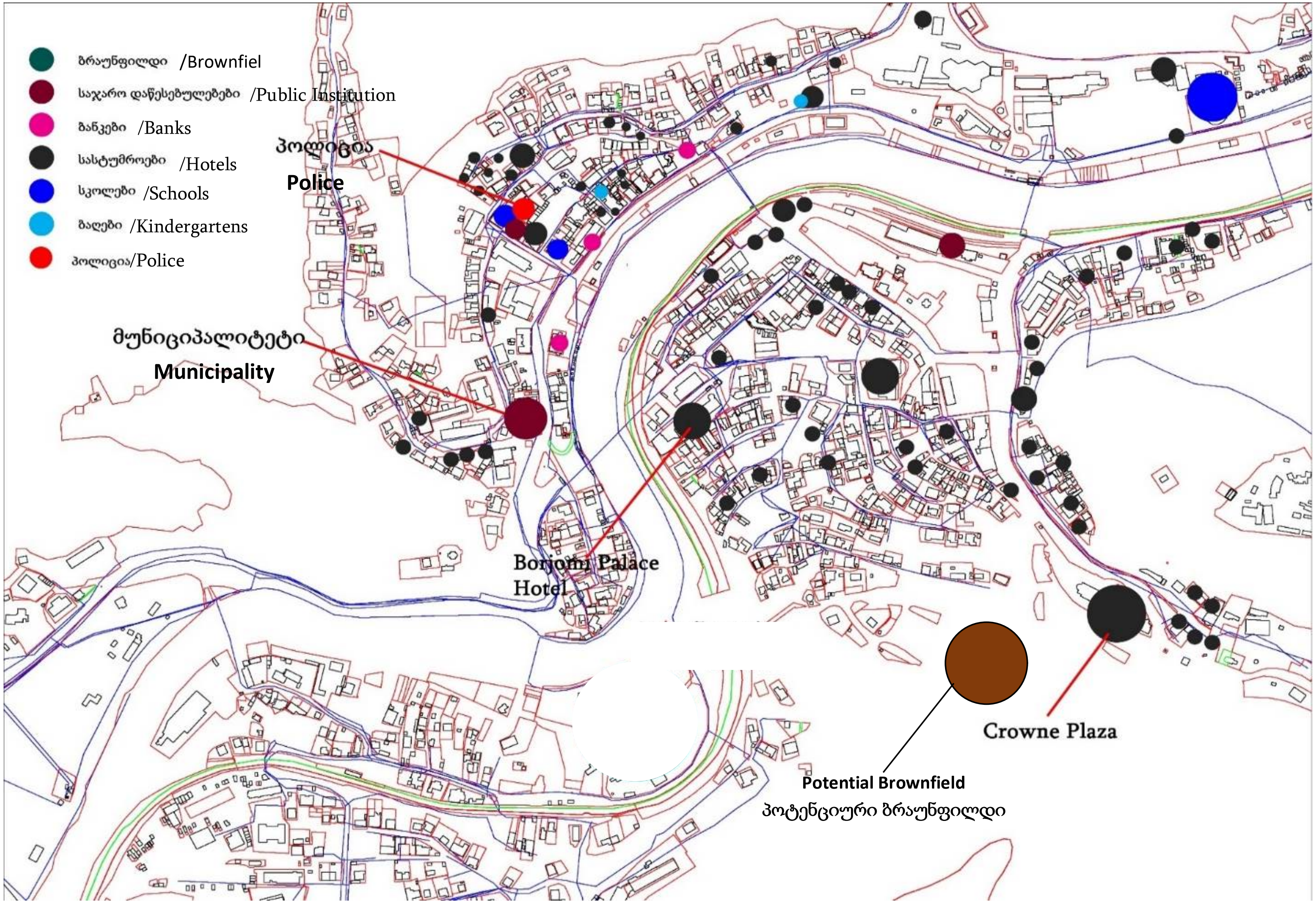
განახლებად ენერგორესურსებზე (ბიომასა, მზე, ჰიდრო ტუმბო და თბური ტუმბო) ოპერირებული საუბნო გამათბობელი სისტემა. ქალაქი ბორჯომი



100 კვტ და მეტი სიმძლავრის სამიზნე მომხმარებელის განთავსების სქემა სითბოს დისტრიბუციის მიზანშეწონილ არეალში

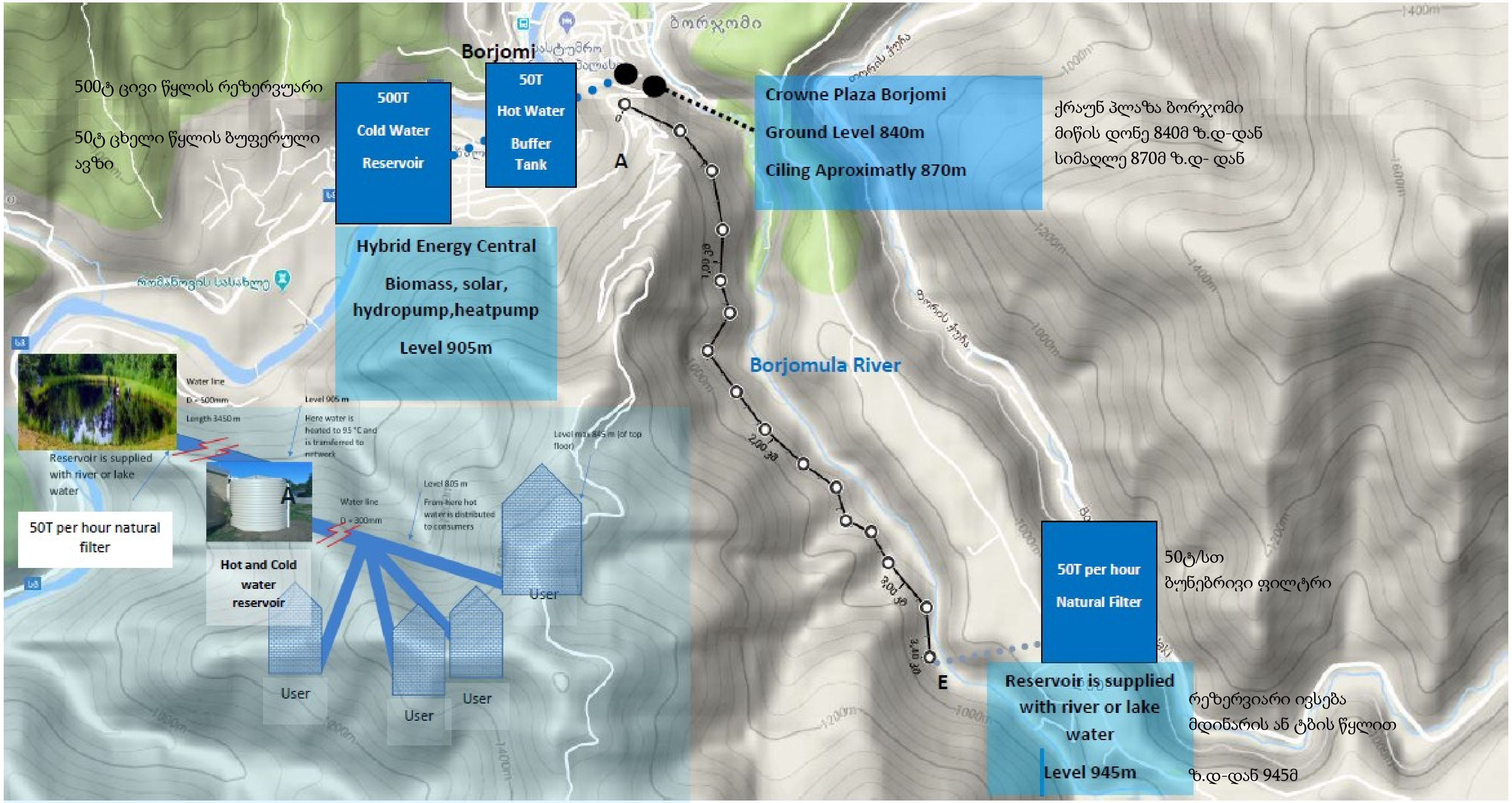
100 kW and more power target users' scheme in the area of heat distribution

