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REGULATORY IMPACT ASSESSMENT ON HIGH MOUNTAINOUS REGION DESIGNATION OF ENERGY DEVELOPMENT AND ACCESS

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ABSTRACT

Ensuring that energy security, equity, and environmental sustainability in the mountainous regions of Georgia play a crucial role in the country's regional development.

This Regulatory Impact Assessment (RIA) examines different policy options to help solve the energy trilemma in mountainous regions, where most villages do not have access to natural gas. Various alternative energy sources have been considered for Households (HH), alongside different support schemes such as grants, loan interest rate subsidies, and lump sum payments for adopting alternative energy sources.

Grants to socially vulnerable HHs and interest rate subsidies are considered to be the most viable support schemes for the implementation of alternative energy sources in Georgia's mountainous regions.

ACRONYMS

AC	Alternating Current
APA	
BOS	Balance-Of-System
CENN	Caucasus Environmental NGO Network
CO_2	Carbon Dioxide
DC	Direct Current
DNI	Direct Normal Irradiance
EECG	Energy Efficiency Center Georgia
EU	European Union
GDP	Gross Domestic Product
GEDF	Georgian Energy Development Fund
GEL	Georgian Lari
GEOSTAT	National Statistics Office of Georgia
GGTC	Georgian Gas Transportation Company
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiance
GNERC	Georgian National Energy and Water Supply Regulatory Impact Assessment
GOGC	Georgian Oil and Gas Corporation
GWh	Gigawatt Hour
ha	Hectare
HH	Household
HPP	Hydro Power Plant
ICC	Information and Consultation Center
ISET-PI	International School of Economics-Policy Institute
kg	Kilogram
ktoe	Kilotonne of Oil Equivalent
kW	Kilowatt
kWh	Kilowatt Hour
kWp	Kilowatt Peak
LEPL	Legal Entity of the Public Law
LPG	Liquefied Petroleum Gas
m^3	Cubic Meter
MEPA	Ministry of Environmental Protection and Agriculture of Georgia
MJ	Megajoule
mln	Million
MoESD	Ministry of Economy and Sustainable Development of Georgia
MRDI	Ministry of Regional Development and Infrastructure of Georgia
MW	Megawatt
NFA	National Forestry Agency
NGO	Non-Governmental Organization
NPV	Net Present Value
O&M	Operations and Maintenance
PPP	Public-Private Partnership
PV	Photovoltaic

RIA	Regulatory Impact Assessment
SDG	Sustainable Development Goal
SSA	Social Service Agency
TBD	To Be Determined
TJ	Terajoule
TSA	Targeted Social Assistance
UNDP	United Nations Development Program
USAID	United States Agency for International Development
USD	United States Dollar
WEG	World Experience for Georgia

CONTENTS

1. EXECUTIVE SUMMARY

The Law of Georgia on Energy and Water Supply, adopted in December 2019, envisages certain general provisions concerning vulnerable customers. The Law states that the Georgian government and local government bodies, in consultation with other interested parties, shall develop special programs / measures / benefits to ensure the supply of electricity and natural gas for vulnerable customers. However, the provisions of the law do not specify the form of the support programs or the measures to be taken in protecting such customers.

Currently, from a policy perspective, there is neither a clear general long-term energy strategy nor individual strategies for municipalities. Moreover, there is no uniform policy to ensure energy access to the high mountainous regions, and certain mountainous municipalities are treated differently than others. For instance, residents permanently living in some villages of the Kazbegi and Dusheti municipalities received $700m^3$ of free gas per month (between 1 December 2019 and 15 May 2020 and from 15 October 2020 to 30 November 2020) (the State Law of Georgia, 2020). Consequently, such policies have to take into account the local context, fairness, and the equal treatment of each mountainous municipality.

Weak execution of the law is yet another challenge. In this case, the main problem relates to lacking a system for the effective collection of utility payments in particular regions (e.g. in Svaneti). Weak execution of the law, as a result, leads to an inefficient utilization of resources. Whereas from the legal perspective, the main challenges lie within the protection of customers, especially the vulnerable.

In order to ensure access to affordable, reliable, sustainable, and modern energy for communities in mountainous regions, the general objectives of governmental intervention are to:

1. Ensure energy security in the mountainous regions of Georgia;
2. Ensure affordability of energy to all existing and potential users in mountainous regions;
3. Ensure environmental sustainability and reduced CO_2 emissions;
4. Ensure compliance with European Union (EU) Directives and the 2030 Agenda for sustainable development.

A number of specific and operational objectives are further associated with the general targets listed above. These specific objectives include:

- The development of a reliable energy infrastructure, through the adoption of modern technologies in the utilization of alternative energy sources;
- The introduction of new economic instruments for reliable, affordable, and sustainable access to energy;
- A redesign of the energy subsidy programs currently implemented in mountainous regions;
- The implementation of awareness raising activities on alternative energy sources and respective modern technologies.

This RIA considers three potential options for attaining the abovementioned objectives:

- Maintaining the status quo, where nothing is changed;
- The provision of grants and interest rate subsidies for Households (HHs) in mountainous regions;
- The provision of lump sum payments to HHs in mountainous regions.

In each option, the relevant alternative energy sources for the various mountainous regions were selected based on their potential availability (solar, biomass, etc.).

The results of the multicriteria analysis are presented below:

Evaluation Criteria	Option 1. Grants and interest rate subsidies for HHs in mountainous regions	Option 2. Lump sum payments to HHs in mountainous regions
Net Present Value (NPV) of net benefits (Georgian Lari (GEL))	109,496,029	146,644,235
Increased energy security	+	+
Increased access to energy	+	+
Affordability of energy source	++	+
Environmental sustainability and reduction in CO_2 emissions	++	++

Evaluation Criteria	Option 1. Grants and interest rate subsidies for HHs in mountainous regions	Option 2. Lump sum payments to HHs in mountainous regions
Compliance with the EU directives	++	+
Feasibility/ease of realization	--	-
Mitigated conflict of interests	-	-
Systemic efficiency	+	+
Minimization of risks	+	++
Maximization of potential benefits	++	+

The results of the analysis highlight that the suggested policy options are equivalent to one another and have more benefits than costs, which is reflected in the positive NPV of net benefits. The final selection for the option therefore depends on the amount of state support to HHs.

In both policy options the current state energy support programs (electricity subsidy and natural gas subsidy) remain in place. However, it is recommended that they be gradually terminated and replaced with natural gas subsidies in the Kazbegi and Dusheti municipalities alongside the suggested policy options.

A sensitivity analysis has also been performed and the results are robust to changes in the discount rate and the adoption rate of technologies.

2. PROCEDURAL ISSUES AND CONSULTATION OF INTERESTED PARTIES

2.1 ORGANIZATION AND TIMING

On 14 February 2020, an inception meeting on the RIA for the designation of energy development and access in high mountainous regions was held between the International School of Economics-Policy Institute (ISET-PI) RIA and the USAID Energy Program teams. During the meeting, the participants agreed on the following issues:

- Problem definition;
- Need for intervention;
- Objective of the assignment;
- Options for analysis.

Particular attention was paid to marginalized groups in the high mountainous regions of Georgia; with the parties defining the two types of marginalized group:

1. Those who have access to natural gas, but cannot afford it;
2. Those who do not have any access to natural gas.

For the purpose of the analysis, it is vital to identify alternative energy sources for villages that do not have an accessible gas supply. Consequently, the RIA team agreed to consider international experiences. Another crucial aspect of the analysis is to consider the monetary benefits associated with increased energy access (e.g. increased number of tourists, increased agricultural production, etc.).

The overall research objective is to identify relevant alternative energy sources for those settlements that do not have access to natural gas and in general to inform energy policy.

Commencing on 17 February 2020, the RIA team started to collect information regarding issues related to energy access in the high mountainous regions of Georgia, as well as to identify the relevant stakeholders.

2.2 CONSULTATION AND EXPERTISE

In order to identify alternative energy sources for specific high mountainous regions and to estimate the potential impact of increased energy access on various stakeholders, the RIA team opted for a wide range of research methods, including but not limited to, a literature review of the existing reports, expert assessments, telephone interviews, and in-depth, face-to-face interviews with the identified stakeholders. Table 1 below presents a comprehensive overview of the stakeholder consultations.

Table 1: A Detailed Summary of Stakeholder Consultations

Interview date	Respondents	Major points of discussion
6 March	The Georgian National Energy and Water Supply Regulatory Commission (GNERC)	During the meeting, the GNERC representatives discussed investment projects on energy access in mountainous regions that are neither financially nor economically viable. Typically, such projects are expensive to implement and, therefore, the costs are reflected in tariffs. According to the GNERC analysis, people largely consume gas for cooking, while they still use wood for heating. Even with an accessible gas supply, people still opt for wood as it is cheaper. If gas consumption is not high enough, the system will not be profitable as gas supply lines require a huge investment, split among many consumers. The main rationale being that the formula which calculates tariffs uses consumption as a denominator, and if consumption is low everybody will automatically have to pay more. The Ministry of Economic and Sustainable Development of Georgia (MoESD) decides which settlements have access to gas. The list of villages requiring a gas supply is defined based on two prerequisites: the population's gas demands alongside other factors like tourism development.

Interview date	Respondents	Major points of discussion
		Specific regions were also discussed during the meeting. More precisely, gas supply lines are already proceeding in Adjara. While, there is also an issue with the collection of payments for electricity in Svaneti, where the local population believe they are entitled to free electricity due to Enguri hydro-power related risks. Regarding the international experience, in many EU countries tariffs remain the same and are not differentiated against, however vulnerable consumers are subsidized in different ways: via monetary payments or certain amounts of free gas. When a tariff is different, it denotes that one segment of the population subsidies another.
9 March	World Experience for Georgia (WEG)	The WEG representative discussed the problems that high mountainous populations face. The major challenge being that people only live in mountains seasonally, with few permanent residents because of the poor living conditions. There is limited access not only to energy, but also to food and hot water. In winter, generally, everything is closed. Access to energy is one of the greatest challenges, particularly access to electricity and heating. For heating, there are two options: wood (biomass) and gas. Creating a gas supply is inefficient in the mountains, thus alternatives should be considered. Regarding wood, according to the new forestry code, social cutting will be restricted and so-called “business yards” will be established.[1] Using this new approach, people are to be allocated vouchers for specific amounts of wood to procure from such yards. The provision of wood for heating may be cheaper than gas, although it is unclear whether mountainous regions have enough resources to meet the wood demand. Another alternative energy source is the use of heat pumps (grid connected, or powered by photovoltaics with a battery storage system). Further emphasis was placed on developing a unified policy for access to energy in high mountainous areas. Through which, direct payments could be given to families to pay for energy access. The amount of payments would most probably differ due to the context and needs of a region. The existence of such a unified support mechanism would lead to less energy consumption. The aim of the policy therefore should be to ensure fair access to energy for everyone using cost-efficient sources. Specific alternative energy sources and their relevance to the regions were further discussed during the meeting. The main benefits relating to increased access to energy are as follows: • Benefits to the tourism sector; • Improvements in social welfare; • Reduced logging; • Reduced emissions; • Increased agricultural production and decreased imports; • Potential population return to the mountains.
11 March	MoESD	The MoESD representative discussed alternative energy sources, such as biomass, and noted that there is no consolidated research document on the potential of various alternative energy sources in Georgia. However, there are separate studies devoted to each alternative and its potential.
11 March	USAID Energy Program	The USAID Energy Program representative discussed the importance of a unified policy to ensure access to energy in the high mountainous regions. There are villages where the local population simply cannot afford to pay for energy and live under poor social conditions, while there are also certain high mountainous villages where local citizens use electricity and gas subsidies to develop businesses.2 This invariably leads to the inefficient energy use. The government should

[1] The forestry code of Georgia (only available in Georgian): https://mepa.gov.ge/Ge/Laws?page=2&pageSize=9
[2] For example, Svaneti inhabitants started cryptocurrency mining and significantly increased their consumption of subsidized electricity.

Interview date	Respondents	Major points of discussion
		then ensure that the population has access to energy and make the relevant investments. The aim of a unified policy should be to: • Ensure equal rights to high mountainous populations; • Ensure increased access to energy; • Reduce energy poverty. International experiences (e.g., in Germany) highlight that countries should employ natural resources and develop local micro hydropower, solar stations, wind turbines, biomass, hybrid stations, each in consideration of the regional potential. It is also vital to increase awareness of energy efficiency. Increased access to energy would support tourism, agricultural production, and economic development, and the population would have greater access to information.
12 March	The Energy Efficiency Center Georgia (EECG)	The EECG representative stated that access to energy is not the main reason why high mountainous villages are uninhabited, with the main driver being poor infrastructure. There is no unified approach or policy relating to energy access in high mountainous regions. When developing a unified policy, each municipality should be involved in the process, as they are better aware of local situations in terms of access to energy. Individual strategies should be developed separately for each municipality to offer a clear idea about the available resource within an area. The government should also only support those who are unable to pay for energy. As for alternative energy sources, a micro grid appears to be the best solution when at least 4-5 households live in close proximity within a village. In addition, NPL-SNG micro distribution channels might also be effective. The data reveals that gas is mostly consumed in the first year after the installation of supply lines. Thereafter, consumption decreases due to high costs, and households substitute gas for wood. Essentially, people prefer the cheapest options. According to the EECG, energy cooperatives should be established as cooperation helps integration. One major benefit associated with increased energy access is that fewer people will leave their villages; they might create a business, start to produce local cheese, or enter into another micro-factory. Energy access is ultimately a pre-condition for business development.
13 March	The National Forestry Agency (NFA), Ministry of Environmental Protection and Agriculture of Georgia (MEPA)	The NFA representative emphasized that the share of wood in Georgia's energy balance is high,3 and forest resources are being exhausted. There are regions that are extremely rich in forests, yet it is unsustainable to use woodlands for heating demands. Besides which, the prevalence of illegal logging is very high. Wood should only be considered as an alternative to gas in certain settlements, and not across the entire country, or eventually obtaining wood will become problematic. To be sustainable, the number of logged woodlands should be less than 300 ths. cubic meters annually. The levels of forest resources are rich in Racha-Lechkhumi and Kvemo Svaneti – moderate in Guria, Imereti, Kakheti, Mtskheta-Mtianeti, Samegrelo-Zemo Svaneti, and Shida Kartli – and they are low in Ajara, Kvemo Kartli, and Samtskhe-Javakheti.
16 March	Georgian Oil and Gas Corporation (GOGC)	During the meeting with GOGC, the current policy related to energy access in high mountainous areas was discussed. The representative claimed there is a need for a unified policy. The main objective of such a policy should be to provide energy access with cost-effective methods. Everyone should pay for energy, with no exemptions. The Georgian government can offer direct payments to households in

[3] The share of wood in total energy consumption is up to 29.9% (GeoStat, Energy consumption in households survey, 2017).

Interview date	Respondents	Major points of discussion
		areas where people do not currently pay for gas or receive large amounts of free gas. This would make households consume energy more efficiently. Besides which, providing electricity or gas is not cost-effective in the mountainous regions of Georgia, and such areas require local energy sources, such as micro hydropower plants.
16 March	The Ministry of Regional Development and Infrastructure of Georgia (MRDI)	According to the MRDI, electricity is available almost everywhere,[4] whereas gas supplies are not always feasible due to geographical restrictions. In settlements 1,500 meters above sea level, it is technically difficult to provide a gas supply. The objective of the Law on High Mountainous Regions is to create equal opportunities for everyone. The MRDI representative placed special emphasis on the definition of high mountainous regions; according to the law, only settlements 1,500 meters over sea level are considered as such. While settlements between 800-1,000 and 1,000-1,500 meters above sea level may receive the status if they satisfy specific criteria. As of today, there are 1,739 mountainous settlements, including historic places. When selecting alternative energy sources it is important to consider options that can serve potential increasing demand in a region. If a region develops, demand for energy will correspondingly increase. Moreover, some energy sources require maintenance and thus the bodies responsible for sustaining energy sources should be further defined. Moreover, access to energy creates jobs, allows people to stay in the mountains, and contributes to sustainable development and production. It promotes tourism development and has a positive environmental impact.
16 March	The Energy Policy and Investment Projects Department, MoESD	There are settlements with no access to electricity where it is very difficult to develop the infrastructure. One solution is to develop micro hydropower plants that can serve a few villages. The policy should be developed considering the characteristics of specific municipalities. On the one hand, people want access to energy, but they may also protest the building of micro hydropower stations. Consequently, there is the need for awareness raising campaigns in such areas. Another reliable solution are off-grid projects; every village would have its own energy source which the local population could maintain, or risk being left without access to energy.
24 March	The Georgian Energy Development Fund (GEDF)	The importance of an integrated, unified policy for energy access in high mountainous villages was discussed during the meeting with the GEDF. The main objective of such a policy should be as follows: 1. Ensure that 100% of the population has access to energy; 2. Energy should be affordable for everybody. If a tariff is expensive, due to high installation costs, the government should have an approach to compensate that tariff. There is a lack of research on alternative energy sources and their potential in Georgia. The representative mentioned energy sources that are relevant for specific regions; for example, biomass is pertinent in Adjara and Svaneti, while micro hydro powers should be considered for regions where solar panels are not appropriate. Mr. Chikovani further posed the key question of who will finance such initiatives: the government, the private sector, or the local population? The GEDF representative suggested that the most efficient method was direct payments for the population unable to afford high energy tariffs. Another option is to pay distribution companies or to subsidize the tariff, however this proves to be less efficient than direct payments.
24 March	The Department of Energy Reforms and International	The related issues are regulated by the Law on High Mountainous Regions, under the competency of the Ministry of Regional Development and Infrastructure of Georgia. A social agency is

[4] Approximately 99% of Georgian population has access to electricity and 68% to gas (WEG, 2018).