ECO ENGINEERING



RENEWABLE ENERGY SOURCE DISTRICT HEATER (biomass, solar, hydro pump, heat pump) IN CITY BORJOMI

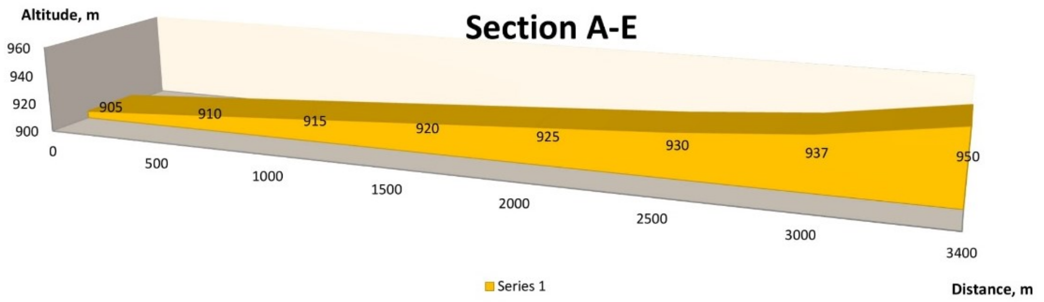
განახლებად ენერგორესურსებზე (ბიომასა, მზე, ჰიდრო ტუმბო და თბური ტუმბო) ოპერირებული საუბნო გამათბობელი სისტემა. ქალაქი ბორჯომი