Interview date	Respondents	Major points of discussion
	Relations, MoESD	responsible for supporting the population with access to energy but who are unable to afford the fees. International experience shows that the most relevant and efficient way to provide energy to high mountainous regions is to use local resources; whether solar, biomass, micro hydropower, or other renewable energy sources. The development of renewable energy sources not only supports the production of green energy, but it would also support the Paris Agreement and Georgia's obligations with the EU.5 Every country has a coefficient that calculates how renewable energy projects can reduce emissions. The use of local renewable energy sources will therefore also help to overcome ecological problems.
6 April	The Georgian Gas Transmission Company (GGTC)	GGTC is a government-owned company, under the management of the MoESD, responsible for transporting natural gas across Georgia in line with new Law on Energy and Water Supply. The MoESD provides an order for a project and sends the list of villages to be covered by the GGTC supply. The organization estimates the cost of the project based on the regulations, installation procedures, the safe operation of power facilities, and the equipment and installation fees. Thereafter, the GGTC announces a tender and the winning company implements the project. The GGTC representative emphasized the importance of identifying and estimating the costs of providing alternative energy sources to high mountainous villages with small populations (with, at times, only 2-3 people living in the area), as it is simply illogical to provide gas to such villages due to the lack of infrastructure and high installation costs.
8 April	Elektra LLC	In terms of access to electricity, Elektra LLC claim that the main challenge to the high mountainous regions is that the areas are weakly interconnected to the main network, and local networks are not well-developed. At one point in Svaneti, the demand for electricity increased due to the cryptocurrency hype, however the distribution network did not have enough capacity and it was necessary to set limits on electricity. In order to ensure that high mountainous regions have access to energy, it is important to involve the private sector. For example, Rooms hotels in Kazbegi has promoted the region's development, attracted tourists, and supported local production. Though energy access in itself cannot be the driver for such change. Off-grid projects, those unconnected to the main network, can be reliable alternatives for electricity and gas. Generally, projects that promote energy access in high mountainous areas are not profitable. These types of project should thus be in the form of grants. The government and policy-makers should attempt to attract grant projects to provide access to alternative energy sources for inaccessible areas. When developing a policy to increase energy access, only successful cases have been considered. This gives rise to a survivorship bias, therefore one cannot gauge the whole picture for policies that have failed. Providing energy access to high mountainous areas requires significant financial resources due to the poorly developed infrastructure. There are two approaches to compensate these costs: 1. The cost can be reflected in the tariffs of the whole population, therefore the entire country covers the expense; 2. The costs are carried by the local population (the American approach). A further method to ensure access to energy is in the use of local alternative energy sources. However, at times, this can be related to

[5] In 2015, 196 parties came together under the Paris Agreement to transform development, and they agreed to a long-term goal for adaptation – to increase the ability to adapt to the adverse impacts of climate change, and to foster climate resilience and low greenhouse gas emission development: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

Interview date	Respondents	Major points of discussion
		environmental risks and might cause conflicts of interest. It was further recommended that an online platform be developed to combine all the information and gather every stakeholder related to the topic.
15 May	Energo-Pro Georgia (EPG)	EPG claim that the number of potential subscribers in high mountainous areas is higher than the number of actual subscribers, which is around 80,000-90,000. The share of households with access to natural gas, though which do not consume it (non-active customers), is around 15%. The Law on High Mountainous Regions offers these subscribers 50% subsidies on their energy bills. However, one of the main issues is that even registered subscribers do not pay electricity bills in certain municipalities (e.g., in Svaneti). Besides which, there are some settlements that have never had access to electricity. The Georgian government has been working on increasing access to energy in the regions via alternative energy sources, as building distribution networks in mountainous areas is economically ineffective.

3. PROBLEM DEFINITION

3.1 POLICY CONTEXT

The development of the energy sector and its markets are dependent on various factors, one of which is the protection of consumer rights. Customers suffering from health, mental, or financial problems, or those living in remote areas are particularly important during the design of an energy policy. Inhabitants of high mountainous regions and remote areas are more isolated, and have less access to electricity, natural gas, and services provided by the energy sector. They, moreover, do not always have enough information to exercise their rights effectively and to enjoy the benefits provided by the state. Therefore, it is important to develop and implement special support tools and programs for such customers.

To provide various support schemes to the population (customers), the government should determine rules for the special treatment for certain vulnerable customers. Vulnerability is a complex issue since it is tightly bound to both country policy and the state budget allocated for supporting those customers. While there are no uniform approaches or definitions, there are nevertheless some requirements and internationally recognized standards regarding the provision of energy to vulnerable customers.

3.1.1 REQUIREMENTS UNDER EU LAW

EU legislation focuses on support schemes and instruments that protect customers, especially the vulnerable. Based on an analysis of the international best practice, even developed countries – members of the European Union – and the Energy Community do not maintain the same approaches towards, or definitions of, vulnerable customers.

Protecting vulnerable customers is not only a question of energy policy. Problems and challenges related to this issue need to be addressed in the context of broader social policy; various groups of people are beneficeries of state social support programs and schemes in every country. However, issues related to vulnerable customers are particularly sensitive within the energy sector, as energy can be considered a non-substitional product, is necessary for everybody. Therefore, helping vulnerable costumers should be a key priority within the country's strategy and its policy. Social allowances, provided by the central or local government, should thus directly or indirectly go to the beneficiaries.

Despite the fact that a uniform definition of "vulnerable customers" does not exist in the EU, two main forms of vulnerability exist in practise: i) vulnerability highly connected to the environment and living conditions; and ii) vulnerability highly connected to private and personal characteristics.

According to the EU energy law,[6] countries are obliged to consider the concept of vulnerability and to define vulnerable customers. In general, they use the aforementioned categories to prepare and implement support schemes and take the necessary measures.

Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009, concerning common rules for the internal market in electricity (repealing Directive 2003/54/EC),[7] alongside Direrctive 2009/73/EC concerning the common rules for the internal market in natural gas (repealing Directive 2003/55/EC),[8] encompass the main requirements member states must fulfil, listed as a number of obligations (rights and functions) regarding both energy markets and customers.

Directives 2009/72/EC[9] and 2009/73/EC[10] do not outline the definition of vulnerable customers, which was previously defined, but envisage certain provisions for their protection to be ensured by member states.

These directives also express that member states shall take appropriate measures to protect the final customer, and, in particular, ensure that there are adequate safeguards to protect vulnerable customers. Consequently, each member state must define the concept of "vulnerable customers";

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[6] https://eur-lex.europa.eu/summary/chapter/18.html
[7] https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32009L0072
[8] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0073
[9] https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32009L0072
[10] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0073

which may refer to energy poverty and, inter alia, to the prohibition of disconnection of electricity to customers during critical times. However, neither “energy poverty” nor “critical times” are defined by the directive and should be specified by the member states themselves, taking into consideration the specificities of each country, their markets, and economical and social conditions. One crucial aspect of this abovementioned provision is therefore the link between energy poverty and vulnerability.

Considering vulnerabilty due to inhabitation of high mountainous areas, EU energy legislation, including the Third Energy Package (adopted in 2009, comprised of three directives and two regulations) does not specify vulnerability or access to energy in mountainous regions, however, the partice and the legal framework within the European Union and Energy Community Contracting Parties highlight that vulnerability is very much related to living conditions and residing area, as previously mentioned.

Considering the EU requirements and the Third Energy Package, the new Forth Energy Package, known as the “Clean Energy Package”, should be also mentioned. After the adoption of the Third Energy Package, work on the next package commenced, and the new Clean Energy Package was adopted in 2019. The main objecitves of this package are to support the utilization of renewable energy sources, improve energy efficiency, protect customers, and to ensure digitalization in the energy sector. Tendency predicts that much more attention will be paid to protecting customers, particularly considering the importance of customer protection and the relevant threats (in terms of cybersecurity, digitalisation, scarcity of resources, etc.).

The aforementioned Third Energy Package and EU requirements also apply to Georgia. These obligations to transpose EU directives and regulations (including standards and mechanisms) relate to the international agreements concluded between EU and Georgia. The two main documents, the Association Agreement and the Accession Protocol,[11] also then need to be considered. In 2014, the Association Agreement was signed between the European Union and Georgia (which fully entered into force on 1 July 2016). While in 2016, the Accession Protocol was signed, according to which Georgia became a full member of the Energy Community (responsible for energy issues and one of the most important institutions in the EU). Pursuant to these two core documents, Georgia is currently obliged to harmonize its legislation with the EU energy acquis.

Based on the obligations imposed by EU legislation, Georgia has started its transposition process and reforms are being implemented for that purpose. Completely new mechanisms and tools are to be introduced into the energy sector for protecting vulnerable customers, however, the current Georgian legislation envisages certain supporting schemes that may be revised and improved.

3.1.2 GEORGIAN LEGISLATION

The Law of Georgia on Energy and Water Supply, adopted in December 2019,[12] envisages some general provisions concerning vulnerable customers. The Law maintains that a vulnerable customer, in accordance with the applicable legal acts, is a household consumer that due to social status and/or health condition is recognized by the competent national authority of Georgia as being vulnerable; for whom the right to use electricity and natural gas is granted under special conditions in accordance with the provisions of this Law.

Another more specific provision with the view of protecting vulnerable customers affirms that the state and local government bodies, in consultation with other interested parties, will develop special programs/measures/benefits to ensure the demand for electricity and natural gas, and/or increasing access, and will define the respective vulnerable customers who can benefit. However, this Article does not specify what type of support program or measure may be taken to protect vulnerable customers. These issues will be further described by secondary legal acts that are to be developed and approved by the Georgian government.

Based on the Law of Georgia on Energy and Water Supply, the government together with the main stakeholders –GNERC, the Social Service Agency (SSA), the corresponding Ministries, and the distribution companies – have started working on this secondary legislation. The first draft of the government’s resolution comprises a definition for vulnerable customers and the criteria for receiving future state benefits and support schemes. However, the working process has not yet been completed and some political decisions are to be made before its adoption and further implementation.

[11] https://www.energy-community.org/dam/jcr:71db75bd-ba91-4e54-8aa1-16ecb8f68d51/PRO_2016_MC_Georgia.pdf
[12] https://matsne.gov.ge/document/view/23098?publication=13

Nevertheless, before the latest primary and secondary legal acts determine the new approaches and the mechanisms or programs for protecting customers, the existing legislation offers the possibility of providing energy customers, especially the vulnerable, both economic and non-economic support.

Other relevant laws and programs are listed below:

- The Law of Georgia on Social Assistance,[13] adopted by the Georgian parliament in 2006, envisages certain categories of socially vulnerable persons who are subject to financial support or aid from the government. In 2014, the government also adopted Resolution N758 on Approving the Methodology of Assessment of Social-Economic Conditions of Socially Unprotected Families (households), in which certain families are recognized as unprotected and are subject to financial support from the government. The resolution provides a formula for calculating the various indexes necessary for making legally justifiable and reasonable decisions regarding support;
- The Law on the Development of High Mountainous Regions, adopted in 2015, aims to determine the benefits of social and economic progress in the mountains. According to the Law, the government, in accordance with Georgian legislation, shall provide social benefits to the populations of high mountainous regions. The government must compensate subscribers (household customers) for 50%, up to 100 kWh, of monthly consumed electricity charges in high mountainous settlements. For the purpose of the Law, a subscriber is a person who permanently resides in a high mountainous region to have signed a contract with the relevant license holder for the provision of electricity;
- The Law of Georgia on Approving the State Budget for 2020, notes that subscribers permanently living in some villages in Kazbegi and Dusheti receive $700m^3$ free gas per month; from 1 December 2019 to 15 May 2020 and from 15 October 2020 to 30 November 2020 (in May and October the volume of gas constitutes $350m^3$ rather than $700m^3$). Between 2010-2019, public expenditure on this program was, on average, 5.1 mln. GEL per annum (the Ministry of Finance, 2020);
- There is a support scheme for villages near the border lines, since 27 December 2017, Decree N2711 offers the population residing near the occupation border line 200 GEL from the state budget during winter for heating purposes;
- The Tbilisi Municipality Program for socially vulnerable residents of Tbilisi subsidizes electricity, cleaning services, and water costs over five months (January, February, March, November, and December). The beneficiaries of this program – socially vulnerable families with a rating score of less than 70,000 – receive 106 GEL per month; while families with a rating over 70,000 but less than 200,000 receive 20 GEL per month;
- According to Article 14 of the Supply and Consumption Rules, approved by GNERC Resolution N20 on 18 September 2008, if a customer has not paid their electricity bill, and disconnection of the supply could cause death, worsening of health conditions, or cause unreasonable costs for the customer, and if the distribution company is aware of these circumstances, they are barred from disconnecting the customer for a maximum of one month.

3.2 PROBLEM DEFINITION

The problems in Georgia's energy sector are often complex and multidimensional. There are notable challenges both on the supply and demand sides. Typically, supply side problems relate to the availability of energy sources and security of the supply. There are also two dimensions to availability: energy quantity and quality. In terms of quantity, 99% of the country is electrified, but some rural areas suffer from limited access to energy. While as of today, 973 villages in the high mountainous regions do not have access to natural gas. There are moreover various challenges related to the quality of the energy sources (the ability of a unit of energy to produce goods and services), as well as the reliability of resources and technologies. Given the local population's notable dependence on wood and the limited use of modern technologies, energy supplies are still considered to be unreliable.

[13] https://matsne.gov.ge/document/view/2924386?publication=3

From the demand side, the dimensions of affordability and acceptability have to be considered. Affordability concerns the ability of the population to pay for energy, whereas acceptability relates to perceptions about various energy sources and the need for capacity building. A part of the population is currently supported by state social transfers; the elderly, people with disabilities, etc., each represent vulnerable groups that struggle to afford energy costs. Therefore, there are clear issues regarding affordability in the energy sector. While regarding acceptability, it is noteworthy that knowledge of alternative energy sources (the utilization of biomass, solar panels, etc.) is relatively limited and requires capacity building interventions.

In light of the challenges, in order to increase the availability of energy in mountainous regions, it is vital to identify viable, cost-efficient alternative energy sources. Equally, given the inability of vulnerable customers to pay for energy, it is essential to discern policy recommendations and support schemes that are directed at increasing the affordability of energy for those customers.

The nature of energy

Widespread energy poverty leaves people in darkness, with poor health, and missed opportunities. Thus, energy security is emphasized by the UN Sustainable Development Goals (SDGs), with energy poverty a threat to achieving sustainable development, SDG 17 in particular.

Energy security has become increasingly more important, with energy becoming crucial to all aspects of modern life (Mineli, 2017). Studies show that the "heat or eat" dilemma is a common trade-off that low-income households face just to meet the basic necessities of life. In certain cases, vulnerable, marginalized groups are forced to decide between food and energy, often sacrificing one for the other (Frank et al., 2006). Energy security has important economic, social, and environmental significance for the country's sustainable development; therefore, any policy must be designed in a way that ensures such security.

The economic benefits of increased energy access in high mountainous areas can be generated via further opportunities for farming (e.g., unused farm resources may be utilized; added-value products can be produced and exported to other regions in order to meet the new local demand in tourism development, etc.). Furthermore, access to energy can create greater opportunities for off-farm diversification (e.g., agro-tourism). The adoption of alternative energy sources can also produce even greater benefits, those particularly notable for households using wood as an energy source for cooking and heating. Residents often have to travel long distances to collect firewood, which leaves little time for additional income generating activities. Consequently, switching to alternative energy sources can increase a household's time endowment as a result of reducing the time required searching for fuel (the opportunity cost of using wood).

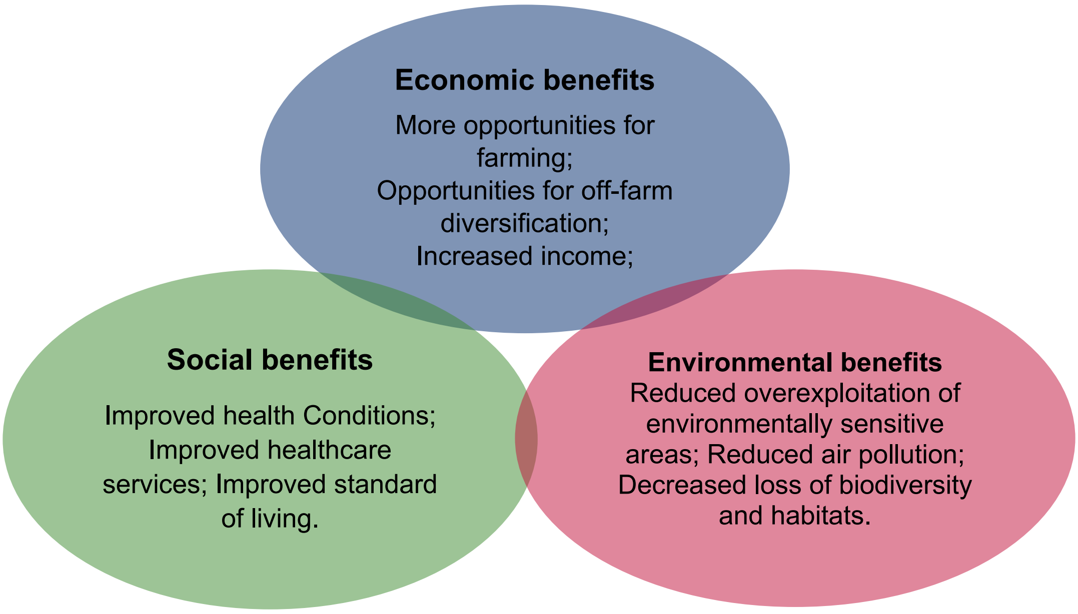
Concerning the social impacts, energy insecurity can also affect health in multiple ways. Firstly, unreliable energy sources lead to low-quality healthcare services within communities (e.g., the potential inability to power emergency medical equipment). Secondly, given that most village households use wood to heat only one room of a house, this may deteriorate a family's health. Residential wood heating can cause substantial air pollution, through either direct exposure or infiltration from the outside. Wood heating is thus associated with serious health conditions, such as respiratory and cardiovascular mortality and morbidity (WTO, 2015). Studies have found that children in homes with moderate and severe energy insecurity are also more inclined to hospitalizations, poorer health ratings, and food insecurity than children in "energy secure" homes (Cook et al., 2008). Therefore, access to alternative energy sources improves the standard of living for households using wood for cooking and heating.

Aside from the economic and social benefits, energy security also has environmental value. The impacts of energy-related hardship are often reflected in the overexploitation of environmentally sensitive areas. Depending on the extent of forest utilization, the negative environmental effects differ by severity and significance; its influence can be critical at the local level or even have global significance. Studies regarding whether forest utilization alters environmental conditions or the environmental functions of forests are often limited. Hence, as most impacts are rather indirect and complex, it is often difficult to prove either the positive or negative influences of forest utilization on the environment (FAO, 2005).

The biggest drawback, and the greatest environmental impact, from wood burning is wood-smoke pollution. While the overuse of wood can also lead to deforestation. Consequently, it cause a degradation of watersheds, and the loss of biodiversity and habitats. Switching to alternative energy sources would thus support the sustainable use of wood.

The various economic, social, and environmental benefits of energy access are summarized below in Figure 1:

Figure 1: Economic, Social, and Environmental Benefits of Increased Energy Access



3.2.1 THE SOCIO-ECONOMIC PERSPECTIVE

Energy security is a particularly important issue for Georgia's mountainous regions where the electricity distribution network either fails to reach the population or the service is less reliable than in the lowlands. Although 99% of Georgia is electrified (186 potential subscribers currently do not have access to electricity), a central gas supply does not exist in most of these regions, leaving 1,460, from a total 1,730, high mountainous settlements without access to natural gas. Consequently, their inhabitants tend to use wood for heating.

Poor living conditions in such mountainous areas have caused **depopulation of those regions**; from 2002 to 2014 the population decreased by 28% (the Strategy of Development of High Mountainous Regions, 2019-2023). The majority of residents live in the mountains only seasonally, and even if they were to live permanently, research shows that developing a gas supply would not be economically viable. Ultimately, small population levels lead to low consumption of gas, making the system unprofitable (stakeholder interviews).

The majority of the population in high mountainous areas have reached retirement age and their main source of income is a pension and social assistance (ISET PI, 2019). **The low income** of the local population results in an energy affordability problem: even with access, people cannot always afford to pay for gas or electricity and thus prefer cheaper alternatives (e.g., wood).[14] A lack of access to energy services further limits economic opportunities and widens the gap between rich and poor. Poor people are, notably, often prevented from accessing valuable information and efficient technologies. Not having reliable access to sustainable energy requires excess time, money, and effort on securing a basic energy supply.