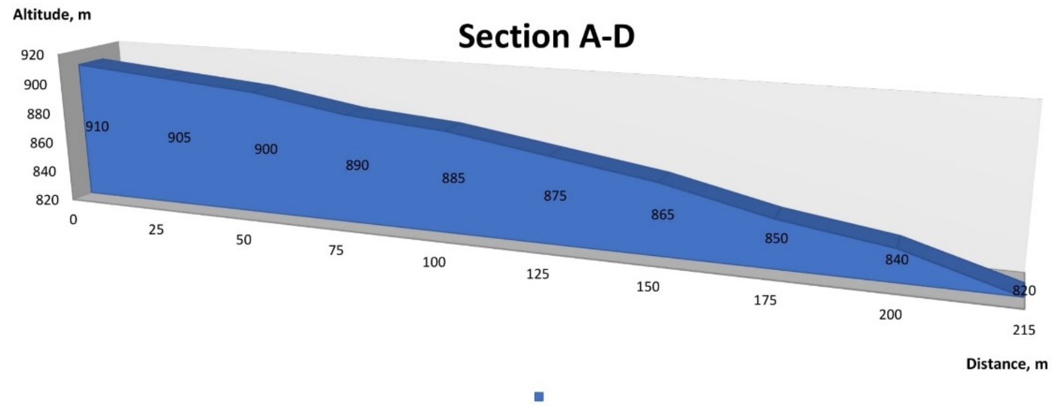


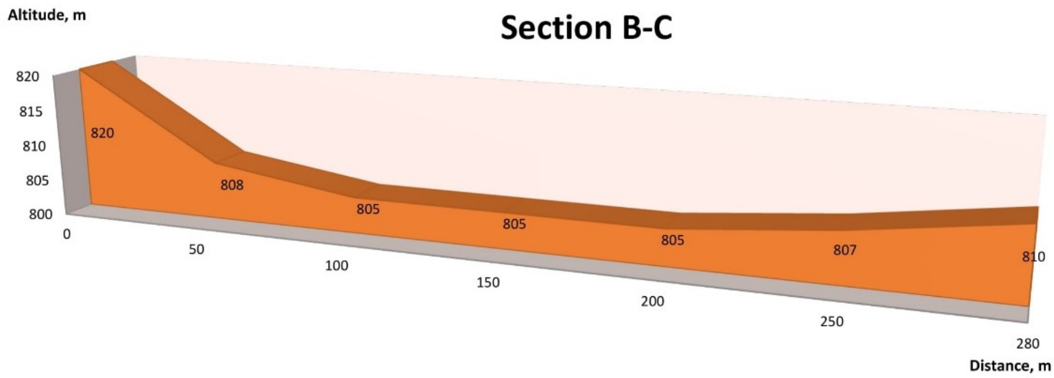
სადაწნეო მაგისტრალის განთავსების სქემა

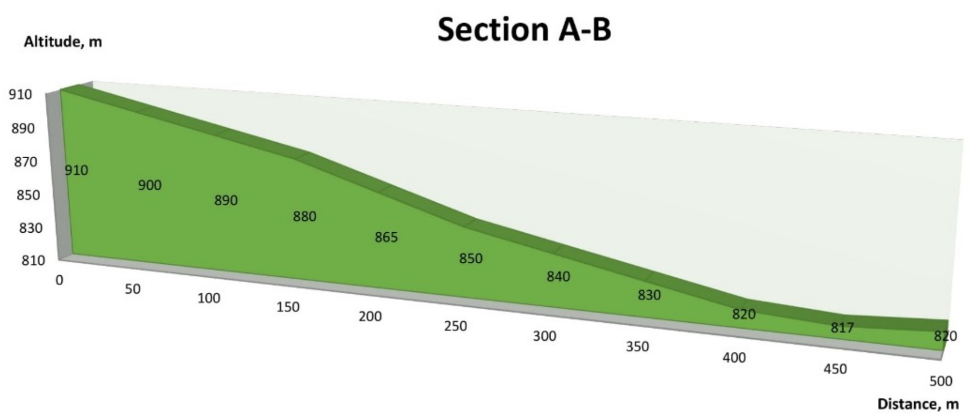
Hot and cold water

ცხელი და ცივი წლის მაგისტრალების ჭრილები



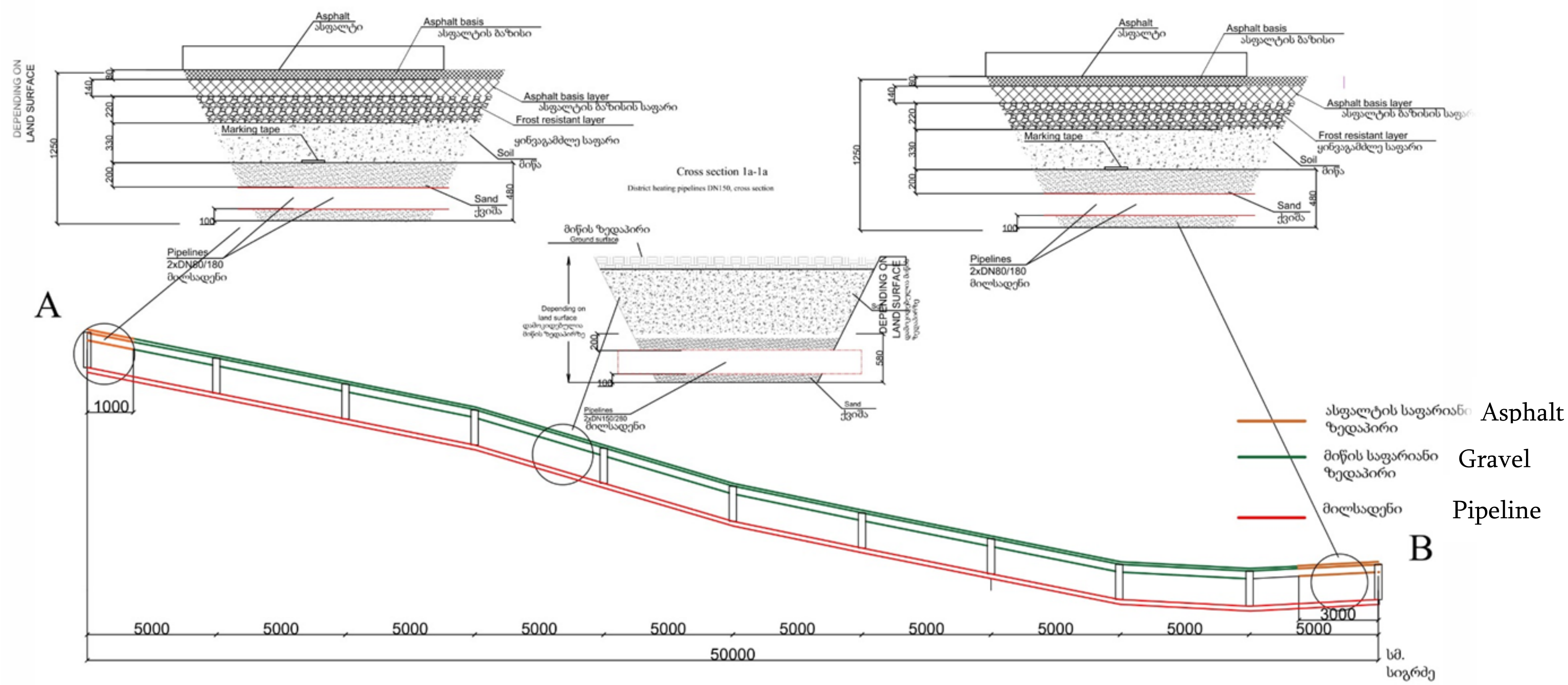