The inhabitants of mountainous regions face the energy security and equity problems described below:

Energy security – infrastructural related challenges:

Road quality – Poor road infrastructure is one of the key obstacles faced in building distribution networks for electricity or gas in the mountains. In general, there are central roads through high mountainous areas, and they are in a good condition (United Nations Development Program (UNDP), CTC, & ADA, 2019). However, roads remain unpaved outside administrative centers, particularly to villages that are far from the central pipelines and networks. In winter, roads also become blocked due

[14] It is noteworthy that wood is not a cheap alternative when the opportunity and environmental costs are considered.

to heavy snow in some municipalities (Kazbegi, Akhmeta). This creates constraints on the provision of a central electricity and gas supply and, therefore, increases the costs of related work (stakeholder interviews).

Underdeveloped communication infrastructure – In certain high mountainous villages lacking sufficient electricity supplies, communications infrastructure is often also underdeveloped. The introduction of new information and communication technologies, such as the internet, is limited in those areas (e.g., Tusheti). The cost of implementing and using communications is also generally more expensive in remote areas. As a result, inadequate communications infrastructure paired with poor road quality contributes to the poor market integration of remote areas. Increased access to energy provides people in remote areas with the tools, skills, and information required to compete on equal terms with other regions.

Knowledge and information related challenges:

Information gap – Due to the absence of a communications infrastructure in some mountainous regions, access to information, as well as knowledge related to alternative energy sources and their potential, is limited. The knowledge and awareness of alternative energy sources, such as biomass, solar panels, etc., and their utilization is subsequently low (stakeholder interviews). The mountainous population furthermore has limited access to government support programs and cannot fully enjoy the benefits provided by the state: either they do not have enough information to exercise their rights effectively or they cannot gather the necessary documentation before submission deadlines.[15]

Issues with the utilization of wood – There are two core problems: inefficient wood heaters that over consume resources and the insufficient treatment of wood. Wood is often not dry enough for consumption; it is frequently cut in either late summer, in the best case, or late autumn in the worst case (this is also the time when rural households have greater cash inflow, which incentivizes delayed logging). Without proper drying, wet wood loses around 40-50% of its energy when burned. Besides which, the burning of wet wood produces toxic gases which negatively affect health. Those inhabitants using wood for cooking or heating simply do not have sufficient information regarding the health risks posed. According to the World Health Organization (2018), close to 4 million people, largely women and children, die each year as a result of indoor air pollution.

Energy equity – consumption related challenges:

Using wood for heating – While gas is mostly used for cooking, people still use wood for heating. The collection of wood is directly associated with lower costs, rather than the utilization of other energy; even with a supply, gas is not often utilized for other purposes. Consequently, the volume of wood consumed in Georgia is 12 times over the prescribed limit (the State Audit Office, 2016). If access to wood is not restricted and the consumption of gas is not increased, the system would not be profitable. Moreover, if certain areas have a gas supply and an investment is incurred but consumption remains low, tariffs would increase and lead to even lower consumption, which in turn would result in a longer payback period for the infrastructural investment. In essence, the motivation for using biomass and other alternatives remains relatively low, which affects the actual utilization levels of alternative energy sources.

Subsidies – State support through subsidies have resulted in excessive and inefficient use of energy in some remote areas. While there are villages where the local population cannot afford energy and maintain poor living conditions, there are also some mountainous villages where locals take advantage of the current state support system and use the electricity and gas consumption subsidies to develop their businesses,[16] which leads to inefficient energy use.

Illegal logging – While there are large territories of forest, illegal logging has led to their degradation and reduced the potential for proper utilization. The excessive reliance of wood in HHs with access to gas limits availability to HHs with no alternative than wood. Poor HHs depend on wood the most, but also have limited access to resources. According to governmental studies,[17] even when poor families are provided with vouchers or tickets for tree cutting, they often cannot be utilized because of their proximity to forests or lack of financial resources for transportation costs.

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[15] Note that government support programs (for example, agricultural programs) require documentation to be submitted to the Tbilisi office. As some programs are developed on a “first come first serve” basis, the application process is often finished before inhabitants of high mountainous regions are able to travel to Tbilisi.
[16] For example, Svaneti inhabitants started mining cryptocurrency which increased their electricity consumption.
[17] Social usage of timber resources (the State Audit Office, 2016).

3.2.2 THE POLICY AND LEGAL PERSPECTIVE

From a policy perspective, the major challenges are:

Strategic gap – Currently, there is neither a clear general long-term energy strategy nor individual strategies for municipalities.

Policy gap – There is no uniform policy to ensure either access to energy in high mountainous regions or the protection of vulnerable customers. However, some mountainous municipalities are treated differently than others. For instance, subscribers permanently living in Kazbegi and Dusheti municipalities receive 700m^3 of free gas per month (from 1 December 2019 to 15 May 2020 and from 15 October 2020 to 30 November 2020; the volume of gas between May-October constitutes 350m^3 instead of 700m^3) (the State Budget Law, 2020). Therefore, such policies have to take into account local context, fairness, and the equal treatment of each mountainous municipality.

Weak execution of the law – There is a problem with the absence of effective utility payment collection in some regions. For instance, in Svaneti there is an issue with the collection of electricity payments, as the population believes they are entitled to free electricity due to Enguri hydro-power related risks (stakeholder interviews). Thus, weak execution of the law, as a result, leads to inefficient utilization of resources.

From a legal point of view, the main challenges lie in customer protection, especially towards the vulnerable. These challenges include:

- A uniform policy and strategy concerning the protection of vulnerable customers does not exist;
- Primary and secondary legislation includes only general provisions and does not specify supporting programs;
- The functions of relevant stakeholders are not properly distributed and some overlaps and gaps may arise;
- An analysis of the various economic support schemes has not been conducted;
- Different state institutions develop support programs without proper interaction with the corresponding authorities (stakeholders);
- The database of vulnerable customers should be improved and updated regularly to ensure they are all registered in the system;
- Information dissemination is not properly carried out; vulnerable customers, especially in high mountainous regions, do not have enough information on how to access the network and be supplied by electricity or natural gas.

As a result of the prevailing challenges, fair access to energy is currently not ensured for everyone. There is a need for the Georgian government to develop a comprehensive long-term energy strategy, with clear targets, one that is in line with national socio-economic development goals and energy security objectives. It needs to be underlined once again that without governmental support, or another incentive program, most rural electrification projects are not viable; their start-up investment costs are too high relative to the average income in high mountainous regions.

3.2.3 THE ENVIRONMENTAL PERSPECTIVE

Forests provide habitats for animals and livelihoods for people (via food, medicine, and resources). There are however many factors that contribute to deforestation and have a negative impact on the environment. Firstly, deforestation might lead to soil erosion. Logging causes the loosening of soil, which can be blown away or washed down by rain. Eroding soil can also cause mudslides that can clog waterways, and damage infrastructure and irrigation systems. Secondly, soil erosion diminishes the fertility of the topsoil and its ability to generate vital nutrients. Consequently, soil erosion and desertification damage agricultural productivity and land development (Olofin, 2017). Additionally, the increased frequency of extreme weather events, due to deforestation, raises environmental concerns even further. Deforestation and land degradation ultimately cause floods and droughts that have increasing impact on human populations and the environment.

Deforestation is a major contributor to manmade climate change. Whereas forests themselves help to slow climate change by capturing Greenhouse Gases (GHGs), preventing their accumulation in the atmosphere and warming the planet further. Deforestation also leads to a decline in biodiversity, thus many species are becoming endangered or threatened (Sahney et al., 2010).

In addition, deforestation and residential wood heating lead to poor air quality. Although in some instances it can be advantageous to burn biomass, however, on a large scale it has many negative consequences. According to NASA, the biomass humans burn comprises a vast 90% of total fires, while natural fires only around 10%. As fires produce carbon dioxide – a major greenhouse gas – the emissions caused from burning biomass have a significant influence the Earth's atmosphere and climate.

It is moreover important to consider the impact of the construction of gas pipeline infrastructure on the environment and the potential related issues of pollution and contamination.

3.2.2 INNOVATIVE FINANCING MECHANISMS

Well-developed financing schemes tailored to local circumstances are extremely important within the energy sector. In Georgia there are currently concessions for electricity use in mountainous regions; the regulation entered into force on 1 January 2017 and includes subsidies for permanent residents of mountainous areas.

Additionally, in May of 2018, the Georgian parliament adopted the Law on Public-Private Partnerships (‘the PPP Law') that provides a legal framework for co-operation between the public and private sectors when developing public infrastructure or providing municipal services. The PPP Law, and its bylaws, provide clear guidance on the rules related to project identification, initiation, and preparation, as well as detailed procedures for the selection of private partners, the stages of project implementation, monitoring, and even post-implementation relations. The Law states that projects may be initiated not only by the government, but also by potential private investors. This ruling mainly concerns the energy sector, which is considered strategically important. In this context, the Law also envisages the possibility of granting investors long-term guaranteed purchase agreements. The energy sector moreover enjoys certain exemptions from general rules, for instance only PPP projects in the sector can be negotiated directly with a single private partner, thereby skipping the public tender and evaluation procedures. While, for energy projects larger than 100 MW, the initiation process must include a feasibility study to be carried out by an independent company.

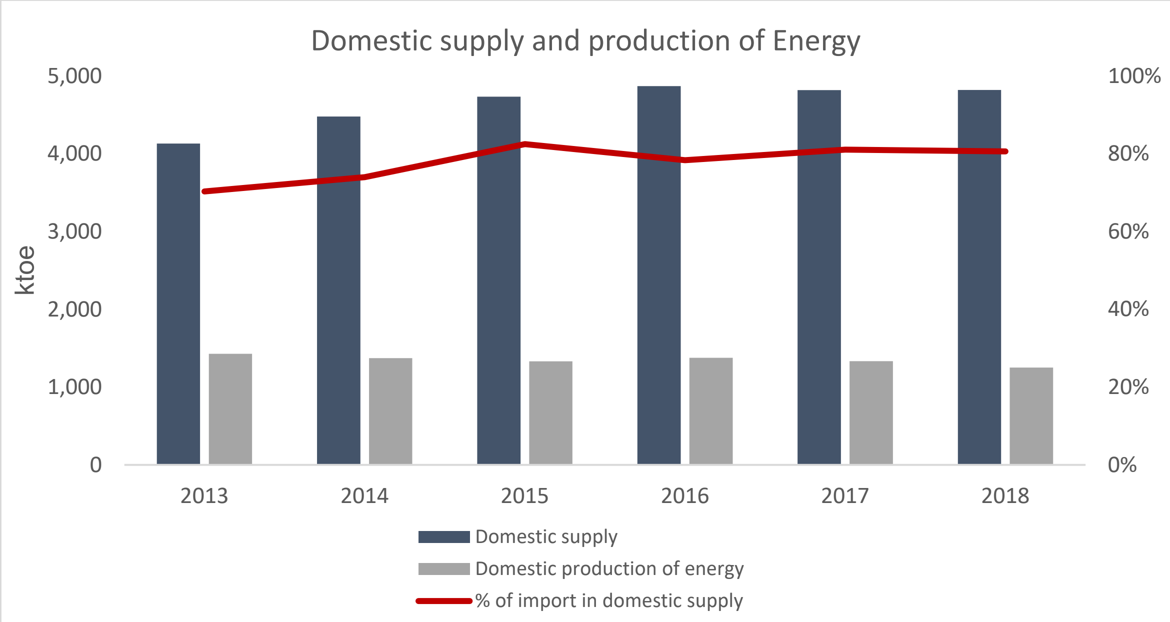
Thus, at present, these two schemes (concessions and PPPs) are the most widely applied in the Georgian energy sector. However, there are other types of innovative scheme that can be used to ensure energy efficiency investments. For example, they can involve different organizations, ownership structures, or financing models, like dedicated credit lines; guarantee facilities; factoring/forfaiting schemes; on-bill (e.g., utility-financed) or on-tax financing schemes; citizen financing (e.g., crowd-funding) for energy efficiency; financing solutions integrating existing market-based instruments relevant to energy efficiency; etc.

3.3 BACKGROUND TO THE BASELINE SCENARIO

3.3.1 ENERGY ENDOWMENT AND USE

Domestic production of energy is extremely low in Georgia and only accounts for around 25-30% of the total supply (Figure 2). Since 2013, domestic production of energy has decreased by 13%, from 1,428 ktoe to 1,251 ktoe in 2018. The share of imports in domestic energy supply is however remarkably high, and accounts for more than 80%.

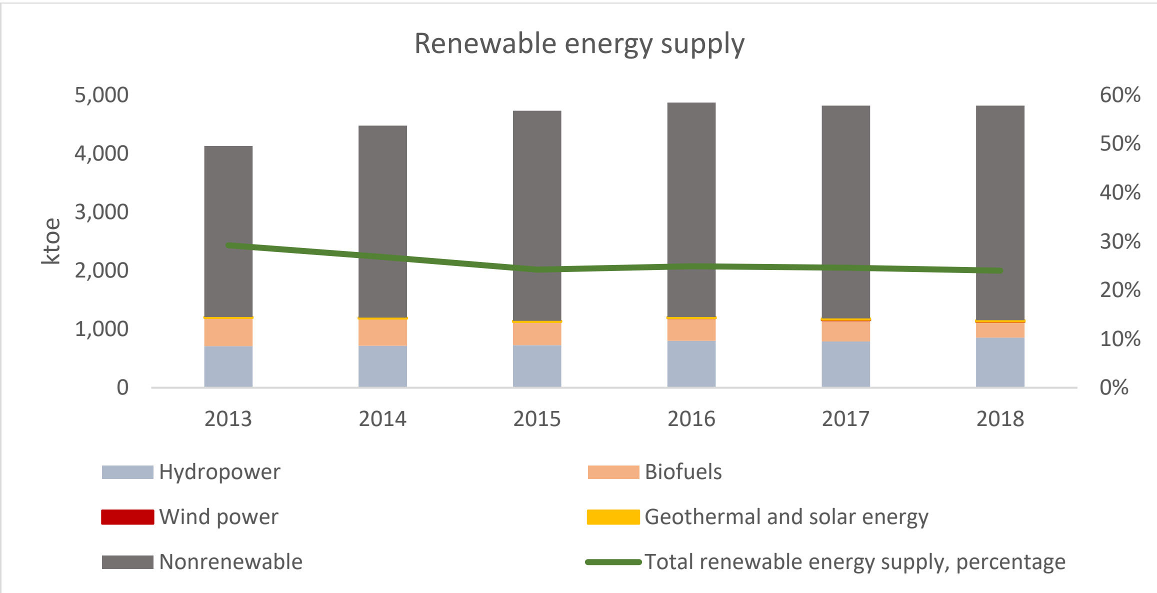
Figure 2: Supply and Production of Energy



Source: National Statistics Office of Georgia (GEOSTAT), 2020

Since 2013, the share of renewable energies in the total supply has decreased, from 29% to 24% in 2018 (Figure 3). Hydropower has the greatest proportion (74%) in the total renewable energy supply, followed by biofuels (23%).

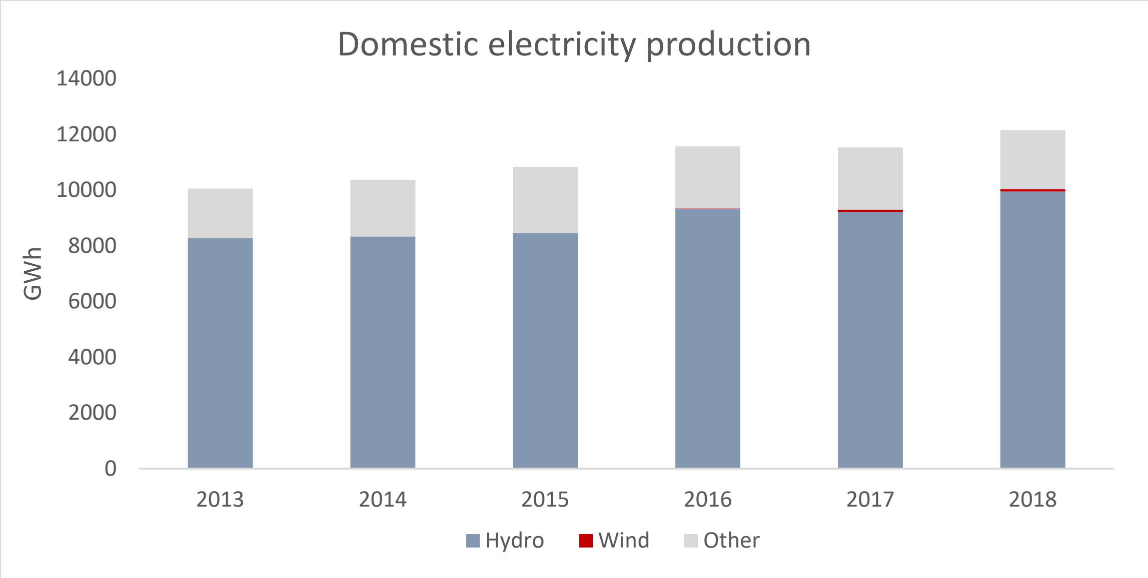
Figure 3: The Share of Renewable Energy in the Total Energy Supply



Source: GEOSTAT, 2020

Domestic production of electricity has increased by 20% since 2013 (Figure 4), when domestic electricity production was 10,059 GWh, by 2018 the corresponding indicator was 12,149. Hydropower has the highest share in total domestic electricity production at 82%.

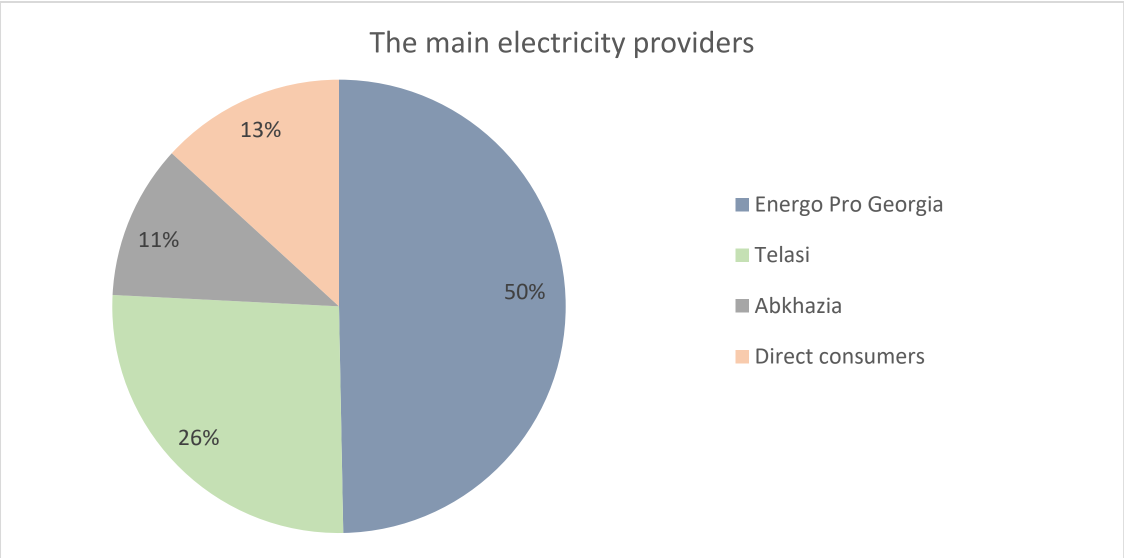
Figure 4: Domestic Electricity Production



Source: GEOSTAT, 2020

Since 2017, the main electricity provider has been EPG (50%) followed by Telasi (26%) (Figure 5).