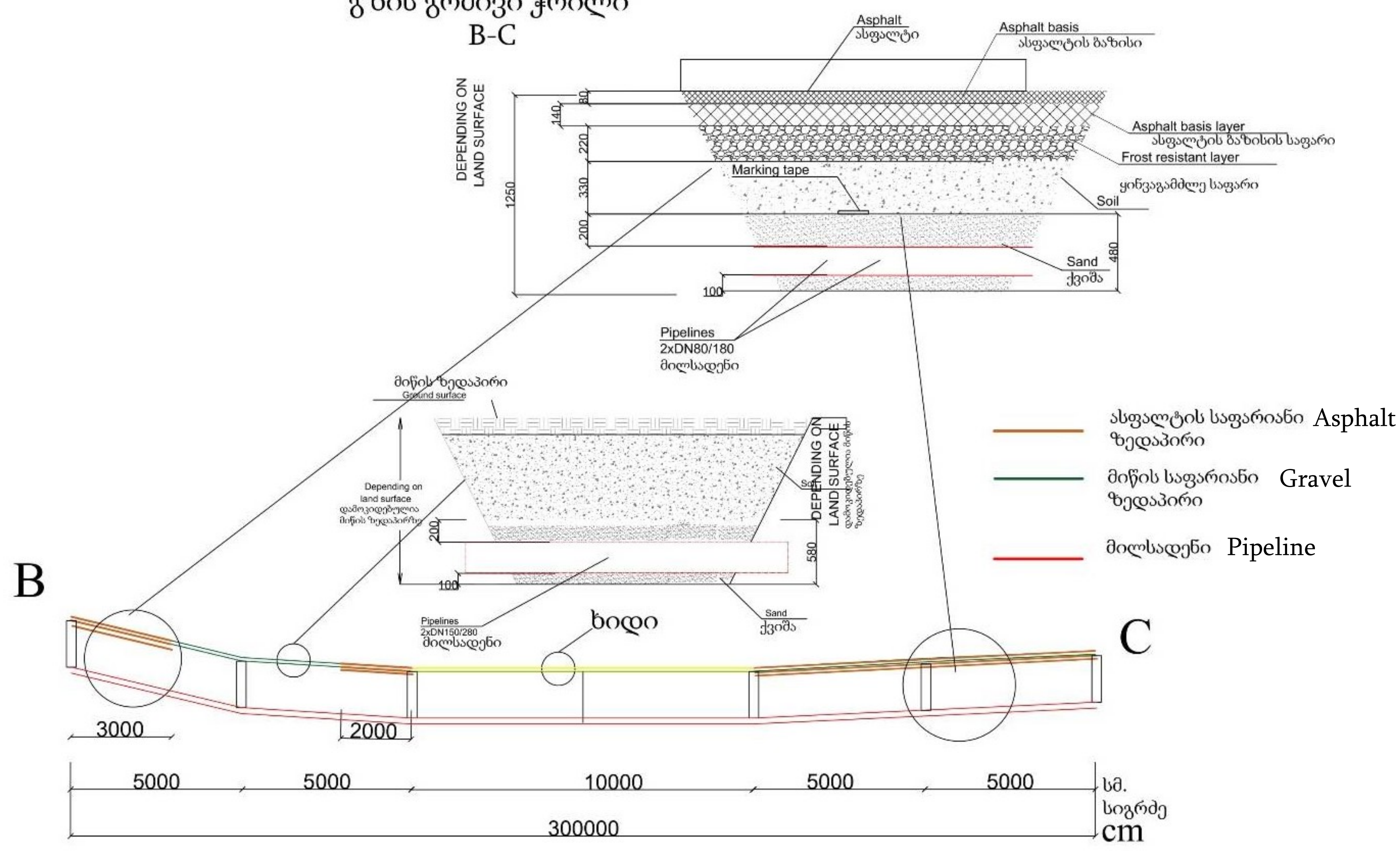
Longitudinal section A-B

გზის გრძივი ჭრილი
A-B



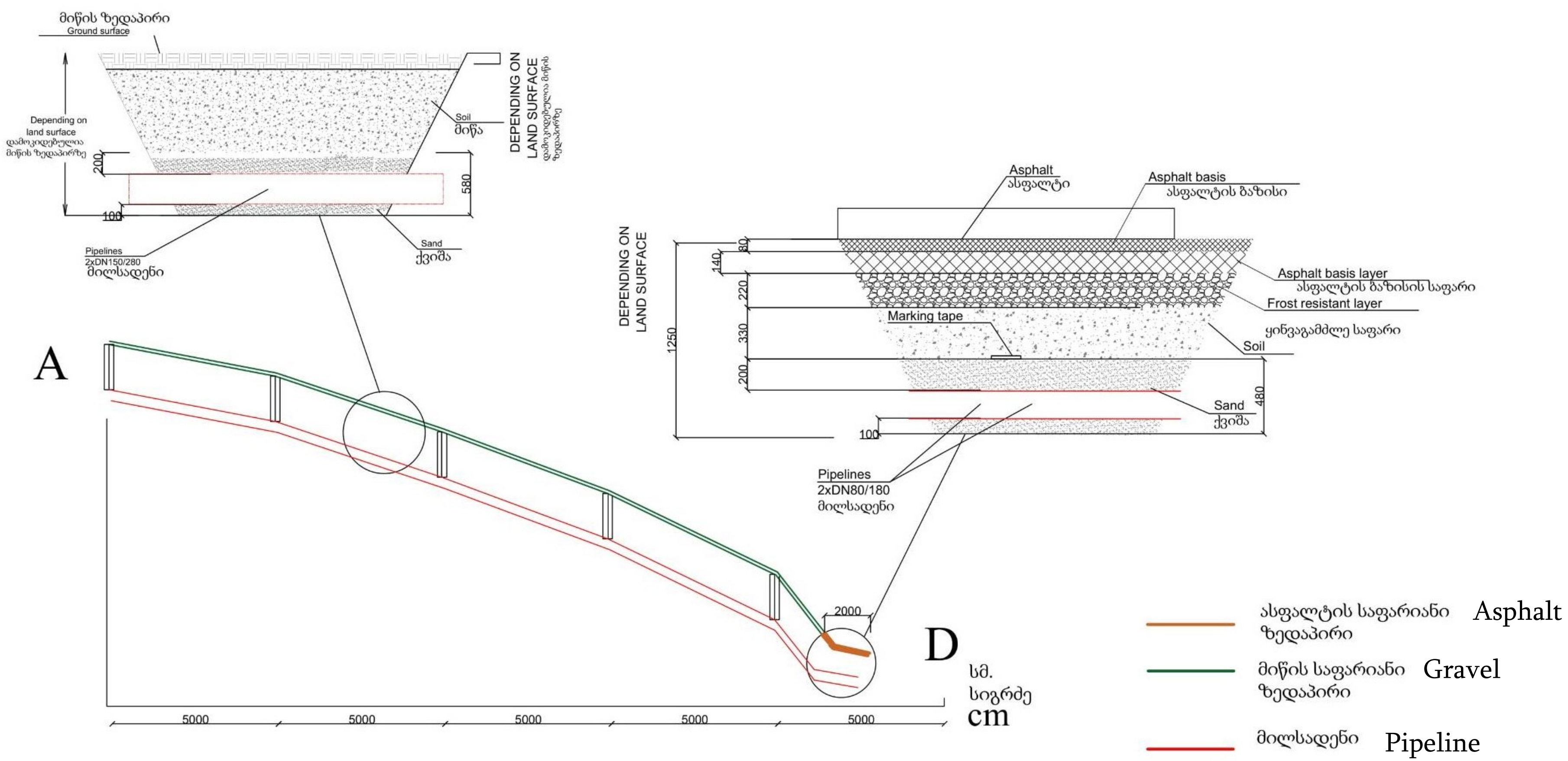
Longitudinal section B-C

გზის გრძივი ჭრილი B-C



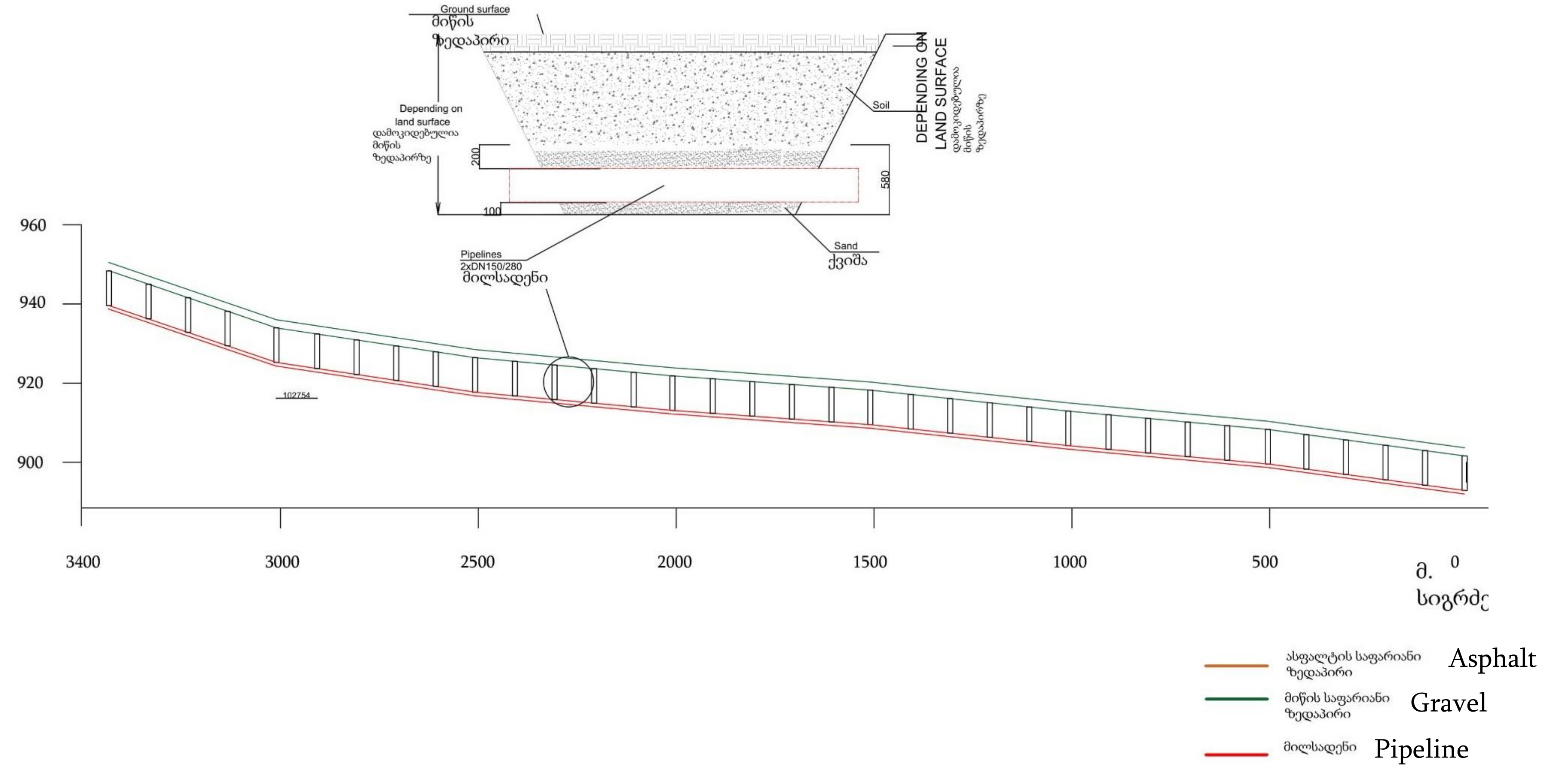
Longitudinal section A- D

გზის გრძივი ჭრილი A-D



Longitudinal section A- E

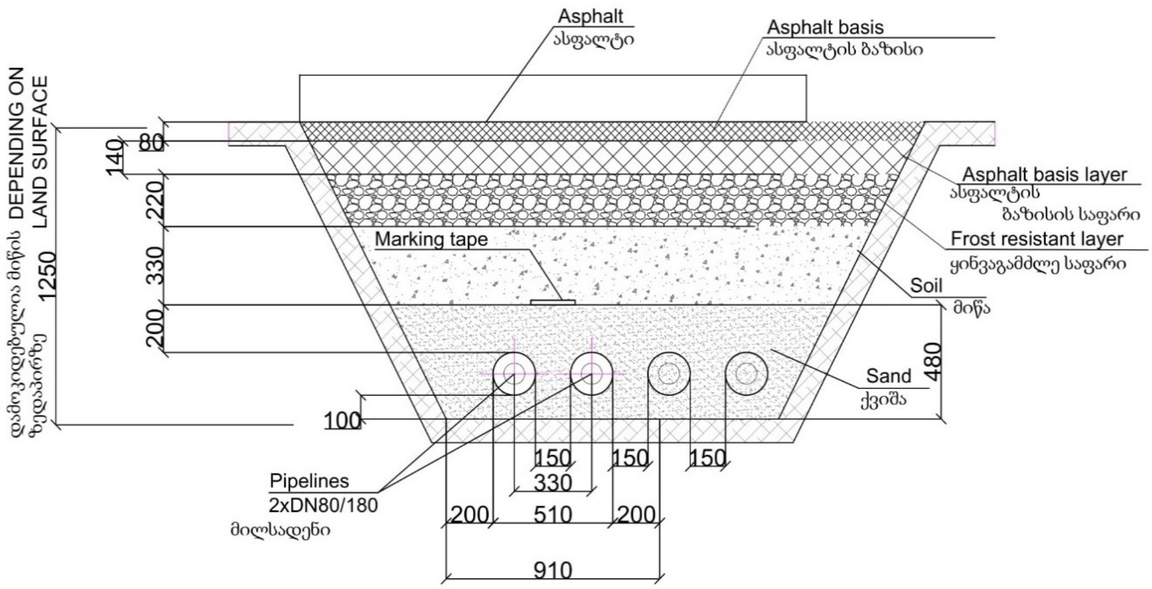
გზის გრძივი ჭრილი
A-E



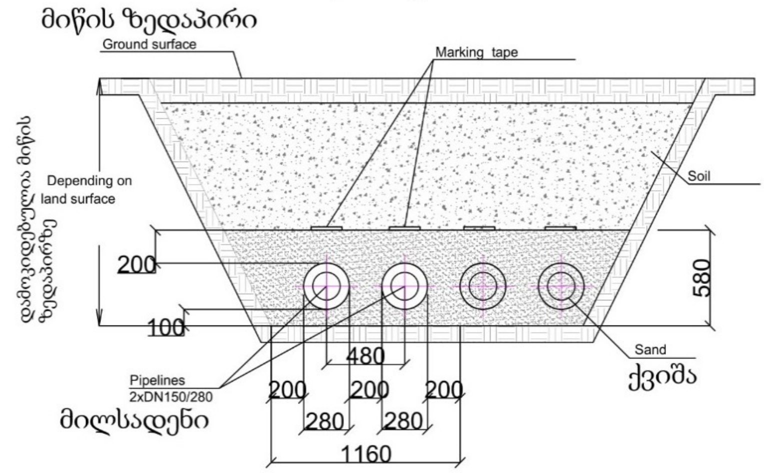
Cross section

გზის განივი ჭრილი

ასფალტის საფარით

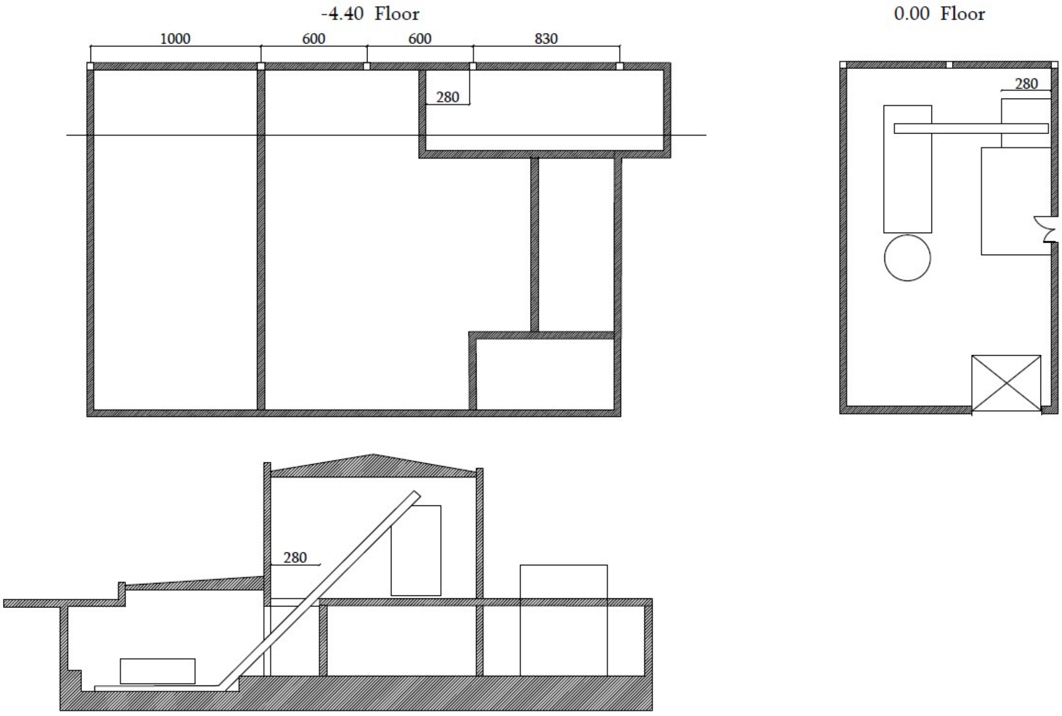