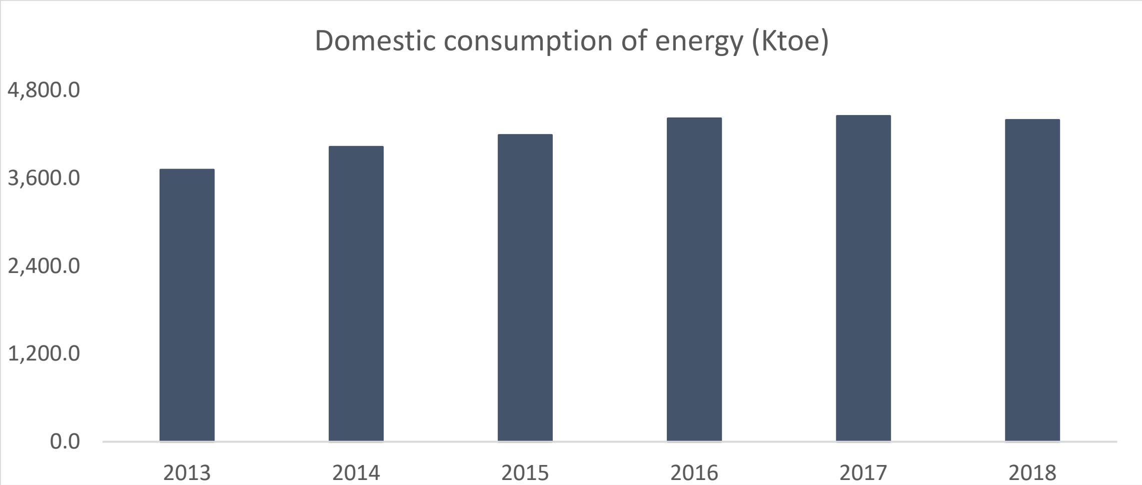
Figure 5: The Main Electricity Providers



Source: MoESD, 2020

Final consumption of energy has been increasing in Georgia (Figure 6), and since 2013, domestic consumption has increased by 18%, from 3,711 ktoe to 4,390 ktoe by 2018.

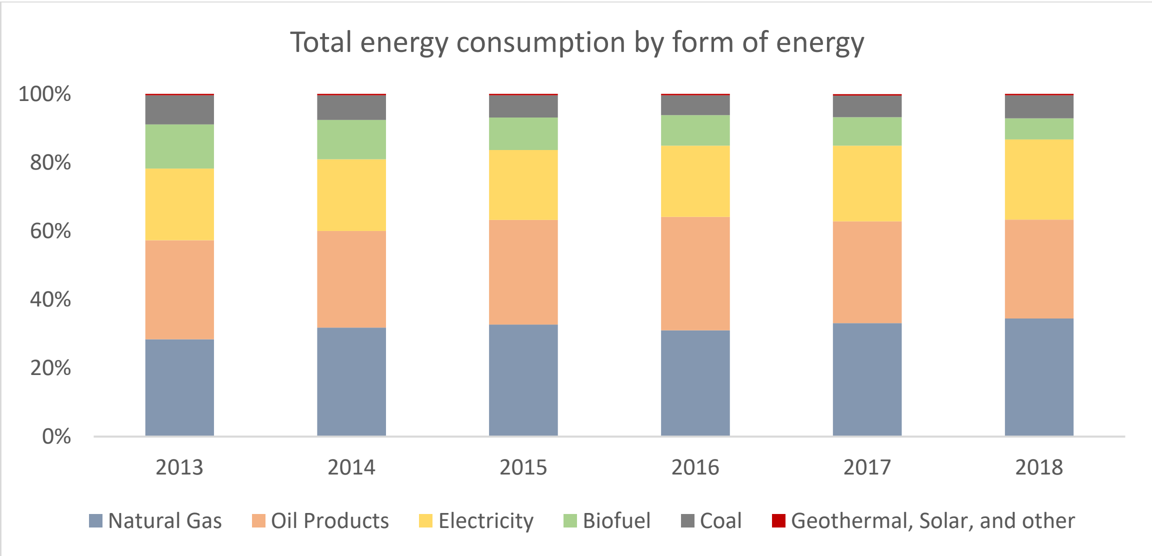
Figure 6: Final Consumption of Energy in Georgia



Source: GEOSTAT, 2020

Natural gas has the highest percentage (34%) of total energy consumption, followed by oil products (29%), and electricity (23%) (Figure 7).

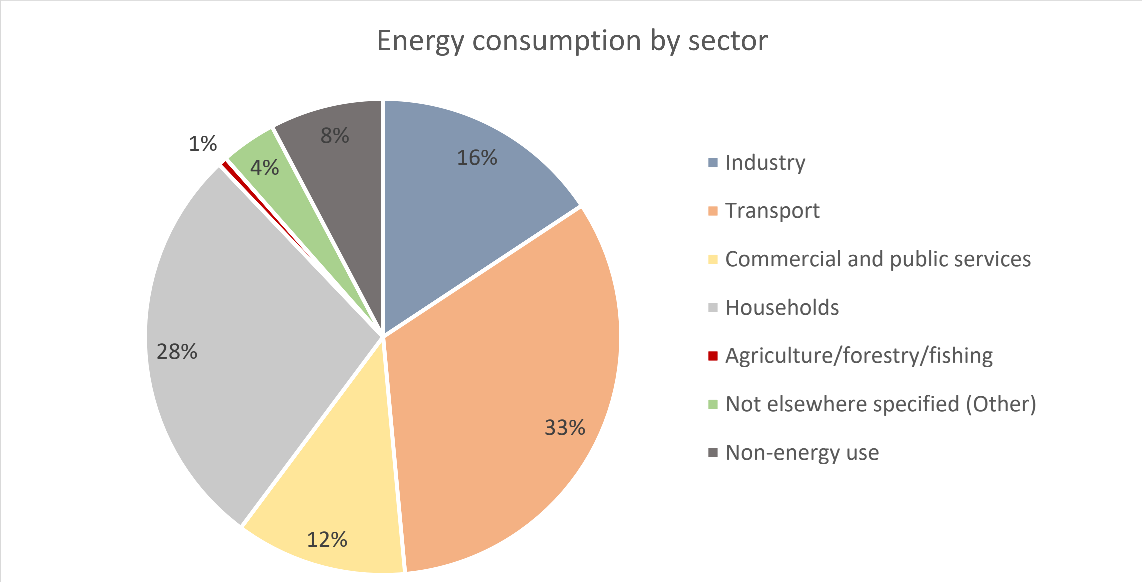
Figure 7: Total Energy Consumption by form of Energy



Source: GEOSTAT, 2020

In 2018, the transport sector was the greatest energy consumer, with a 33% share of total energy consumption. Households maintain the second largest proportion of total energy consumption (28%), followed by industry (16%) (Figure 8).

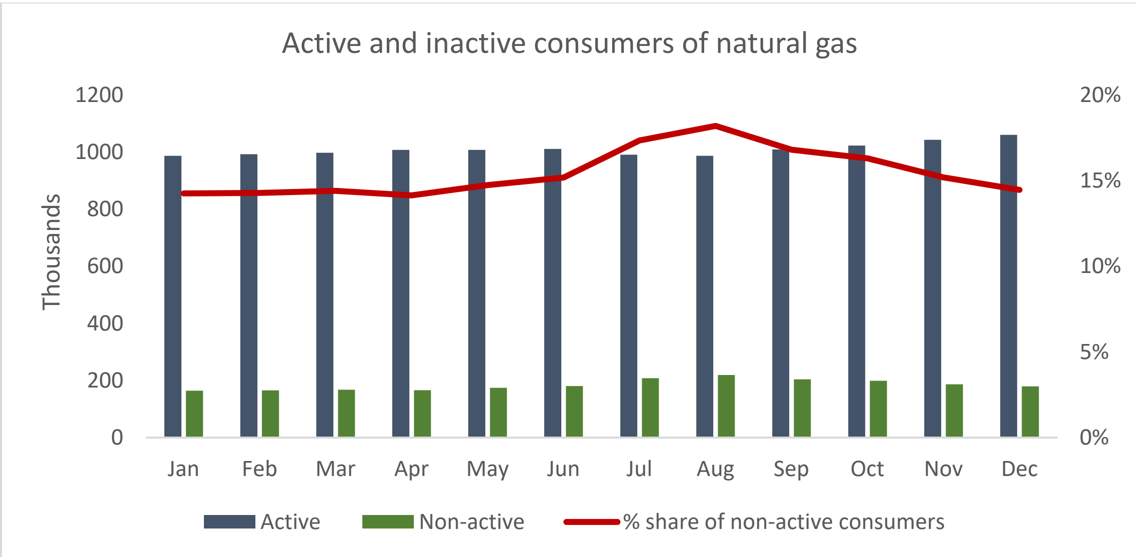
Figure 8: Energy Consumption by Sector



Source: GEOSTAT, 2020

According to the USAID Cost Estimation Study on the Gas Pipeline Network and Alternative Systems for High-Mountainous Settlements in Georgia (2019), the gas supply is extensive in Georgia, with 90% of households delivered natural gas. While, the percent of households that have access to natural gas though do not consume it (non-active customers) is around 15% (GNERC, 2019). This indicator is at its highest in August, at 18% (Figure 9).

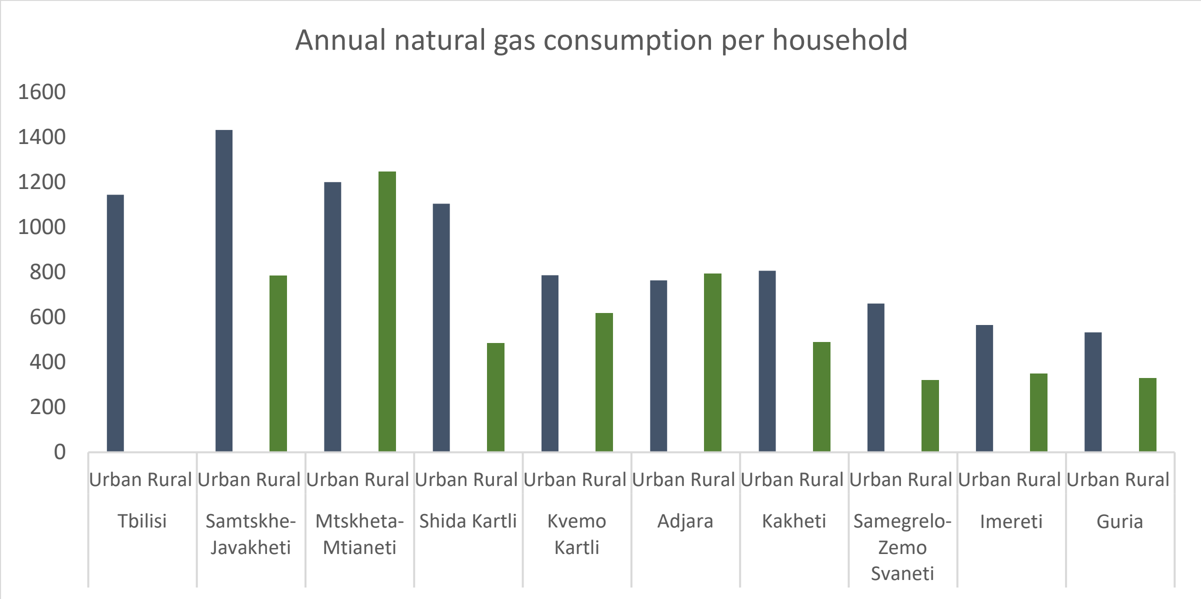
Figure 9: Active and Inactive Consumers of Natural Gas



Source: GNERC, 2019

Natural gas consumption per household differs by urban and rural area, as well as by region (Figure 10). In rural areas, with few exceptions, the consumption of natural gas is lower than in urban areas. The main reason being that access to natural gas is reduced in the regions where firewood is still the main source of energy for cooking and heating. The regions of Mtskheta-Mtianeti and Adjara are the exceptions; natural gas is subsidized by the government in Mtskheta-Mtianeti due to the cold-climate and scarcity of firewood. While the higher consumption of natural gas in rural areas in Adjara can be explained by their developed tourism sector.

Figure 9: Annual Natural Gas Consumption Per Household



Source: GNERC, 2019

Between 2010-2017, 159.6 million m^3 of natural gas, 760.6 mil. kWh of electricity, and 1,722 thousand m^3 of firewood were consumed by rural households (Table 2).

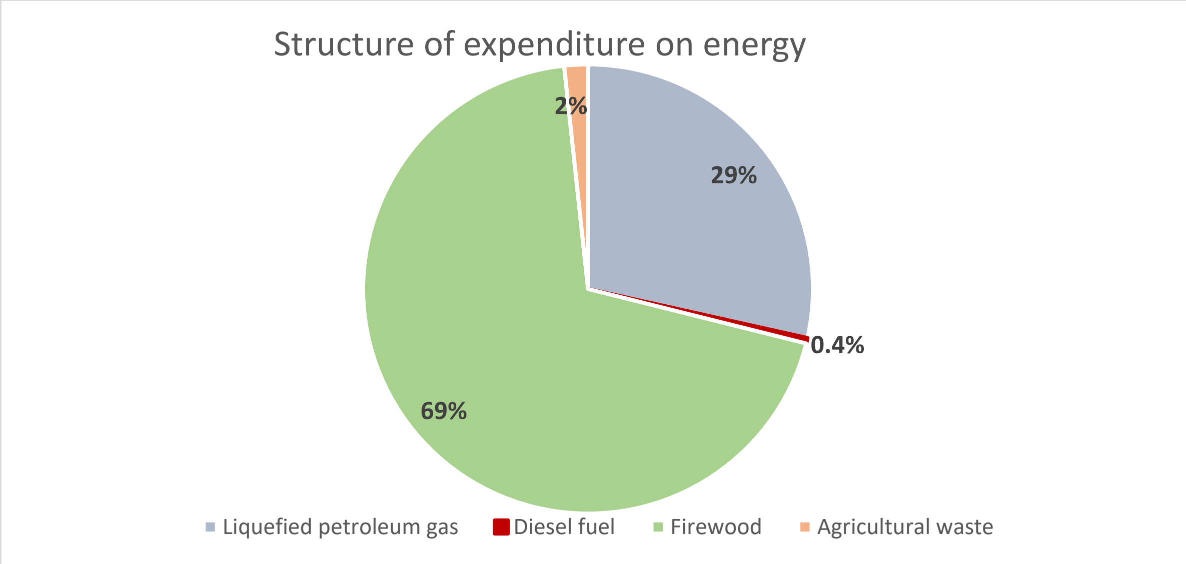
Table 2: Consumption of Energy in Rural Households

Form of energy	Consumption
Coal, ths. tons	2.1
Natural gas, mln. m^3	159.6
Liquefied petroleum gas, ths. tons	10.9
Diesel fuel, ths. liters	289.1
Firewood, ths. m^3	1,722
Wood waste, ths. tons	2.8
Animal waste, ths. tons	14.9
Agricultural waste, ths. tons	11.2
Charcoal, tons	1
Electricity, mln. kWh	760.6

Source: Energy Consumption of Households, GEOSTAT, 2017

In 2017, firewood accounted for 69% of total household expenditure on all energy, excluding natural gas and electricity (Figure 11), while Liquefied Petroleum Gas (LPG) has the second highest share in household energy expenditure (excluding natural gas and electricity) at 29%.

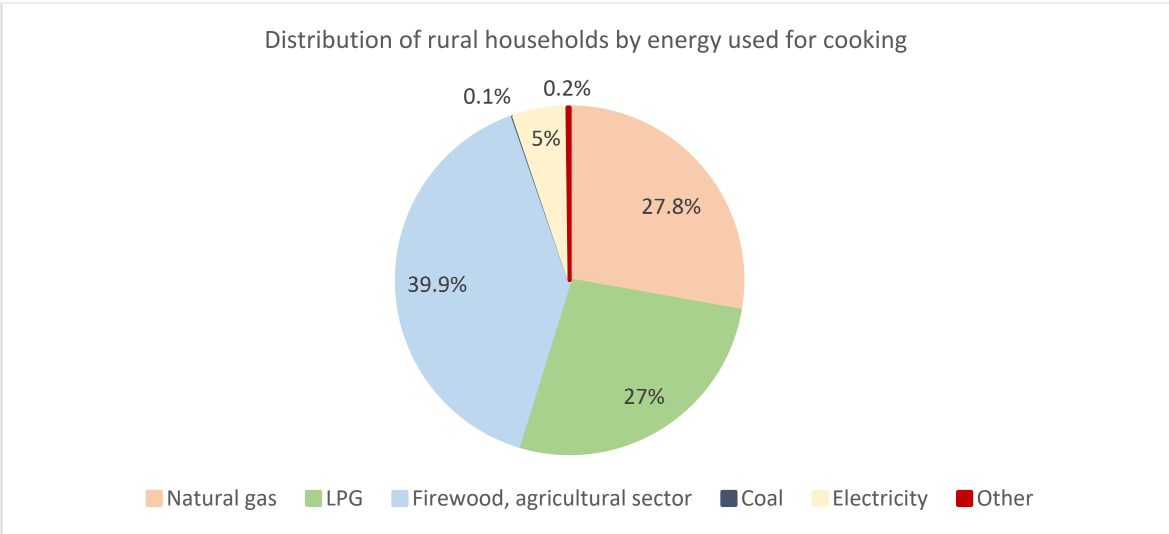
Figure 10: Structure of Household Expenditure on Energy



Source: Energy Consumption of Households, GEOSTAT, 2017

For cooking purposes, 39.9% of rural households use firewood, 27.8% - natural gas, and 27% - LPG (Figure 12).

Figure 11: Distribution of Rural Households by Energy Used for Cooking



Source: Energy Consumption of Households, GEOSTAT, 2017

To summarize, Georgia's domestic energy supply is heavily dependent on imports: the proportion of imports in domestic supply accounts for more than 80% of total energy consumption. Considering that in recent years energy consumption has increased, while production has decreased, the country faces problems in energy security. In terms of access to energy, the population in urban areas have access to the necessary sources to meet demand, whereas rural areas, particularly high mountainous regions, do not always have access to energy and remain off-grid. Therefore, firewood is still the chief source for heating water and cooking in rural areas.

3.3.2 POTENTIAL ENERGY SOURCES IN GEORGIA

Biomass resources

In rural areas, wood is a major energy source. To some extent, every Georgian region has access to forests, although Guria, Samtskhe-Javakheti, and Kvemo Kartli have fewer forest resources, relatively, than other regions (Table 2). While in Adjara the accessibility of resources is poor due to the steep slopes of forested territories.

Table 3: Georgian Forests by Region

Region/area (2018)	Total forest area (thousand hectares)	Covered by forest (thousand hectares)
Georgia	**3,112.0**	**2,676.6**
Forests under the Agency of Protected Areas*	596.0	312.4
Forests under the Forestry Agency of Adjara	150.1	141.8
Forests of Abkhazia AR**	369.0	346.0
Forests under the National Forestry Agency***	1,996.9	1,876.4
Guria	86.0	82.6
Imereti	312.4	301.1
Kakheti	288.4	268.2
Mtskheta-Mtianeti	238.0	222.9
Racha-Lechkhumi and Kvemo Svaneti	282.0	268.0
Samegrelo-Zemo Svaneti	272.7	256.4
Samtskhe-Javakheti	133.4	130.1
Kvemo Kartli	146.7	133.5
Shida Kartli	237.3	213.6

** Including the Autonomous Republic of Abkhazia and Tskhinvali; ** on 1 January 2003; *** Including the Tskhinvali region.*
Source: The Ministry of Environment Protection and Agriculture of Georgia; LEPL Forestry Agency of Adjara; LEPL Agency of Protected Areas; and LEPL National Forestry Agency, 2020.

The optimal regional distribution of permissible logging is presented below (Table 4).

Table 4: Optimal Permissible Logging by Region

Region	Area (ha)	Liquid (thousand m^3)	Wood (thousand m^3)
Guria	2,016	6	3
Imereti	3,524	53	19
Kakheti	746	20	11
Mtskheta-Mtianeti	678	20	11
Racha-Lechkhumi and Kvemo Svaneti	1,733	60	28
Samegrelo-Zemo Svaneti	1,058	54	23
Samtskhe-Javakheti	1,369	58	24
Shida Kartli	160	4	2
Kvemo Kartli	437	14	8

Source: The State Audit Office, 2016

Nevertheless, the real amount of logging is far higher than the optimal level (Table 5).

Table 5: Volume of Cut Timber (m^3)

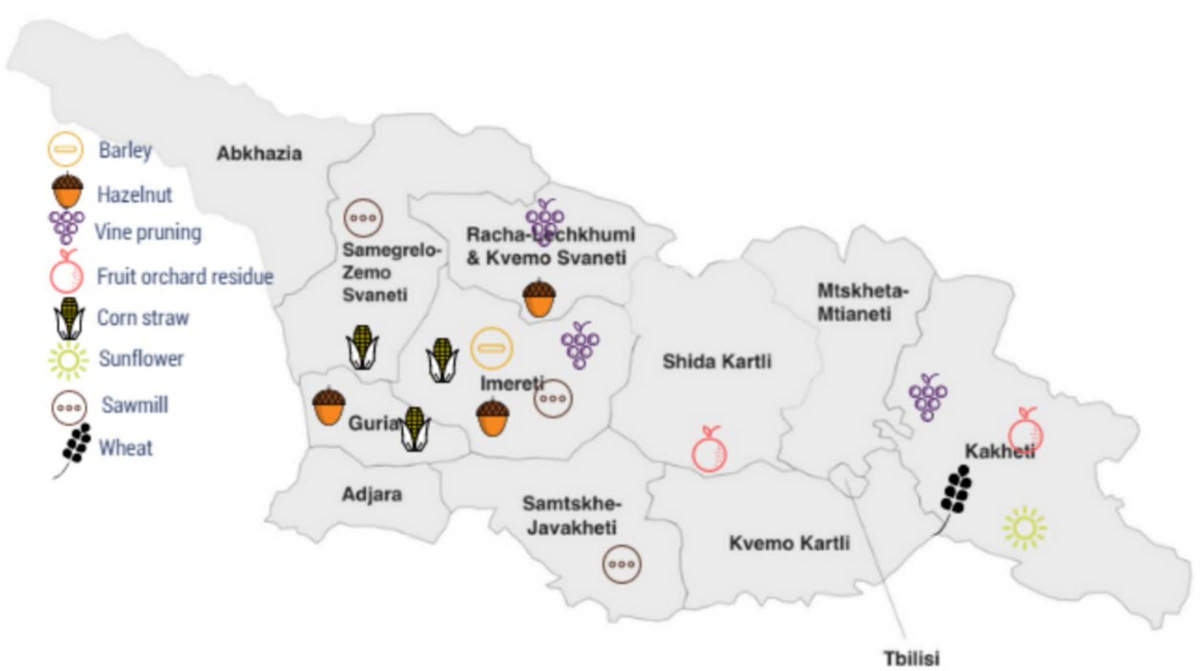
Region	2014	2015	2016	2017	2018
Georgia total	**687,171**	**712,336**	**628,035**	**630,462**	**578,031**
Tbilisi	...	...	...	...	...
Adjara A/R	77,981	75,510	65,422	69,034	58,631
Guria	12,425	12,269	8,526	13,185	9,268
Imereti	77,744	80,775	57,443	53,277	45,483
Kakheti	124,109	140,086	121,773	132,067	97,051
Mtskheta-Mtianeti	63,897	74,956	63,545	66,790	52,485
Racha-Lechkhumi and Kvemo Svaneti	58,545	60,919	59,145	49,523	50,114
Samegrelo-Zemo Svaneti	49,124	29,019	39,538	49,564	54,202
Samtskhe-Javakheti	82,728	89,170	79,784	81,956	102,682
Kvemo Kartli	56,817	52,496	44,222	42,799	34,343
Shida Kartli	66,871	76,661	71,284	58,267	58,257
Protected areas	**16,930**	**20,475**	**17,353**	**14,001**	**15,515**

Source: The Ministry of Environment Protection and Agriculture of Georgia; LEPL Forestry Agency of Adjara; LEPL Agency of Protected Areas; and LEPL National Forestry Agency, 2020

Aside from timber, another potential component of biomass derives from agricultural residue. While there is no solid research on the Georgian agricultural residue that could be used as an energy source, UNDP estimates that over 1.5 mln. tons of agricultural residue and more than 1 mln. m^3 of forest residue is produced every year in Georgia; with the potential to generate 36.5 PJ, or 70% of Georgian residential energy consumption.

The main agricultural residues are derived from corn straw, barley, hazelnuts, vine pruning, orchard residue, sunflowers, sawmills, and wheat. Corn straw is the largest potential source of agriculture residue, with an estimated production of around one million tons per year, and the potential to generate 18.3 PJ of sustainable energy (from which 29% and 26% is harvested in Imereti and Samegrelo-Zemo Svaneti, respectively). Vine pruning also has great potential, with an estimated generation of 108,900 tons per year, which could easily generate 2 PJ of sustainable energy (from which 61% is located in the region of Kakheti) (Figure 13).

Figure 12: Distribution of Agricultural Residue by Region



Unfortunately, there are currently no up-to-date estimates on the total energy available from residual biomass in Georgia, and the latest study, conducted by WEG for UNDP, dates back to 2014 (Table 6).

Table 6: Total Energy Available from Residual Biomass in Georgia

Type of biomass	Total area (ha)	Residue (kg/ha)	Heating value (MJ/kg)	Energy production (MJ/ha)	Annual energy production (TJ/annum)	Accumulated energy (TJ)	Total energy production (TJ)
Vine residue (pruning)	33,000	3,300	18.7	61,710	2,036		2,036
Fruit orchards	59,000	3,500	18	63,000	3,717		3,717
Hazelnut (shells)	15,000	3,600	17	61,200	918	-	918
Bay leaves	600	15,000	19	285,000	171	-	171
Wheat straw	44,900	300	16.9	50,700	2,276	-	2,276
Sunflowers	14,000	4,500	14	63,000	882	-	882
Corn stover	150,000	6,900	17.7	122,130	18,300	-	18,300
Total (TJ)							28,300
Total available (TJ)							7,673

Source: WEG, 2014

Given that animal residue can also serve as an energy source, it is important to consider its potential in terms of animal husbandry (Table 7). The regions of Imereti, Samegrelo-Zemo Svaneti, Kvemo Kartli, and Samtskhe-Javakheti have the greatest number of livestock, and thus animal residue in these regions are considered the most relevant for analysis.

Table 7: The Number of Bovine Animals by Region (end of year, ths. heads)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Georgia	**1,049.4**	**1,087.6**	**1,128.8**	**1,229.7**	**970.0**	**992.1**	**962.7**	**909.7**	**878.9**
Tbilisi	-	-	-	-	-	-	3.9	3.5	4.1
Adjara AR	79.3	87.7	86.1	86.7	75.7	69.7	70.3	63.9	56.3
Guria	-	-	-	-	-	-	48.5	39.9	36.2
Imereti	192.6	197.9	194.3	208.6	163.2	168.4	171.4	166.6	163.0
Kakheti	87.2	94.1	105.7	123.2	110.0	110.6	97.2	95.9	96.1
Mtskheta-Mtianeti	-	-	-	-	-	-	34.8	35.8	33.0
Racha-Lechkhumi and Kvemo Svaneti	-	-	-	-	-	-	18.5	17.8	16.9
Samegrelo and Zemo Svaneti	180.1	197.4	245.4	280.7	183.9	199.7	190.8	175.5	164.2
Samtskhe-Javakheti	111.3	135.6	131.8	149.4	118.0	119.8	116.2	103.5	100.2
Kvemo Kartli	188.0	167.3	160.0	168.3	137.2	144.3	148.9	148.8	149.9
Shida Kartli	79.2	83.4	81.3	77.6	72.4	67.3	62.2	58.6	58.9
The remaining regions	131.7	124.2	124.1	135.1	109.6	112.3	x	x	x

Source: GEOSTAT, 2020

Solar power potential

The potential of solar power in high mountainous villages varies by region (Table 8). For instance, the Global Horizontal Irradiance (GHI) values are highest in Samtskhe-Javakheti, Imereti, Kvemo Kartli, and Mtskheta-Mtianeti, whereas Direct Normal Irradiance (DNI) is highest in Imereti (Table 5).

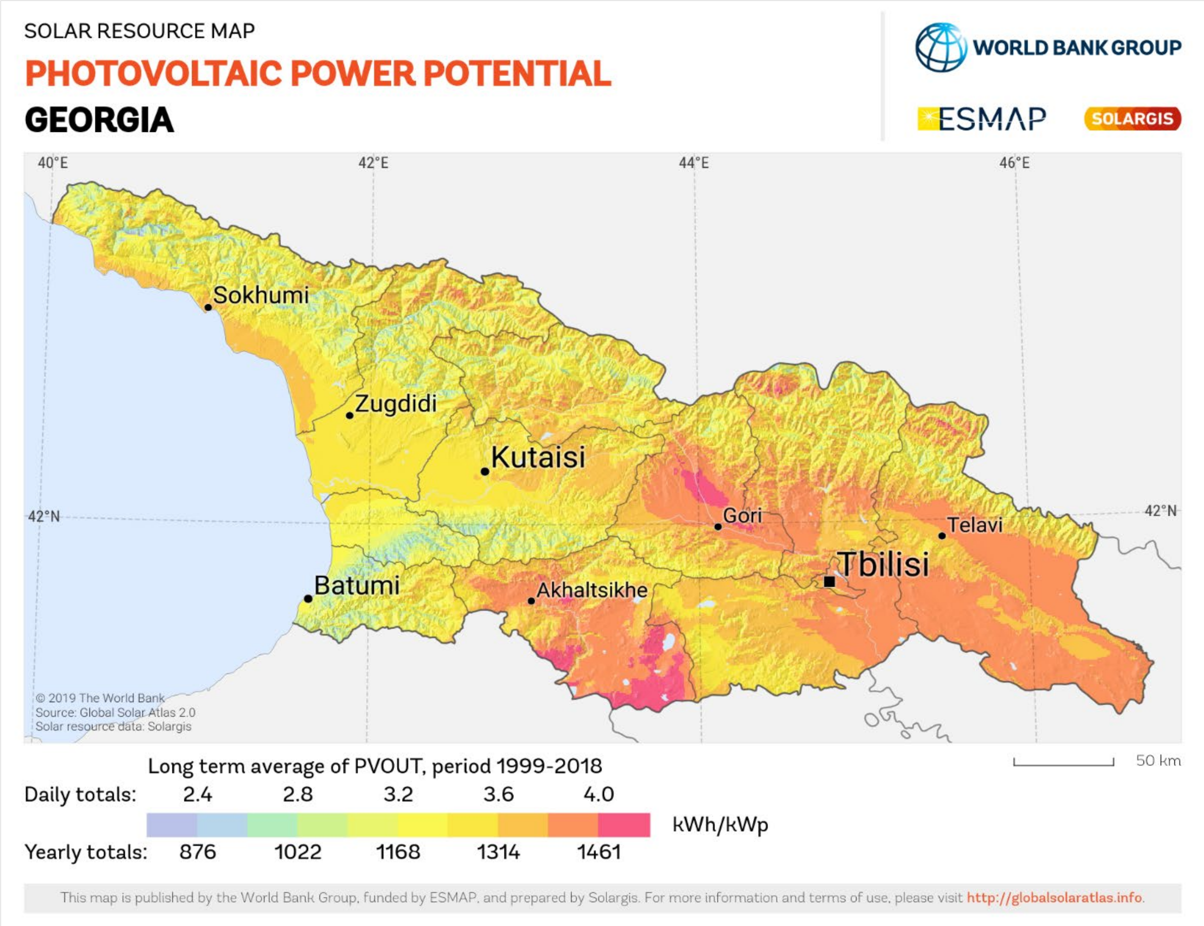
Table 8: Average GHI and DNI by Regions

Region	Average GHI (kWh/m^2)	Average DNI (kWh/m^2)
Ajara	1,232	1,068
Guria	1,095	803
Imereti	1,315	2,953
Kakheti	1,281	1,156
Mtskheta-Mtianeti	1,310	1,163
Racha-Lechkhumi and Kvemo Svaneti	1,258	1,132
Samegrelo-Zemo Svaneti	1,241	1,095
Samtskhe-Javakheti	1,461	1,380
Kvemo Kartli	1,312	1,204
Shida Kartli	1,444	1,331

Source: World Bank Group, 2019

The GHI and DNI values are of particular importance for photovoltaic installations. According to World Bank research, the potential of photovoltaic power is relatively high in the regions of Samtskhe-Javakheti, Kakheti, parts of Kvemo Kartli, Shida Kartli, and Tbilisi (Figure 14).

Figure 13: Potential Photovoltaic Power in Georgia



Source: World Bank Group, 2019

Wind power potential

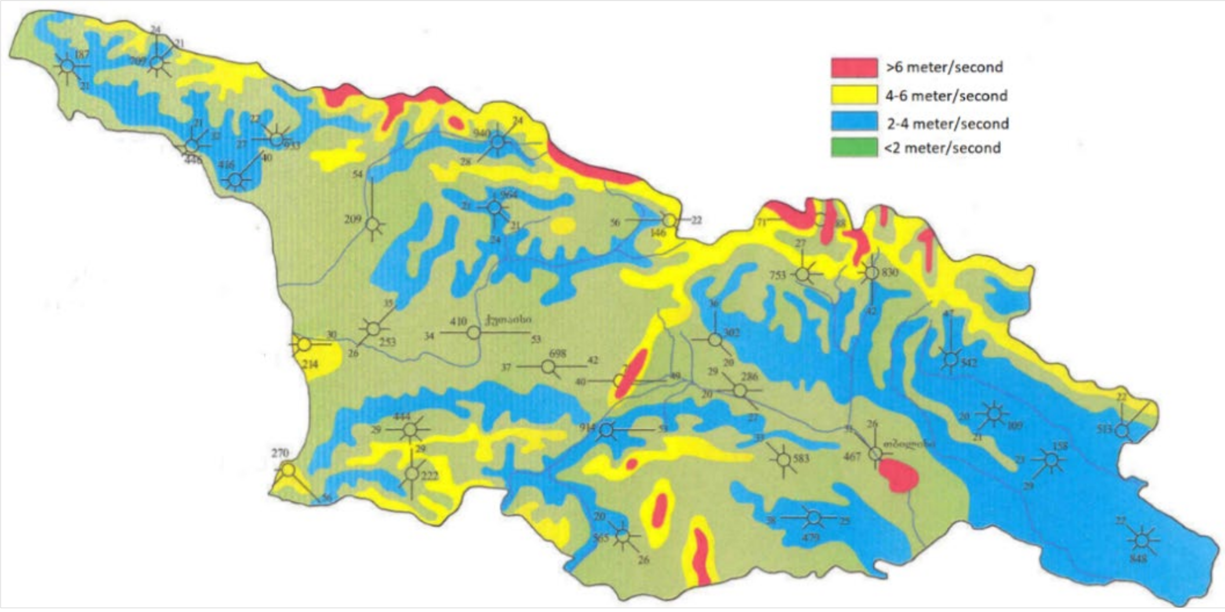
Georgia has quite favorable wind energy resources, nevertheless it is not yet harnessed or used throughout the country. While the first Gori wind power plant (20.7 MW) has been successfully operating over the last three years, aside from projects at the feasibility stage, no further development have occurred. The cost of turbines has been further decreasing, and increased turbine efficiency has also improved power harnessing, though, wind power plants are still uncommon in rural areas.

Georgian wind energy potential is estimated at 4 billion kWh annually.[18] There is an average annual wind speed of 0.5-9.2 meters / second, while in some regions it exceeds 15 meters / second.[19]

[18] http://energy.gov.ge/investor.php?lang=eng&id_pages=20

[19] http://energy.gov.ge/projects/pdf/pages/Sakartvelos%20Karis%20Energetikuli%20Atlasi%20Natsili%20IV%20411%20geo.pdf

Figure 14: Annual Wind Speed and Direction



Source: Georgian wind power atlas, 2004.

Georgia being located on the northern edge of a high-pressure, subtropical zone has high impacts from northern semi-sphere circular processes, with a total wind direction from west to the east. Thus, Georgia's geographical complexity affects the diversity of the local climate. Effectively, the wind in Georgian territories is due to the character of the general circulation of the atmosphere, geographical location, and relief. Georgia is under the influence of both mid and subtropical air circulation, and the conditions of this flow are seen as changes in the active movement of dynamic anticyclones and a polar frontal position, as well as atmospheric processes in the mid and tropical divisions.[20]

During warmer periods, Georgia is under the influence of the eastern branch of the Azores anticyclone, where a high-pressure zone in the Caucasus highlands is established. In the Kolkheti lowland and the coast westerly and southwesterly winds flow from the sea towards terrestrial areas. In the hills of the Caucasus, eastern and southeastern winds are dominant; while northwestern winds are largely the strongest in the Javakheti mountains.[3]

Due to the influence of the western Siberian anticyclone in winters, a low-pressure zone becomes established around the Black Sea, whereas in central Transcaucasia the pressure is higher. Under these circumstances, eastern winds are dominant in the Kolkhida Valley and Rioni Gorge, whose replication reaches 45-60%; in the foothills and the ranges of the Caucasus northern and northeastern winds further increase in duration; whereas in the Javakheti mountainous the south and southeastern directions grow dominant, with a 60% replication rate.