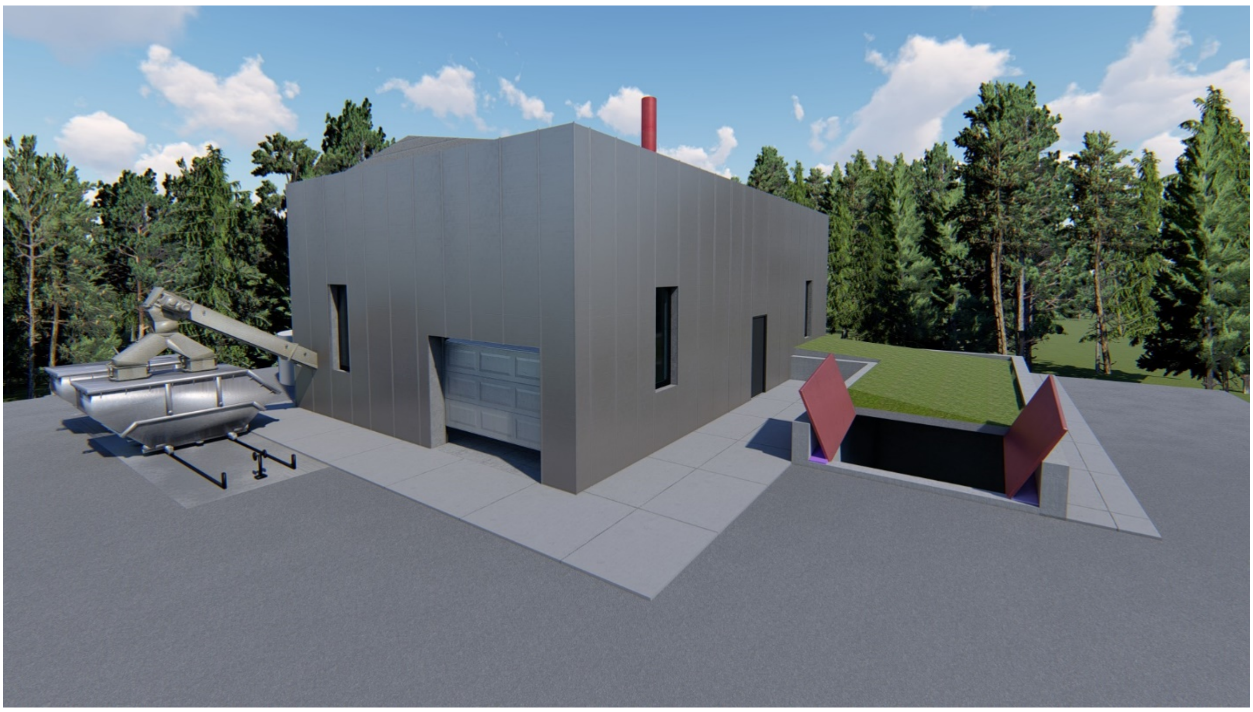
მიწის საფარით

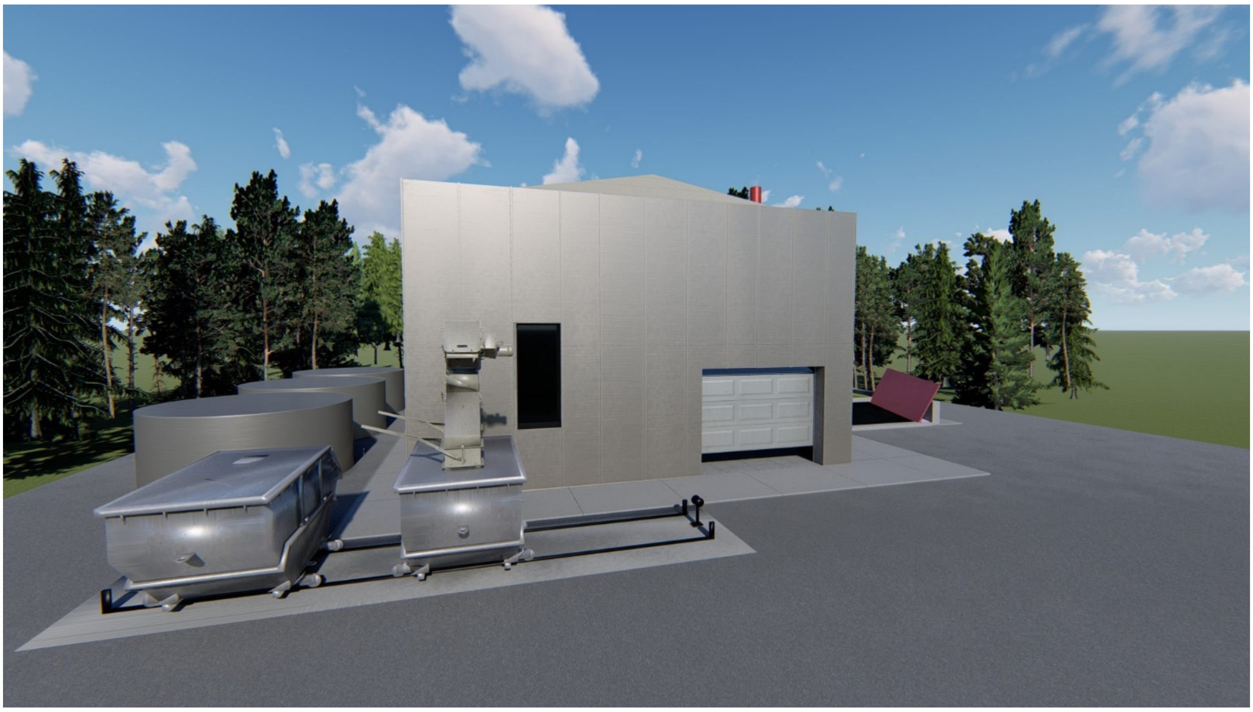


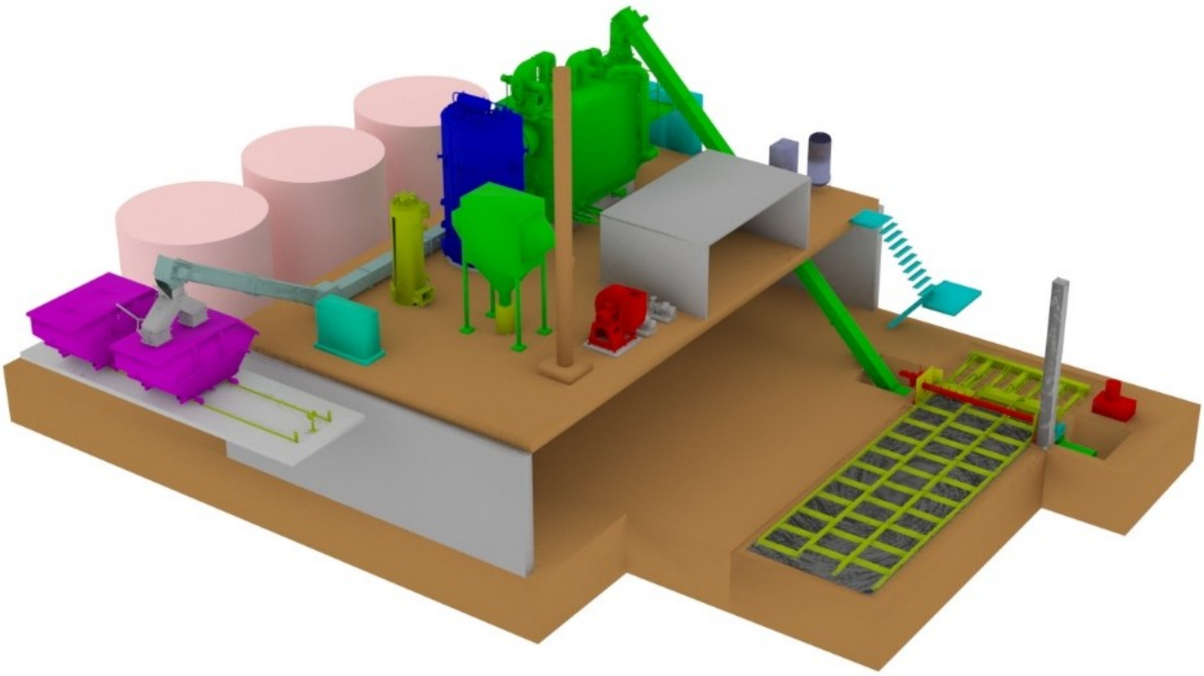
ენერგოცენტრალის მოწყობის პრინციპული სქემა

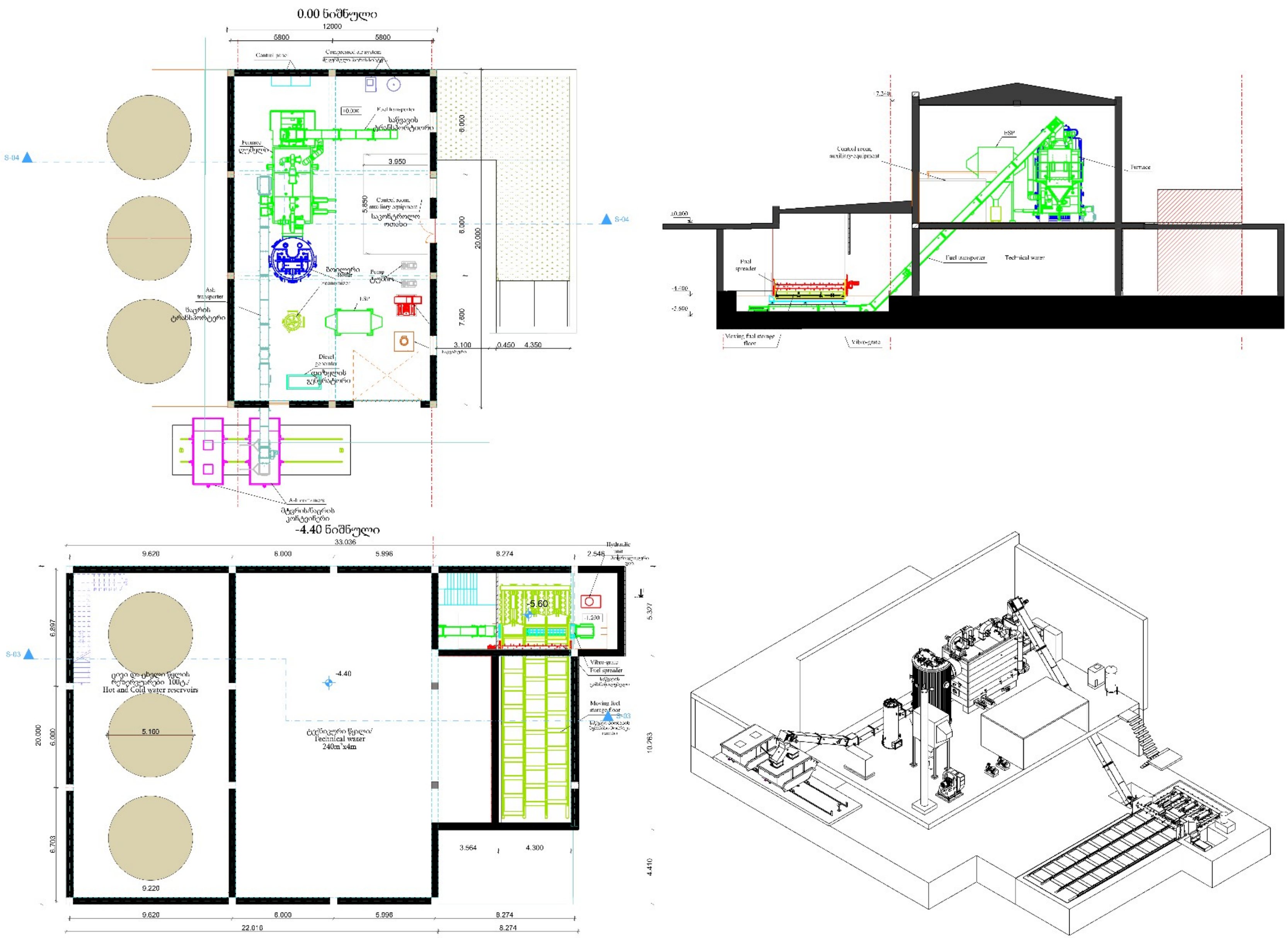
Principal scheme of energy station arrangement