Almost the entire country’s mountainous circulation is well-represented, characterized by daytime periodicity. During the day, the wind blows from lowlands to the mountains, but during the night, the wind pushes to the opposite side of the mountains. In Black Sea coastal areas, the breeze is also added to mountainous circulation, and when combined, the wind strengthens.[3]

In terms of power potential, Georgian territory is divided into four zones:

1. The high-speed zone – the mountainous regions of Southern Georgia, Kakhaberi Vake, and the central region of the Kolkheti Valley, with a working duration period of more than 5,000 hours / year;
2. The part high-speed and low-speed zone – the Mtkvari Gorge from Mtskheta to Rustavi, the southernmost part of Javakheti, and the Black Sea line from Poti to Kakhaber Vake, with a working duration of 4,500-5,000 hours / year;
3. The effective exploitation zone in low-speed mountain ranges – the Gagra mountain range, the Kolkheti Valley, and eastern Georgian lowlands;

[20] https://www.elynspublishing.com/journal/article/renewable-energy-potential-and-its-utilization-in-georgia

4. The limited exploitation zone in low-speed mountain ranges – Iori Zegani and Sioni water reservoir.

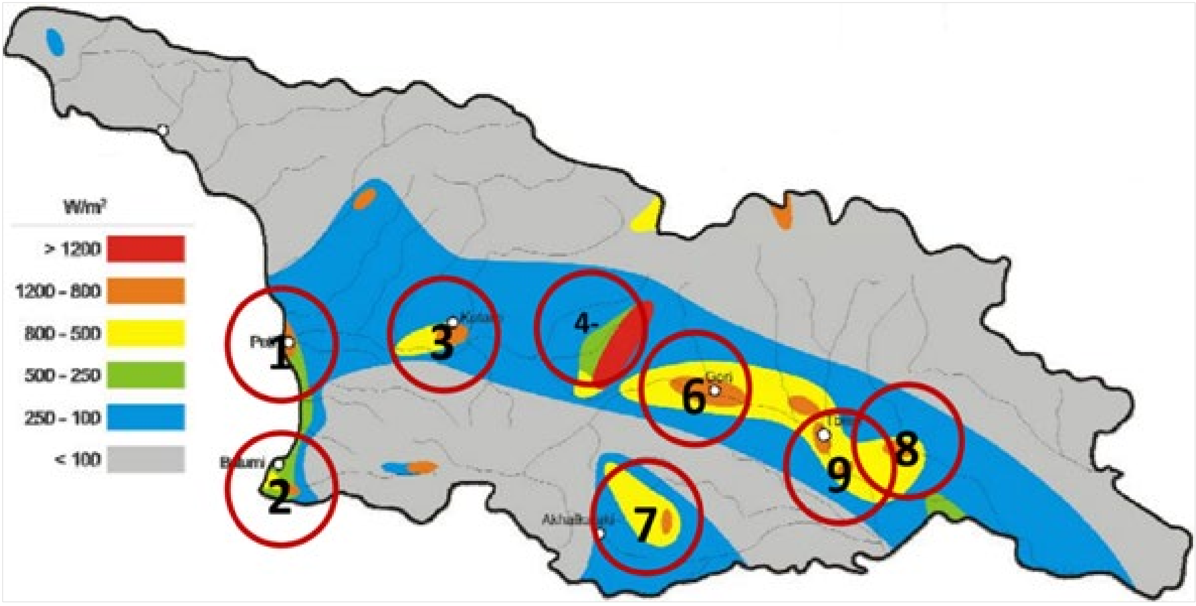
Based on the TYNDP 2019-2029 report, the potential wind power capacity is as follows:[21]

- East – 195 MW;
- Central east – 380 MW;
- West – 150 MW;
- Central west – 605 MW.

Studies have revealed that there are nine sites that are the most reliable areas to build relatively large wind power plants (see Figure 16), while wind power cannot be effectively exploited in the remaining territory. However, there are no current studies on the potential for micro turbines for harvesting wind power on the Georgian market.

Detailed information regarding wind potential (average monthly velocities, mean speed, and mean power density) in different locations, given in Annex 1, is based on the information (accurate measurements) from Meteorological Station and High-Altitude Meteomast reports.

Figure 15: Wind Energy Potential and Locations



Source: Georgian wind power atlas, 2004

Table 9: Potential Wind Energy Locations

Zone	Location	Capacity (MW)	Annual output (million kWh)
1	Poti	50	110
2	Tchorokhi	50	120
3	Kutaisi	100	200
4	Mta Sabueti 1	150	450
5	Mta Sabueti 2	600	2,000
6	Goti-Kaspi	200	500
7	Faravani	200	500
8	Samgori	50	130
9	Rustavi	50	150
	Sum:	**1,450**	**4,160**

Source: Georgian wind power atlas, 2004

[21] http://www.gse.com.ge/sw/static/file/TYNDP_GE-2019-2029_ENG.pdf

3.3.3 POWER GENERATION TECHNOLOGIES FOR MOUNTAINOUS REGIONS

One of the most effective ways to implement sustainable energy projects is to utilize the existing potential, that which would have minimal operational and maintenance costs and would not require the purchase of an energy source.

Planning rural electrification in mountainous regions requires the optimization of electrical access within a given territory and timeframe. It thus involves proposing a plan for the development of electricity services for a territory, thereby attaining the eventual objective of the preformulated rural electrification strategy. Traditionally, an objective can be translated under an electrification rate, to be achieved within a set time horizon, with or without investment constraints. The most important factors for the assessment are: the coverage rate – including the number of locations without supply – and the access rate – the number of households in locations without an energy supply.

Considering the current potential, knowledge, and information regarding various energy sources, the following options can be considered for the mountainous areas of Georgia:

Electricity:

- Micro hydro turbines;
- Micro wind turbines;
- Solar Photovoltaic (PV);
- Diesel-engine generators.

Heating & cooking:

- Energy efficient stoves for cooking & heating;
- Biogas for cooking & heating;
- Solar water heaters;
- Gas (propane-butane).

Electricity:

Micro hydro turbines

Small HPPs can aid development in the high mountains, both in centralized and decentralized regions, making an additional contribution by improving productivity – for example, powering small agro-industries. Micro hydro systems have also had an impact on social cohesion both at the community and household levels.

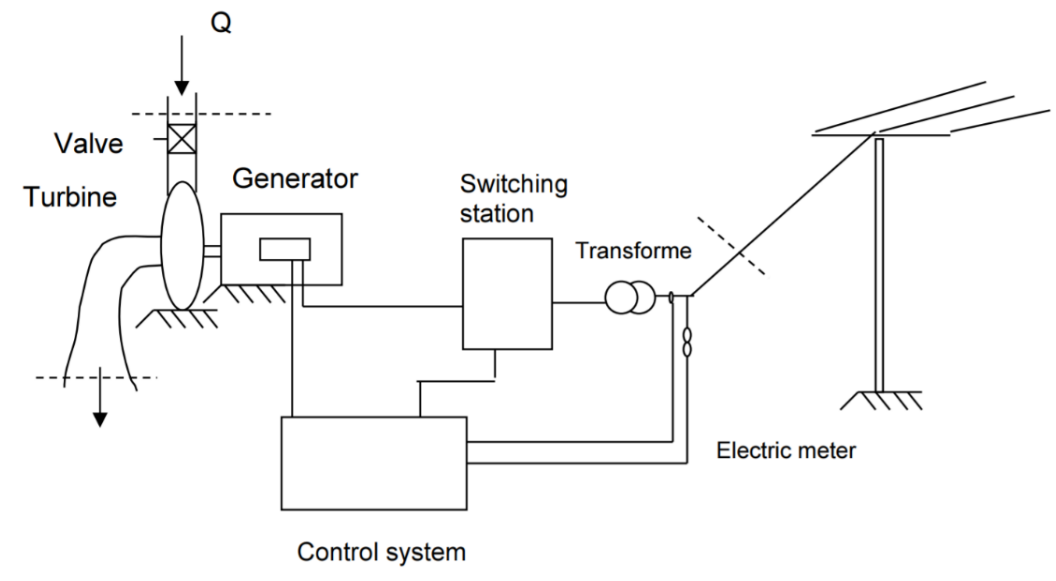
Before planning the technology, the potential and social situation within rural areas needs to be assessed. The design ought to be based around long-term river flow data, which is often missing in Georgian rural areas; or when the data exists, it is from the Soviet period and is outdated. Moreover, when taking global and regional climate change into account, river flows patterns are also uncertain.

As they require large components (dams, penstocks, powerhouse, etc.), the design and operation of hydropower plants greater than 1,000 kW is complex, and such installations are typically connected to either the national or a local electric grid. However, in high mountainous regions it becomes more viable to have installations of between 1 to 500 kW capacity installed.

Micro Hydro Power Plants (HPPs) are simpler to install and many plants are run off-the-river, meaning that no storage is required, and all stream flow is either run through the plant or spilled. For most equipment, standardized options exist as an entire package. The turbines, for instance, are very simple in design (for example crossflow, or Pelton – often chosen for its large operating range, as it can handle large water flow variations using only one unit). A typical installation may serve one or more isolated communities, and can also be connected to a larger grid.

Operation and maintenance are an important factor to be considered in the design of micro HPPs, where operational safety should be taken into account. Nevertheless, the cost of electricity from a micro hydro system has proved cheaper than other sources, moreover, they can provide 24-hour generation.

Figure 16: Schematic Diagram of a Micro Power Plant



The following equation is used for calculating the power of an HPP:

Power = m x g x H_{net} x η

Where:

P = Power output, watts
m = water flow rate in kg/s
g = the gravitational constant, (9.81 m/s2)
H_{net} = falling height, head in m
η = the product of all component efficiencies, normally the turbine, drive system, and generator

Before choosing the appropriate appliance, the following items need to be considered:

- References – to obtain information from other developers who have used the same supplier;
- Efficiency – to be critical of the alleged turbine efficiencies, not supported by reliable data;
- The operational reliability can be just as important as a high efficiency;
- Power plant automation – regarding how much work is required for daily operations;
- Turbine operating range – such as the maximum and minimum rate of water flow for continuous operation, vital for maximizing use of the flow.

Before installing and operating a power plant, members of a community need to be trained, both in theory and practice, in hydro turbine selection and installation. The training should include several aspects: the building of hydraulic works, the installation of hydro turbines, the construction of the electrical lines, and the creation of interior facilities.

Major obstacles

- The three problems most often associated with unsuccessful small HPP projects are: poor planning and operation, high capital costs, and the low load factor;
- Poor training or selection of plant operators is a universal problem;
- Small hydro plants are obviously limited to sites near communities with good hydrologic and hydraulic potential. They are most suited to small, densely populated communities, where transmission distances are small if grid connected;
- Hydro plants depend on local meteorological conditions. Without seasonal storage, stream flow in the dry season may fall below plant capacity and power shortages may occur;
- The impact of geography on logistics needs to be considered to avoid project delays and additional costs.

Micro wind turbines

Wind energy systems can be one of the better cost-effective, home-based renewable energy systems. However, wind electric systems only work if there is sufficient wind, and if they are grid connected or have a battery storage system.

Wind itself is created by the uneven heating of the Earth's surface by the sun. Wind turbines convert the kinetic energy in wind into a mechanical power that runs a generator, producing clean electricity; essentially, wind turns the blades, which then spin a shaft connected to a generator or rotor, which creates electricity.[22] Modern turbines are versatile and modular sources of electricity, with aerodynamically designed blades that capture maximum energy from the wind.

The size of the wind turbine required depends on its application. Small turbines range in size from 20 watts to 100 kW; "micro" (20-500 Watt) turbines are used for small-scale applications, such as charging batteries; while 1 to 10 kW turbines can be used for functions such as pumping water.

Wind speeds fluctuate, impacting electricity generation capacity and operating characteristics. In general, wind speeds are as follows:[23]

- A minimum wind speed of two meters/second is required to rotate most small turbines;
- At 3.5 meters/second is the typical cut-in speed when a small turbine starts generating power;
- At 10-15 meters/second it produces its maximum power generation;
- At a maximum of 25 meters/second (the cut-out speed) the turbine stops or is decelerated.

The Rated Annual Energy of a wind turbine is the calculated total energy that would be produced during a one-year period at an average wind speed of five meters/second. The formula below illustrates the important factors in wind turbine performance. Note that wind speed (V) has an exponent of 3 applied. Thus, even a small increase in wind speed results in a large increase in power. Consequently, taller towers increase the productivity of any turbine by offering access to higher wind speeds.

The following equation is used for calculating the power of a wind turbine:

$$P = C_p \, 1/2 \, \rho \, A \, V^3$$

Where:

P = Power output, watts
Cp = Maximum power coefficient, ranging from 0.25 to 0.45, dimension less (theoretical maximum = 0.59)
ρ = Air density, kg/m³
A = Rotor swept area, m² or π D²/4 (D is the rotor diameter in m, π = 3.14)
V = Wind speed, meters/second

At present, there are a growing number of companies designing turbines that operate in less-than-ideal wind conditions. Many producers also provide small scale wind turbines applicable for rural areas.[24]

Major obstacles

- Wind power can be used in off-grid systems (stand-alone systems), however, without creating hybrid power systems (small solar system, battery storage), they cannot provide a reliable power supply and the consumer may only receive intermittent power;
- Wind is unpredictable, and assuming no wind measurements have been tested on site, it is always a gamble. Regularly, people simply "feel" there is a lot of wind, which usually means that the wind speed is only around 4-5 m/s, a low value for a wind turbine;
- The cost of wind power turbines can be higher compared to other sources;
- The design and the location of a power plant must be secure to avoid low generation (considering obstacles such as hills, trees, buildings, structures, etc.);
- Considering geographic location and available road access road, the logistics of providing larger wind turbines may be a problem in some mountainous areas.

Energy efficient stoves

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[22] https://windexchange.energy.gov/small-wind-guidebook#intro
[23] http://www.level.org.nz/energy/renewable-electricity-generation/wind-turbine-systems/
[24] https://www.renewableresourcescoalition.org/best-home-wind-turbines/

In order to assess the relevant biomass technologies, it is important to define the biomass used for producing energy (for warmth, cooking, and heating water). The most widespread technology currently used is in energy efficient stoves. Moreover, such stoves are easy to produce and are manufactured locally, including production in the Shuakhevi municipality.

One recent project sourcing alternative energy sources for villages without access to natural gas was completed by an Non-Governmental Organization (NGO), Green Borjomi, in the village of Qvabiskhevi located near Borjomi. Eleven families were given energy efficient woodburning stoves for cooking and heating, solar water heaters were also installed for a hot water supply.

The use of wood stoves in Georgia has been comprehensively discussed in a Winrock International report; which describes current rural wood stoves as inefficient, poorly made, failing to meet consumer needs, requiring continuous tending, and not meeting basic safety requirements. However, the report fails to provide the exact models of stove on the market. Although the report is very old, the situation still remains the same.

Solar PV

A PV system consists of photovoltaic modules (an array of cells generating electricity) and the Balance-Of-System (BOS). Depending on the size of the system, an appropriate number of PV modules are electrically connected, forming a module array. PV modules that are connected in a series form PV strings that are then connected in parallel via string boxes to the BOS. The BOS generally includes, apart from the necessary cabling, batteries (if applicable), a charge controller, a DC/AC inverter, and other components based on the system configuration.

The global formula used to estimate the electricity output generated in a photovoltaic system is as follows:

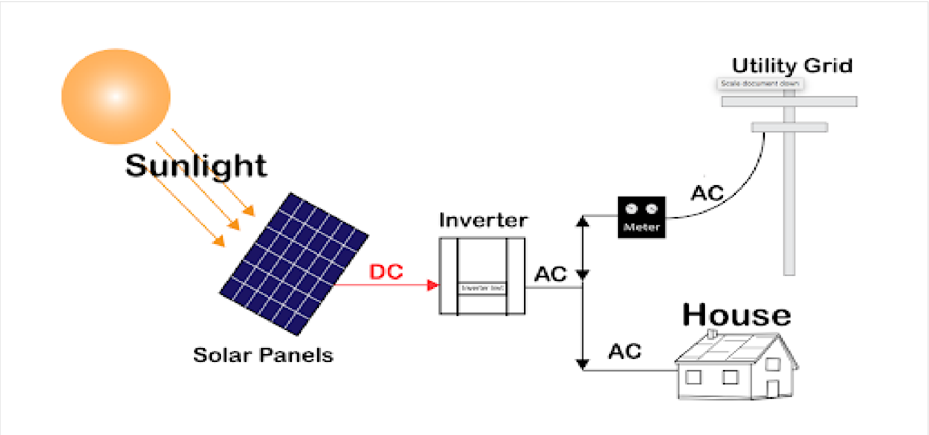
$$E = A * r * H * PR$$

Where:

E = Energy, kWh
A = Total solar panel area, m^2
r = Solar panel yield or efficiency, %
H = Annual average solar radiation on tilted panels, kWh/m^2 year
PR = Performance ratio, coefficient for losses (ranging between 0.5 and 0.9, default value = 0.75)

The following (Figure 18) provides an indicative layout of a PV system:

Figure 18. Schematic Diagram of PV Solar System[25]



Major obstacles

- Location and available sunlight are the main factors in determining the efficacy of solar power. Not all locations receive equal sunlight annually, thus the potential efficacy of solar power can drop dramatically;

[25] http://www.nt-energysolutions.com/en/Article/Detail/101927

- A lack of system reliability; solar efficiency is also determined by the season and daylight hours, with lower generation in winter, and zero generation during the night. Consequently, either excess energy from the day needs to be stored, or buildings need to connect to an alternate power source, such as the local utility grid, which decreases the viability of solar panels;
- Most household solar panels convert only 14% of their available energy into power. The most efficient solar panels, already available on the market, convert only 22% of their available energy into power;
- Solar panels undergo deterioration from ultra-violet rays, moreover, elements like wind, hail, snow, dirt, and temperature fluctuations are serious threats to solar panels. Most PV panels have a lifespan of 20-25 years;
- Storing large amounts of electricity is the greatest obstacle in producing solar power. Currently, the battery storage options for storing solar energy as electricity are extremely expensive. For example, Tesla has created the Powerwall battery to store solar energy,[26] however, one 14 kWh battery costs around $7,100 including installation;
- Beside the declining cost of PV panels, the initial investment is still high, especially when including battery storage systems. On the Georgian market, local suppliers will install a 1 kW system for somewhere in the range of 600-800 USD;
- Poor design, quality, and improper operation and maintenance may also prove a drawback. Particularly in the quality of the PV panels, which ought to be purchased from verified, experienced seller.

Diesel-engine generators

The modern diesel generator has proven to be exceptionally versatile and robust at providing moderate amounts of electricity. Diesel generators are common in many remote settlements, either for a single user or as part of a local distribution network. Such systems may be operated by a power utility or by private enterprises. Generally, the electricity produced by diesel generators is more expensive than from electrical grids, however when there is no access to the grid, a generator can be used as an auxiliary source during critical periods. Typically, generators satisfy basic household needs and certain agricultural and cottage industry applications.

The expense of maintenance, and of transporting diesel fuel and lubricating oil to remote places, ensures such electricity is costly, however, energy is typically highly valued by local populations because of the enormous improvements it brings to living standards.