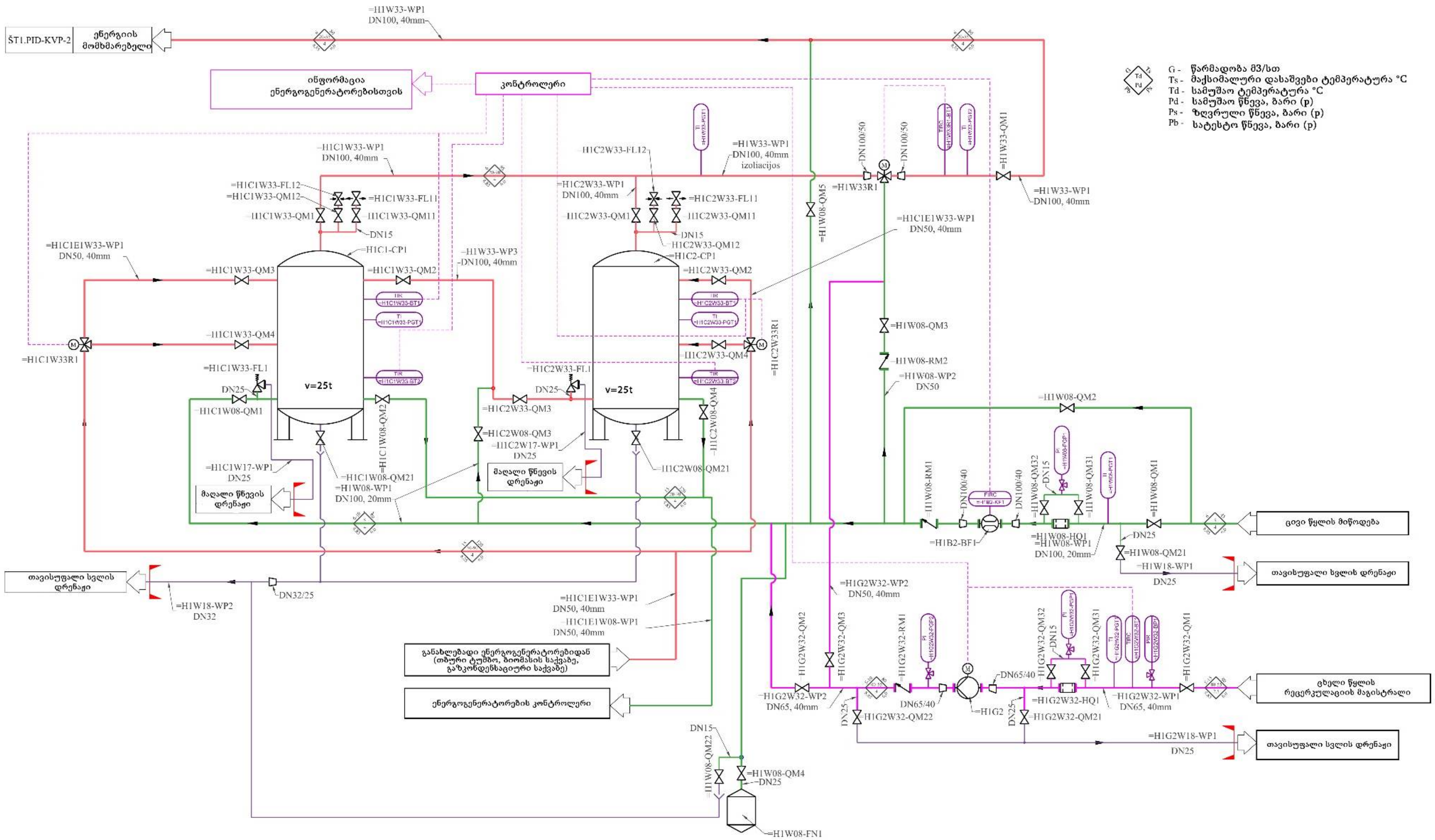








ენერგოცენტრალის ტექნიკური მოდელი
Technical model of Energy Station



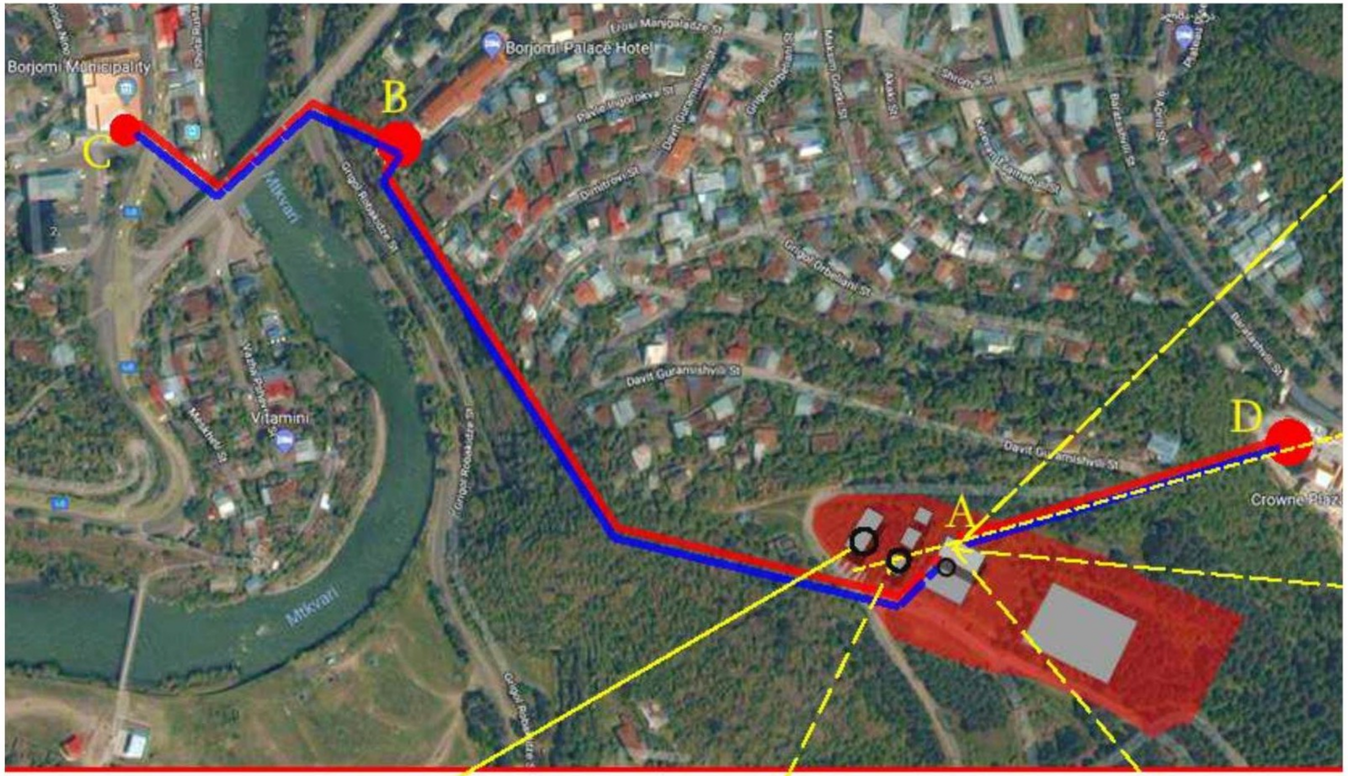
ბუფერული სადგურების ტექნიკური მოდელი

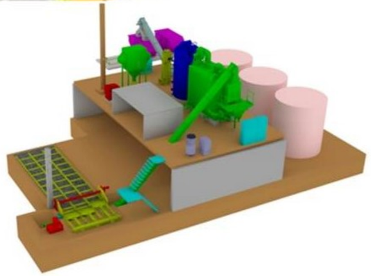
Technical model of Buffer Station

No.	Position	Quantitie	Unit
1	Engineering services	1	Set
2	Zero level preparation	1	Set
3	Demolition of existing networks, leveling	1	Set
4	Construction site preparation	1	Set
5	Technological equipment foundations	1	Set
6	Boiler house building	250	m2
7	Fuel storage building	170	m2
8	Environmental management works	1	Set
9	Hot water boiler, 2 MW	1	Set
10	Biomass furnace	1	Set
11	Biomass supply system, moving floor with hydrocilinder	1	Set
12	Biomass supply system, biomass crusher	1	Set
13	Biomass supply system, feeder to the furnace	1	Set
14	Biomass supply system, transporters	30	m
15	Ash removal system	1	Set
16	Equipment mounting works	1	Set
17	Flue gas removal system	1	Set
18	Fule gas treatment system	1	Set
19	Flue gas condenser	1	Set
20	Chimney	1	Set
21	Hot water pipelines system	1	Set
22	Compressed air system	1	Set
23	Furnace cooling system	1	Set
24	Other tanks, pressure tanks, headings and etc.	1	Set
25	Other minor equipment, pumps, heat exchanger, armature, valves, metering equipment and etc.	1	Set
26	Water pipelines network	1	Set
27	Waste water pipelines network	1	Set
28	Storm water pipeline network	1	Set
29	Heating, ventilating and air conditioning	1	Set
30	Isolating of the pipelines	1	Set
31	Electricity and automation systems	1	Set
32	Startup works	1	Set
33	Rent of construction equipment, crane, wagon and etc.	1	Set
34	Service areas for equipment, supports, technological metal constructions	10	tones
35	Project management services	1	Set
36	Reports and test protocols	1	Set
Total			

შესასრულებელ სამუშაოთა ნუსხა

List of Works





ადმინისტრაციული შენობა ლაბორატორიით

საცხოვრებელი კოტეჯები პერსონალისთვის

საბოილერო

Annex #3: Operating and Maintenance expenses (OPEX)

The operational and maintenance expenditures for a renewable energy plant may be divided into four subcategories:

1. Variable Operational Costs

These are costs related to consumables, electricity consumption, disposal of residues, etc. that are directly linked to the amount of fuel used and the amount of energy produced.