Major obstacles

- Fuel can be extremely expensive, or completely inaccessible, especially if mountainous communities have no additional income;
- The generators are dependent on a fuel supply, which, among other issues, creates difficulties with transportation;
- Maintenance is far from trivial, and spare parts may be unavailable in rural areas;
- Diesel generators are often noisy, highly polluting, and have low overall efficiency.

Heating & cooking:

Energy efficient wood stoves

The wood stove currently available in Georgia are inefficient, poorly made, do not meet consumer needs, require continuous tending, and fail to meet basic safety requirements. Because there are no additional options, there is a significant amount of wood use in rural Georgia. Nearly every rural home has a woodpile; it is often possible to see the gathering of wood along roadsides and being transported by carts and trucks. In addition, wood is relatively expensive.[27]

Because there is currently no alternate production of wood pellets, brackets, etc., wood remains the main source for stoves in Georgia alongside agricultural residue.

Efficient wood stoves are quite beneficial in mountainous regions as they use cheap, renewable local fuel, and do not rely on petroleum. They produce far less pollution than a fireplace (though even

[26] https://www.tesla.com/powerwall

[27] Wood Heating Stoves in Rural Georgia, May 2008, Winrock International, USAID

certified wood stoves produce higher emissions than natural gas stoves). However, a wood stove is only as efficient as its installation; proper installation considers a house's heating requirements and uses the natural movement of heat and air to get the most from its output. Careless installation, on the other hand, might ensure a wood stove is no better than a fireplace.

Major obstacles

- Continual use requires a regular supply of wood and biomass (agricultural remains), which may not always be available in every rural area;
- The upfront capital cost of building a sizeable wood energy facility (particularly those with automated conveyor systems) can be high and can take years to realize any savings;
- The use of wet materials should be avoided as they decrease burning efficiency. Though, equipment to dry wood and improve efficiency is very expensive. While dry wood is highly flammable and requires a sophisticated boiler system;
- Wood stoves require regular cleaning and care, where improper maintenance could lead to pollution from the chimney;
- Wood stoves also present risks, such as accidental fires and carbon monoxide poisoning.

Biogas

The technology used to produce biogas is quite cheap. It is also easy to set up and requires little investment to operate at a small scale. For instance, small biodigesters can be beneficial in homes, utilizing kitchen waste and animal manure. The gas manifested can thus be used directly for cooking and electricity generation. A household system pays for itself after a time, and the materials used for generation are free. Hence, the cost of biogas production can be relatively low.

Major obstacles

- An unfortunate disadvantage of biogas is that the present production systems are inefficient. There have been no new technologies to simplify the process, or to make it both abundant and low cost. Therefore, large scale production for a large population is still not possible;
- Biogas generation is also affected by the weather. The optimal temperature bacteria need to digest waste is around 37°C. In cold climates, digesters therefore require a heat source to maintain a constant biogas supply;
- Biogas digesters are not cost-effective for areas with a high population;
- These biodigesters have a moderately low lifespan (around 15 years) and thus require replacement after a relatively short time;
- Another disadvantage is that industrial biogas plants are only viable when raw materials are local and in plentiful supply.

Solar water heaters

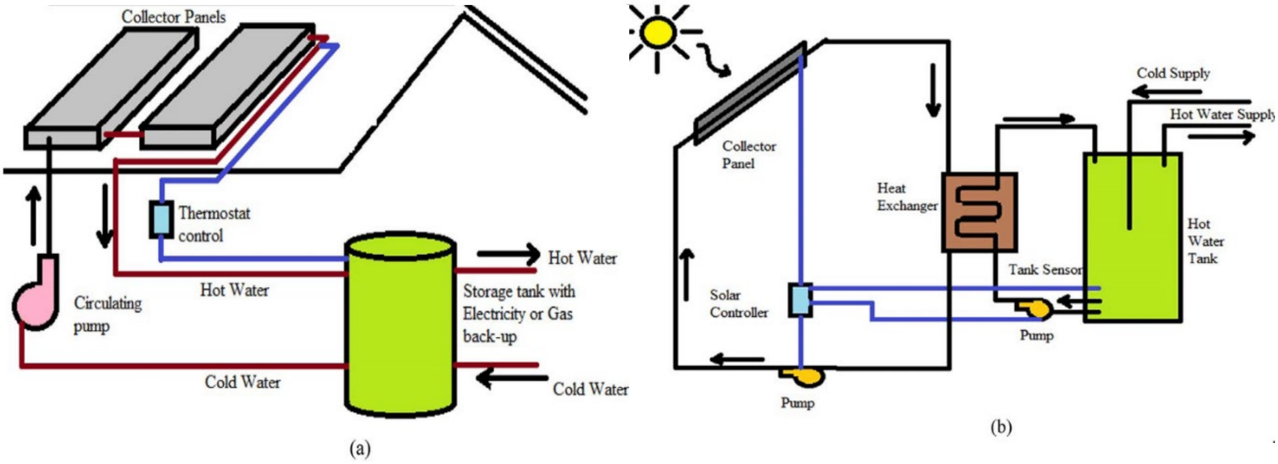
Using a large-scale solar heating system to provides hot water from a solar collector array; including a solar collection system, a water storage system, a control system, and a pump system. Solar hot water engineering works in a similar manner to domestic solar hot water systems, and acts like a large central heating system.

There are generally two types of solar water heating system on the market: active and passive.

Active solar panels solely rely on external energy sources, and use hot water pumps or fans to pump fluids. One of their main benefits is that they can be used to increase the effectiveness of a solar system.

Passive energy systems use the sun’s energy for heating and cooling purposes and operate without reliance on external devices. The total success of a passive solar system depends on its overall orientation and the thermal mass of its walls. Passive solar panels also depend heavily on their design, construction, and on the building.

Figure 19: Schematic Diagram of Active (a) and Passive (b) Solar Water Heaters



Major obstacles

- The same obstacles apply as with solar PV panels; though, it should be reiterated that solar water heaters require direct sunlight to function;
- The system does not function on cloudy, rainy, or foggy days;
- Annual maintenance is also recommended to check the pump and the antifreeze levels, especially in high mountainous areas during winters, when temperatures can drop below 0 degree Celsius.

Gas (propane-butane)

The use of cooking gas containers was fairly active during the Soviet period in Georgia, and regularly acted as an alternative energy source, especially in rural areas. However, it is no longer popular due to the price and logistics of supply.

In areas where wood is less widely available and the power grid is not connected, using gas cylinders remains an effective and viable option, moreover, it might reduce logging in critical regions.

Major obstacles

- The cost of fuel might not be viable for people in rural areas;
- Liquefied petroleum gas is stored in a cylinder attached to a gas stove. The fuel for cooking is toxic and is highly dangerous; if it leaks, turning on any device or even switching on the power could cause the cylinder to explode;
- Limited quantities ensure that buyers have to purchase a new gas cylinder, which requires secure logistics in place to quickly substitute or refill the fuel when necessary;
- Although natural gas is easy to store and transport it has one big disadvantage, its volume is four times that of petrol. Thus, it is more expensive to store since additional space is required;
- Aside from the positives of natural gas, it is worth recalling that it is also a non-renewable energy source.

4. OBJECTIVES

Around 65% of Georgian territory is covered by mountains, thus the sustainable development of mountainous regions is an essential component of regional development policy. The policy on development is directed towards ensuring equal socio-economic progress across all regions, and aims at solving the socio-economic challenges faced by inhabitants of mountainous regions. The primary objectives of the development policy are to improve the wellbeing of residents in mountainous areas, increase levels of employment, and stimulate economic growth.

GENERAL OBJECTIVES

Access to affordable, reliable, sustainable, and modern energy holds a crucial role in the wellbeing of communities in Georgia's mountainous regions. In order to ensure this goal, the general objectives of governmental intervention are to:

1. Ensure energy security in Georgia's mountainous regions;
2. Ensure affordability of energy to all existing and potential users in mountainous regions;
3. Ensure environmental sustainability and reduced CO_2 emissions;
4. Ensure compliance with EU Directives and the UN 2030 Agenda for sustainable development.

SPECIFIC AND OPERATIONAL OBJECTIVES

A number of specific and operational objectives are further associated with the general objectives listed above.

The specific objectives include:

- The development of a reliable energy infrastructure, through the adoption of modern technologies for the utilization of alternative energy sources;
- The introduction of new economic instruments for reliable, affordable, and sustainable access to energy;
- A redesign of the energy subsidy programs currently implemented in mountainous regions;
- The implementation of awareness raising activities concerning alternative energy sources and respective modern technologies.

Table 10: Summary of the Objectives

OBJECTIVE	INDICATOR	RESPONSIBILITY	TIMING
Ensure energy security in the mountainous regions of Georgia			
Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for everyone.[28]	Investments in energy efficiency in rural areas, as a percentage of Gross Domestic Product (GDP) and an amount of foreign direct investment in financial transfers, for infrastructure and technology for sustainable development services.	MoESD	To be measured annually.
All individuals willing to use alternative energy sources have access to such sources and the respective appliances.	% of HH and enterprises using alternative energy sources.	MoESD and MRDI	TBD.
Ensure the accessibility of information regarding state programs for HHs and enterprises.	The percentage of Targeted Social Assistance (TSA) and non-TSA HHs obtaining information on state programs for alternative energy sources.	MoESD	To be measured during the first year of the intervention.
Social workers become aware of HH energy supply and efficiency practices.	The number of trained social workers; A change in pre- and post-test scores of trained social workers.	MoESD	All social workers covering mountainous regions are trained by year Y.[29]

[28] This objective and indicator are taken from the national SDG matrix (SDG 17).
[29] To be defined by the respective body.

OBJECTIVE	INDICATOR	RESPONSIBILITY	TIMING
Ensure affordable energy to all existing and potential users in mountainous regions			
New economic instruments in the form of grants, loan guarantees, and interest rate and investment subsidies are introduced for HHs and enterprises.	% of TSA HHs receiving grants for adopting alternative energy sources; % of non-TSA HHs receiving loan guarantees and interest rate subsidies for adopting alternative energy sources; % of enterprises receiving subsidies for providing communities with energy supply services; % of HHs and enterprises receiving investment subsidies.	MoESD and MRDI	To be measured annually.
Ensure environmental sustainability and reduced CO_2 emissions			
Increased access to reliable and modern energy sources.	% of population with access to reliable and modern energy services.	MoESD and MRDI	To be measured annually.
The share of renewable energy (hydro, geothermal, solar, biofuel and waste) increases.[30]	% share of renewable energy on the market.	MoESD	To be measured annually.
Ensure compliance with EU Directives and the 2030 Agenda for sustainable development			
The state policy on energy supply is revised to ensure the fair treatment of all existing and potential users and the efficient use of energy.	The energy supply policy is adapted to local needs and justification for subsidies is documented.	MoESD and MRDI	Achieved by year Y.
Enhanced international cooperation that facilitates access to clean energy research and technology, including renewable energy; energy efficiency; advanced, cleaner fossil-fuel technology. To also promote investment in infrastructure and clean energy technologies in Georgia.[31]	An amount of foreign investment is mobilized towards clean energy research and technology.	MoESD	To be measured annually.

[30] This objective and indicator are taken from the national SDG matrix (SDG 17).
[31] This objective and indicator are taken from the national SDG matrix (SDG 17).

5. POLICY OPTIONS

The policy alternatives described below aim at solving the issues of energy security, equity, and environmental sustainability in high mountainous settlements. When designing these policy alternatives, we have tried to consider local contexts and the difficulties of energy access in the mountains. It is noteworthy that 99% of the Georgian population has electricity access, yet the major challenge the population in high mountainous regions face is satisfying basic heating needs (GEOSTAT, 2020). These policy alternatives thus aim to resolve the energy trilemma in mountainous regions, and are formulated as follows:

- Option 0 – The status quo where provisions on energy access in mountain settlements remain unchanged;
- Option 1 – Grants and interest rate subsidies for HHs in mountainous regions;
- Option 2 – Lump sum payments to HHs in mountainous regions.

The policy options are described in greater detail below:

Option 0 – The status quo, provisions on energy access in mountain settlements remain unchanged

In the status quo scenario, the current support mechanisms that ensure energy access in mountainous regions are unaffected. The government will continue providing 50% payment of electricity, up to 100 kWh,[32] for households permanently inhabiting in high mountainous regions. Furthermore, the government will, rather sporadically, continue providing payments for certain forms of energy across different parts of the country; such as free electricity to households in Upper Svaneti or provision of up to 700m^3 of natural gas to households in the Kazbegi municipality. On average, 5 mln. GEL is spent annually on natural gas subsidies in the Kazbegi and Dusheti municipalities.

Under the status quo, certain laws and regulations from the environmental and energy legislation will have an impact on access to energy in the mountains. Notably, provisions of the Law on Energy and Water Supply require the central government and local municipalities to develop specific policies for the electricity and natural gas supply of vulnerable customers.[33]

Within this option, the government will fail to implement policies uniformly addressed towards high mountainous settlements. The status quo therefore assumes that local municipalities and the central government will not design any specific policies for energy access in mountain settlements.

Keeping the status quo is associated with the following positive outcomes:

- Continuing with the current energy support scheme in high mountainous regions entails low fiscal pressure on the state budget;
- The government has the opportunity to continue providing specific support in consideration of local conditions and needs.

The risks associated with the status quo are as follows:

- The current governmental support (provisions of the Law on High Mountainous Regions) will not resolve the persisting energy trilemma in mountain settlements;
- The current sporadic governmental support, only provided in few regions, creates notable inequalities;
- The sporadic approach encourages the overconsumption of energy in respective regions.

Option 1 – Grants and interest rate subsidies for HHs in mountainous regions[34]

This option aims at providing subsidies to the population permanently residing in high mountainous regions. This policy considers support based on the social condition and vulnerabilities of a household in order to maximize its reach and effectiveness. An investment subsidy program would be oriented towards helping permanent mountainous residents purchase and install necessary energy generating appliances, such as solar panels, solar thermal collectors, biomass heaters, biomass reactors, etc. The investment subsidy could potentially include three instruments:

[32] The Law of Georgia on the Development of High Mountainous Regions – Article 4.
[33] The Law of Georgia on Energy and Water Supply – Article 112.
[34] The option is adapted from Estonian, Romanian, Austrian, and German cases. See: http://www.res-legal.eu/

- **Grants** – Households receiving TSA would be eligible for a specific grant for the purchase and installation of appliances, and the initial purchase of necessary fuel to improve energy access. To ensure the effectiveness of the program, any grant received or respective appliance should not be counted against the social assistance score of a household receiving TSA. Furthermore, any grant would be provided based on a pre-purchase invoice submitted to a social worker, and the household would receive their appliance once the state completes the transfer.[35]
- **Loan guarantees and interest rate subsidies** – Households that do not receive targeted social assistance could apply for a subsidized loan at a commercial bank. In this respect, the government would provide two types of support. To minimize risks and ensure that credit is available, the government would provide a guarantee on the loan amount. Furthermore, borrowers would receive a subsidy for the full amount of the loan during a specific period. To simplify procedural issues, loan guarantees and interest rate subsidies, payable in installments, should be available for permanent residents of high mountain settlements directly from the relevant appliance stores.

In addition to grants, loan guarantees, and interest subsidies, the government would conduct an awareness raising campaign. This includes distribution of information regarding the three potential propositions using every available channel (e.g., local Information and Consultation Centers (ICCs), municipality representatives, the local media, etc.). Moreover, as social workers have the most contact with marginalized HHs who receive TSA and have limited access to the program, any information campaign should, to ensure the effectiveness of the program, include training for social workers to raise their own awareness about energy supply and efficiency.

Therefore, Option 1 entails both a grant program for socially vulnerable, TSA beneficiaries and a loan interest subsidy for other HHs. Enterprises are not eligible for the program, and specific support for technologies is provided only indirectly through subsidizing loans. In this option, the state would provide a list of the appliances available under subsidy.

Option 1 is associated with the following potentially positive outcomes:

- A grant program, implemented with the support of social workers, provides decentralized assistance and considers individual household needs. This would be conditional on an effective awareness raising program from social workers;
- A well-organized information campaign, on alternative energy sources and energy efficiency, has the potential to substantially increase the awareness of the local population in mountainous settlements;
- Option 1 would reach all social groups in high mountainous areas, based on their social vulnerabilities;
- Potential inefficiencies associated with the implementation of commercially unfeasible gas supply line projects could be avoided;
- The loan program would create some incentivization for the more sustainable use of appliances, as costs are partially incurred by a household;
- The option contributes to increased energy security, affordability, and environmental sustainability.

Option 1 is associated with some potential risks:

- In the case of insufficient awareness raising efforts, the effectiveness of the program may be limited;
- The grant program represents an additional challenge for social workers. Considering the current limited capacity and unrest in the institution,[36] the project could have implementation troubles, both in terms of quality and coverage;
- The grant program may not be sustainable in the longer term, as socially vulnerable groups might not retain enough fuel to utilize their appliances after the first year;
- One risk associated with state subsidies and loan programs is non-payment of a loan, although this would also influence the credit status of a borrower, it might not be a sufficient disincentive to ensure long-term payments;

[35] It ought to be noted that the program can be implemented both by the local municipal government and the social service agency.
[36] Social workers in Georgia recently protested over their working conditions (EMC 2019).

- The short-term nature of the guarantee and loan program does not incentivize community solutions for heating or electricity supply, those that could potentially be implemented by a group of households;
- State subsidies might incentivize inefficiencies through decreasing rural-urban and inter-regional migration within the country.

Option 2 – Lump sum payments to HHs in mountainous regions[37]

The second option intends to provide investment support for specific types of technology to be implemented in high mountain settlements. All investment subsidies for specific technologies would be provided to the HHs. Similar to Option 1, enterprises would not be covered by the policy. The investment subsidy consists of two potential components:

- **A loan guarantee** to enable individuals and companies to take loans for the purchase and installation of specific technologies;

- **An investment subsidy** of a one-time lump sum payment to an individual. The investment subsidy could be given for a specific installed capacity (or heating capacity) of the technology used. Another method could potentially be the use of a specific methodology to define the amount of the subsidy (see The methodologies defined by Italy for different technologies). In Option 2, the investment subsidy would be unconnected to loan interest rates and could be provided to an individual HH irrespective of taking on debt for project implementation. Furthermore, investment subsidies for individuals could be centrally managed (by an executive institution or local municipality).[38]

One major condition for receiving an investment subsidy would be to demonstrate that the technology purchased had been installed and is being used.

Akin to Option 1, the second option entails creating awareness raising campaigns among local populations in the mountains. This is intended to increase their understanding of the opportunities of using different technologies and to communicate the structure of the support scheme.

Option 2 is associated with the following potentially positive outcomes:

- An investment subsidy could potentially decrease energy poverty and issues with energy access. It may also facilitate the more efficient and sustainable use of resources;
- Investment subsidies could potentially provide greater incentive for individuals to implement energy access projects;
- Potential inefficiencies associated with the implementation of commercially unfeasible gas supply line projects could be avoided;
- An investment subsidy would positively influence the financial feasibility of projects and decrease payback periods.