Variable operational costs of the project are as follows:

Expenses	Unit	Cost $
Power	kWh	0.0857
Biomass	Cubic meter	2.8571
Biomass collection, production and transportation	Cubic meter	11.0000
Water	Cubic meter	0.0816
Water and energy supply costs	Cubic meter	0.970684221

Variable operational costs for production of 1 MW (80% thermal and 20% power) energy equals to 22.24 USD.

2. Variable Maintenance Costs

These are costs related to the maintenance of process equipment, such as fuel handling, boiler, turbine/generator, flue gas treatment, etc. They depend, to a certain extent, on the amount of fuel used and the amount of energy produced.

The costs may be averaged over the plant lifetime, but, in practice, costs will vary from one year to the other. The annual maintenance cost has substantial variations over the plant life. During the first few years, some of the equipment will still have to be repaired, or even exchanged under the contractor's guarantee. During the plant life, some years will show considerable maintenance costs for major repairs or equipment refurbishment but compensated by less-than average costs in other years.

These costs do not include the salary, etc., for the plant's in-house maintenance personnel, which is usually accounted for together with the plant's other staff. A large plant will normally have in-house staff with the skills to deal with all or most day-to-day maintenance requirements. A smaller plant typically will have less in-house capabilities and therefore will depend more on outside contractors and service companies.

Due to the difficulty of forecasting variable maintenance costs, these were calculated together with fixed maintenance costs. Sum of these two operational costs equals 2% of the capital invested in the project (CAPEX).

3. Fixed Operational Costs

These costs are related to operational costs independent of the amount of fuel used and the amount of energy produced, for example, salaries, insurance costs, electricity consumption for lighting, ventilation and other consumption linked to non-process equipment.

Fixed operational costs are divided into the following categories:

1. Staff (5 employees) wages - 29 388 $/year
2. Property tax (1%) – 96 582 $/year

3. Power consumption - 8 000 $/y

4. Fixed maintenance costs

These costs are related to maintenance of non-process equipment, which needs to be maintained independently of the amount of fuel used and the amount of energy produced, such as buildings and roads.

Given costs were calculated together with Variable Maintenance Costs. Sum of these two maintenance costs equals 2% of the capital invested in the project (CAPEX).

Annex #4: Loan amortization schedule

Inputs

Loan Amount	$ 2 760 960
Annual Interest Rate	1.00%
Term of Loan in Years	50
First Payment Date	15.01.2030
Frequency of Payment	Annually

Summary

Rate (per period)	1.000%
Payment (per period)	$84 086.69
Total Payments	$3 363 456.46
Total Interest	$602 468.46
Interest Savings	$39.05

No.	Due Date	Payment Due	Additional Payment	Interest	Principal	Balance
						$2 760 960.00
1	15.01.2030	84 086.69	0.00	27 609.60	56 477.09	2 704 482.91
2	15.01.2031	84 086.69	0.00	27 044.83	57 041.86	2 647 441.05
3	15.01.2032	84 086.69	0.00	26 474.41	57 612.28	2 589 828.77
4	15.01.2033	84 086.69	0.00	25 898.29	58 188.40	2 531 640.37
5	15.01.2034	84 086.69	0.00	25 316.40	58 770.29	2 472 870.08
6	15.01.2035	84 086.69	0.00	24 728.70	59 357.99	2 413 512.09
7	15.01.2036	84 086.69	0.00	24 135.12	59 951.57	2 353 560.52
8	15.01.2037	84 086.69	0.00	23 535.61	60 551.08	2 293 009.44
9	15.01.2038	84 086.69	0.00	22 930.09	61 156.60	2 231 852.84
10	15.01.2039	84 086.69	0.00	22 318.53	61 768.16	2 170 084.68
11	15.01.2040	84 086.69	0.00	21 700.85	62 385.84	2 107 698.84
12	15.01.2041	84 086.69	0.00	21 076.99	63 009.70	2 044 689.14
13	15.01.2042	84 086.69	1.00	20 446.89	63 640.80	1 981 048.34
14	15.01.2043	84 086.69	2.00	19 810.48	64 278.21	1 916 770.13
15	15.01.2044	84 086.69	3.00	19 167.70	64 921.99	1 851 848.14
16	15.01.2045	84 086.69	4.00	18 518.48	65 572.21	1 786 275.93
17	15.01.2046	84 086.69	5.00	17 862.76	66 228.93	1 720 047.00
18	15.01.2047	84 086.69	6.00	17 200.47	66 892.22	1 653 154.78
19	15.01.2048	84 086.69	7.00	16 531.55	67 562.14	1 585 592.64
20	15.01.2049	84 086.69	8.00	15 855.93	68 238.76	1 517 353.88
21	15.01.2050	84 086.69	9.00	15 173.54	68 922.15	1 448 431.73
22	15.01.2051	84 086.69	10.00	14 484.32	69 612.37	1 378 819.36
23	15.01.2052	84 086.69	11.00	13 788.19	70 309.50	1 308 509.86
24	15.01.2053	84 086.69	12.00	13 085.10	71 013.59	1 237 496.27
25	15.01.2054	84 086.69	13.00	12 374.96	71 724.73	1 165 771.54
26	15.01.2055	84 086.69	14.00	11 657.72	72 442.97	1 093 328.57

27	15.01.2056	84 086.69	15.00	10 933.29	73 168.40	1 020 160.17
28	15.01.2057	84 086.69	16.00	10 201.60	73 901.09	946 259.08
29	15.01.2058	84 086.69	17.00	9 462.59	74 641.10	871 617.98
30	15.01.2059	84 086.69	18.00	8 716.18	75 388.51	796 229.47
31	15.01.2060	84 086.69	19.00	7 962.29	76 143.40	720 086.07
32	15.01.2061	84 086.69	20.00	7 200.86	76 905.83	643 180.24
33	15.01.2062	84 086.69	21.00	6 431.80	77 675.89	565 504.35
34	15.01.2063	84 086.69	22.00	5 655.04	78 453.65	487 050.70
35	15.01.2064	84 086.69	23.00	4 870.51	79 239.18	407 811.52
36	15.01.2065	84 086.69	24.00	4 078.12	80 032.57	327 778.95
37	15.01.2066	84 086.69	25.00	3 277.79	80 833.90	246 945.05
38	15.01.2067	84 086.69	26.00	2 469.45	81 643.24	165 301.81
39	15.01.2068	84 086.69	27.00	1 653.02	82 460.67	82 841.14
40	15.01.2069	83 669.55	28.00	828.41	82 869.14	-28.00

Literature

1. Financing Urban District Energy Systems: Trends and Policy Implications for Portland
2. Biomass, Lectures 2017. Murman Margvelashvili, Gocha Mikiashvili, Zaal Kheladze, Vakhtang Berishvili
3. Converting Biomass to Energy: A Guide for Developers and Investors, 2017 June
4. Field survey of biomass energy potential in Georgia, 2016;
5. Evaluation of the potential waste of forest and agriculture residual biomass in Georgia, 2015;
6. Residual Biomass Energy Potential in Georgia (Cadaster), 2013;
7. Development of long-term (2030 years) energy-efficiency measures to be implemented in the construction sector of Georgia in order to achieve compliance with the requirements of the European Union 2016
8. Georgia's Energy Development Strategy for 2016-2025: http://www.energy.gov.ge/projects/pdf/pages/Sakartvelos%20Energetikis%20Ganvitarebis%20Strategia%2020172026%20Bunebrivi%20Gazis%20Natsili%201637%20geo.pdf
   and
   http://www.energy.gov.ge/projects/pdf/pages/Sakartvelos%20Energetikis%20Ganvitarebis%20Strategia%2020172026%20Bunebrivi%20Gazis%20Natsili%201637%20geo.pdf
9. Efficient systems and renewable energies, Technology and Energy Panel, Federation of German Heating Industry: http://www.bdh-koeln.de/fileadmin/user_upload/Publikationen/Efficient%20systems%20and%20renewable%20energies%202015.pdf