Option 2 is associated with some potential risks:

- Awareness raising campaigns might not be a sufficient to increase local awareness or stimulate project implementation;
- One risk associated with bank guarantees is non-payment of a loan, although this would also influence the credit status of a borrower, it might not be a sufficient disincentive to ensure long-term payments;
- Projects may not have sufficient cashflow for implementation during their initial stages;
- The methodology defined and the investment subsidy may not best enhance efficiency.

In both Option 1 and 2, state energy support programs remain in place. However, it is recommended that they be gradually terminated and the population (in Dusheti and Kazbegi in particular) be incentivized to use alternative energy sources. While most stakeholders admit the current state policy is discriminative and that a uniform approach towards regions should be prioritized, the options suggested in the analysis do not wholly allow for the termination of energy subsidies in Dusheti or Kazbegi, as they focus only on HHs without access to natural gas. Those HHs with access to electricity and natural gas, subsidized by the state, have already incurred investment costs for

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[37] The option is adapted from German and Italian cases. See: http://www.res-legal.eu/

[38] For example: the Ministry of Economy and Sustainable Development, the Ministry of Infrastructure and Regional Development, or the municipal development fund.

respective appliances, therefore such HHs should be targeted and incentivized differently. While both options include awareness raising campaigns that would contribute to an increase in the use of alternative energy sources.

The gradual termination of the electricity subsidy in mountainous regions and natural gas subsidies in the Dusheti and Kazbegi municipalities, as well as removing preferential treatment in Svaneti, would instead enable the state to finance support schemes for the adoption of alternative energy sources.

The data highlights that the average state spending on gas subsidies in Dusheti and Kazbegi equates to 5,136,460 GEL annually, while the electricity subsidy in mountainous regions amounts to an average 8,303,333 GEL annually. Thus if these subsidies were eliminated, the government, on average, would annually save 13,439,793 mln. GEL.

6. ANALYSIS OF IMPACTS

6.1 METHODOLOGICAL APPROACH

For the quantitative study of the impacts, a cost-benefit analysis has been coupled with a qualitative analysis to capture all the major influences. The results of this quantitative analysis have to be taken cautiously, as it does not constitute a forecast, rather an exercise in identifying the distribution of costs and benefits among the major stakeholders in the sector.

The objective of the analysis is to identify the main quantitative impacts of the suggested options for the various stakeholders, in comparison to the baseline scenario. Thus, the quantitative analysis only considers the incremental costs and benefits of Options 1 and 2 with regard to the baseline scenario. The following stakeholders have been considered within the analysis:

Households that can be divided into the two following categories (presented in Table 11):

I. HHs that do not have access to gas and receive TSA;
II. HHs that do not have access to gas and do not receive TSA.

The government maintains the primary role in implementing policy options, and is responsible for providing various support schemes for HHs adopting alternative energy sources.

Table 11: Category of HH in Mountainous Regions

Region	Number of HHs receiving TSA	Number of HHs without TSA
Guria	82	267
Racha-Lechkhumi and Kvemo Svaneti	3,692	11,975
Kakheti	106	388
Imereti	475	1,482
Mtskheta-Mtianeti	442	2,075
Samegrelo-Zemo Svaneti	867	2,459
Samtskhe-Javakheti	567	3,368
Kvemo Kartli	913	5,610
Shida Kartli	143	1,019
Adjara	2,540	10,745

Source: GNERC, 2020; and SSA, 2020

Although the analysis provides recommendations for non-residential users, given that policy options do not concern such users, the quantitative analysis is conducted around HHs – the main target for state intervention.

For the analysis of the policy options the following data sources have been used:

- GEOSTAT;
- GNERC;
- SSA;
- MEPA;
- NFA;
- APA;
- MoESD;
- NBG.

The set of assumptions developed for the policy options is described below:

- The analysis covers 15 years. Given that mountainous regions suffer from depopulation, it is recommended that the energy security problems be resolved within the short or mid-term, rather than longer. Therefore, a maximum of 15 years has been considered within the analysis. The recommendation to solve the country's energy security problem over a short period is also in line with the 2030 Agenda Sustainable Development Goals (SDGs). Relating to the 2030 Agenda and the nationalized SDG matrix, Georgia's target for SDG 7 – "Ensure access to affordable, reliable, sustainable and modern energy for all" – is for almost 100% of the population to have access to electricity and 75% to natural gas by 2030;

- GNERC data shows that, between 2017-2019, the number of gas subscribers across the country increased annually. While the growth rate of the population is currently at zero, and mountainous regions also suffer from depopulation. Therefore, in these regions, the growth rate of the population is negative. Increased access to alternative energy sources is likely to contribute to a reduction in depopulation. In the long-term, increased access to energy, coupled with other components of rural and regional development, might reverse negative growth rate trends. However, since the policy options analyzed deal only with energy security issue, population growth is not expected, rather depopulation is considered halted;
- By the end of the 15-year period, 100% of HHs without access to gas will adopt alternative energy sources or technologies;
- In all regions, except Mtskheta-Mtianeti, 15% of HHs would adopt alternative energy sources in year one of the analysis. In Mtskheta-Mtianeti, it is assumed that the entire Dusheti municipality, which constitutes 60% of the regional population, would adopt alternative energy sources in year one. Therefore, the adoption rate in the first year for Mtskheta-Mtianeti is 60%, not 15%, due to the 100% adoption rate around Dusheti;
- To ensure the 100% adoption rate in the Dusheti municipality in Option 1, in addition to grants and loans for appliances, the state would also subsidize 50% of the energy costs for energy efficient wood stoves. While in Option 2, the lump sum payment is higher in Mtskheta-Mtianeti than other regions;
- The costs of building a gas pipeline would be avoided due to the adoption of alternative energy sources;
- Energy efficient wood stoves consume 20% less wood.

The major variables common to both policy options are summarized in Table 12 below:

Table 12. Model Characteristics

Variable	Value	Comment
Total years of analysis.	15	N/A.
Adoption rate in 15 years.	1	100% of the population uses alternative energy sources within 15 years.
Proportion of the population adopting alternative energy sources in one year.	15.0%	60% for the region of Mtskheta-Mtianeti.
Annual adoption rate (excluding year 1).	14.5%	Assuming that in year one 15% of customers would start to use alternative energy sources, in order to reach 100% by year 15, the annual growth rate should be around 14.5%.
Gas tariff (GEL/m^3).	0.57	N/A.
Annual growth rate of gas tariff.	1%	N/A.

The following macroeconomic variables have been used in the analysis (Table 13):

Table 13: Macroeconomic Variables

Variable	Value	Source
Discounted rate	9.7%	The National Bank of Georgia (the average real interest paid on a 10-year government bond)
GEL/USD exchange rate (reference date – 10 July 2020)	3.0624 GEL/USD	The National Bank of Georgia

Selected alternative technologies

In total, eight technology alternatives were discussed as potential energy sources for the mountainous regions. However, considering the available natural and capital resources, as well as the economic scale of adopting such technologies, only the following four are used in the assessment:

1. PV panels;
2. Energy efficient stoves;
3. Biogas reactors;
4. Solar water heaters.

The use of micro wind turbines has not been considered at this stage as it remains relatively costly for small-scale systems use. It is also difficult to assess the use of micro hydro turbines as they require specific locations to study. While the use of diesel-engine generators and gas (propane-butane) can only be considered in some villages; those without access to gas or electricity, and where it is impossible, due to logistics, to have a grid connected supply.

As Georgia has extremely good solar potential and most of the population has access to wood, the use of energy efficient wood stoves and solar water heaters alongside PV panels are considered the most viable alternatives for household users.

In regions with limited access to wood but high solar potential, it is recommended that energy efficient stoves and solar water heaters be utilized. In certain cases, PV panels are also recommended. In regions with limited access to wood but well-developed animal husbandry, it is recommended that energy efficient stoves and bioreactors are used, while solar water heaters can be employed in all municipalities given Georgia's high solar potential.

Alternatives for residential users (HHs)

As previously discussed, wood remains the largest energy source in rural areas. However, the regions of Guria, Samtskhe-Javakheti, and Kvemo Kartli have the least forested areas, under NFA, compared to other regions (Table 3); access to forests is also reduced in Adjara.

Under current practices, the loss of heat from the consumption of raw firewood is around 30-40% (Caucasus Environmental NGO Network (CENN), 2016). Consequently, due to inefficient firewood use, the population consumes more resources than are actually required. Therefore, by increasing the productivity of firewood, it is possible to reduce the resources consumed.

CENN estimates that, due to its geographical-climatic conditions, the rate of firewood consumption during the winter varies from 4 to 15m^3 in Georgia. Considering the number of rural households, 6m^3 is regarded as the average rate of firewood consumption during the winter season. While households considered to be partial users consume an average of 3m^3 of firewood, however in mountainous regions the volume in winter is 15m^3.

Replacing existing wood stoves with energy efficient equivalents in rural areas would reduce resource consumption and consequently diminish the negative impacts on forests.

The population in rural areas is currently reliant on wood stoves for cooking and heating, and considering limitations on forestry and the available solar potential in Georgia, it is advisable to combine the use of solar water heaters with energy efficient wood stoves. The adoption of such a combination of technologies would allow households hot water access throughout the year.

In order to assess the number of energy efficient wood stoves and solar water heaters necessary to satisfy all municipal family needs, the number of current subscribers has been used as an indicator; where each subscriber is considered to represent one family. It is assumed that every family needs one solar water heater and one energy efficient wood stove to meet household energy demands.

Regarding photovoltaics, high mountainous solar potential varies by region, with Global Horizontal Irradiance (GHI) ranging from 876-1,461 kWh/kWp. Photovoltaic potential is relatively high in the regions of Samtskhe-Javakheti, Kakheti, parts of Kvemo Kartli and Shida Kartli. The installed capacity of PV panels has been calculated by municipalities in order to identify the demand for solar panels. To calculate the necessary installed capacity for solar photovoltaics, actual municipal consumption figures were used from 2019. PV installers operating in Georgia suggest that 1 kW of installed capacity can generate on average 1,350 kWh per year. While the average consumption per HH was calculated and then divided by 1,350 kWh in order to identify the required installed capacity.

Alternatives for non-residential users

Regarding the electricity consumption of non-residential (commercial) users in high mountainous regions, it is recommended that solar photovoltaics (PV) and bioreactors be installed. The core rationality for selecting PV panels are their decreasing prices and the implementation of net metering rules in the country. Thus, these developments create incentives for using the technology. To calculate the necessary installed capacity for non-residential users, the same approach for HHs can be used.

Another alternative to natural gas for non-residential consumption is the production of biogas using livestock residuals in bioreactors. Beyond the energy potential, the use of livestock waste also offers particularly good economic and environmental effects. The equivalent of 1m^3 of biogas, equates to 0.6m^3 of natural gas, 0.7 liters of fuel oil, 0.4 liters of gasoline, or to 3.5kg of firewood. With USAID assistance, some biogas production projects have already been implemented in Georgia. However, as the technologies installed were improperly managed by the owners, these projects were only operational for a few years and are no longer functioning. Nevertheless, considering the country's potential, measured in GEOSTAT data, it is recommended that such projects be implemented in the regions of Imereti, Samegrelo-Zemo Svaneti, Kvemo Kartli, and Samtskhe-Javakheti.

For such biogas reactors, only regions with large number of bovine animals were considered. To calculate the number of biogas digesters needed to utilize the existing potential, certain standard size biogas plants, widely used in other countries, were assessed by their rated daily gas production (m^3/day) with effective digester volumes (m^3).

Using the waste of 3-5 cattle or 8-12 pigs, a 8-10m^3 biogas plant typically produces 1.5-2m^3 gas and 100 liters of digested slurry per day; with this amount of biogas a 6-8-person family can: cook 2-3 meals, operate a refrigerator all day, burn two lamps for three hours and operate a 3 kW motor generator for one hour.

One head of cattle provides 10kg of manure daily, thus, on average, one animal can produce 3,650kg of manure annually. While to produce 1m^3 of biogas around 40kg of manure is required. Therefore, considering the number of bovines, using the previously described assumption for Imereti, in total around 111 m^3 of biogas digesters could be constructed. The same capacity is recommended for Kvemo Kartli, while in the Mestia municipality and the region of Samtskhe-Javakheti, the suggested capacities are 68.6 m^3 and 102.7 m^3, respectively.

Table 14 summarizes the information regarding the types of alternative energy relevant to each municipality, as well as the number of appliances and installed capacity for each technology per HH and non-residential user.

Table 14: Types of Alternative Energy Sources and Technologies

Region / Municipality	Households			Non-residential use	
	Energy efficient stoves	**Solar water heaters**	**Photovoltaics**	**Photovoltaics**	**Bioreactors**
	Number of energy efficient stoves per HH	Number of solar water heaters per HH	Installed capacity of PV panels (kW) per HH	Installed capacity of PV panels (kW)	Capacity of bioreactor digester volume (m^3 gas)
Adjara					
Khulo	1	1			
Khelvachauri	1	1			
Shuakhevi-Qeda	1	1			
Imereti					
Tskaltubo		1			111,6
Kharagauli		1			
Khoni		1			
Bagdati		1			
Kakheti					
Akhmeta		1	0.72	10,663	
Gurjaani		1	0.95	93,102	
Sagarejo		1	1.00	27,951	
Telavi		1	0.96	42,411	
Kvemo Kartli					
Dmanisi	1	1	0.79	3,714	111,6
Tetritskaro	1	1	0.72	10,516	
Marneuli	1	1	1.10	72,248	
Tsalka	1	1	1.06	4,689	
Bolnisi	1	1	0.87	52,850	
Shida Kartli					
Kaspi		1	0.77	62,410	
Khashuri		1	0.78	40,451	
Gori		1	0.88	65,449	
Mtskheta-Mtianeti					
Dusheti	1	1			
Mtskheta	1	1			
Tianeti	1	1			
Racha-Lechkhumi					

Region / Municipality	Households			Non-residential use	
	Energy efficient stoves	Solar water heaters	Photovoltaics	Photovoltaics	Bioreactors
	Number of energy efficient stoves per HH	Number of solar water heaters per HH	Installed capacity of PV panels (kW) per HH	Installed capacity of PV panels (kW)	Capacity of bioreactor digester volume (m^3 gas)
and Kvemo Svaneti					
Oni	1	1			
Ambrolauri	1	1			
Tsageri-Lentekhi	1	1			
Samegrelo-Zemo Svaneti					
Mestia	1	1			68.6
Samtskhe-Javakheti					
Aspindza	1	1	1.18	4,675	
Akhalkalaki	1	1	1.01	13,300	102.7
Akhaltsikhe-Adigeni	1	1	0.92	25,980	
Borjomi		1	0.92	25,980	
Guria					
Chokhatauri	1	1			

Table 15 contains information on appliance characteristics and additional assumptions:

Table 15: Appliance Characteristics

Technology	Installed cost (GEL)	Replacement cost (GEL)	Operations and Maintenance (O&M) cost (GEL)	Energy cost (GEL)	Useful life (years)
Energy efficient stoves	450	-	-	1,200	15
Solar water heater	936	936	28	-	10
Photovoltaics	2,220	-	-	-	20

Energy efficient wood stoves

The installed cost relates to the expense of procuring a Svanetian type wood stove. Online research of the local market shows that such wood stoves cost around 450 GEL on average.

The replacement cost is set to zero as the useful life of a stove is around 15 years, which does not lie within the timespan of the analysis, therefore no replacement would be needed.

The Operations and Maintenance (O&M) costs are set at zero as wood stoves require almost no maintenance and rarely break down.

The energy costs were estimated by determining the required volume of wooden logs (m^3) and multiplying the determined number by local prices per m^3. Each HH from mountainous regions can receive 15m^3 of wood annually under the framework of the social cuts program. Assuming a price of 100 GEL per 1m^3, and that energy efficient stoves consume 20% less wood, if a HH participates in the social cuts program the total energy cost is 1,200 GEL per HH per annum.

Solar water heaters

The installed cost is estimated to be 936 GEL.

The replacement cost is considered as a heater's useful life is 10 years, less than the timespan of the analysis.

The O&M costs comprises 3% of the appliance's cost and equates to 28 GEL on average.

The energy cost is set at zero as the project uses passive solar heaters, in which systems do not use a pump to circulate water from the collection point to storage or other locations.

PV panels

The installed cost is estimated to be 2,220 GEL; given that the price of solar PV varies from 650 USD to 800 USD, under the approximate USD/GEL exchange rate it would amount to around 2,220 GEL.

The replacement cost is set at zero as the useful life of the appliance is 20 years, which is longer than the timespan considered by the analysis.

The O&M costs are set at zero with the assumption that households would clean the PV modules themselves and would not encounter any breakdowns.

The energy costs are also set at zero as the systems are connected to the grid and only generate power when there is a solar resource, therefore they do not require external energy inputs to run.

One benefit of installing PV panels in rural areas is the net-metering scheme, when consumers do not consume their full power production they can receive compensation from selling excess energy to the grid. Generally, net metering represents one wide-spread policy for aiding the development of micro generation power systems (wind, solar, hydro) owned by customers; which are primarily used for HH consumption, though they can also deliver excess energy to a network with respective compensation from the distribution companies.

According to the current Electricity (Capacity) Supply-Demand Rules, micro generation sources are defined as having an installed capacity of up to 500 kW. Micro generation sources are connected to the distribution grid by customers, who then apply to the corresponding distribution licensee and the company is obliged to install a reverse meter, instead of the existing meter, within 10 to 20 working days of the application submission. The customer pays for the connection and meter substitution fee, though the distribution company is obliged to receive electricity from the micro generation source into the network and arrange a settlement according to the remaining net after deducting electricity consumed.

The calculated net power is defined within a May to May settlement period, thus if at the end of April, the customer has delivered surplus electricity throughout the year, the distribution licensee is obliged to arrange a final settlement with the customer according to the weighted average price of electricity, as reflected by the GNERC household tariffs of the respective distribution company.

The net metering mechanism can be used by any natural person, homeowner partnership, urban or rural resident and is not regarded as entrepreneurial activity. Moreover, power sources may not always be the property of the consumer and can be under temporary ownership, such as by lease, rent, or under any other type of agreement.

A further option for net metering is the generation and consumption of electricity occurring in different locations, though all in the area of one distribution company.

According to the 2019 GNERC Annual Report, by end of 2019, the total number of subscribers connected to net metering reached 156, with an installed capacity of 2,158 kW.[39]

6.2 QUALITATIVE IMPACT

The qualitative impacts of the selected policy options are summarized in Table 16 below:

Table 16: The Qualitative Impacts of the Policy Options

Impact	Option 0. Status quo	Option 1. Grants and interest rate subsidies for HHs in mountainous regions	Option 2. Lump sum payments to HHs in mountainous regions
Administrative / state budget	There are currently two forms of assistance in the state budget: 1) Subsidies on electricity and natural gas	This option has both positive and negative effects on the state budget. On the positive side, the government might benefit from the decreased carbon footprints. On the negative side, there are public administrative costs associated with this	The expected positive impacts are similar to Option 1. On the negative side, Option 2 does not distinguish between households with and without TSA, and involves a one-time lump sum payment to the

[39] https://gnerc.org/en/commission/commission-reports/tsliuri-angarishebi

Impact	Option 0. Status quo	Option 1. Grants and interest rate subsidies for HHs in mountainous regions	Option 2. Lump sum payments to HHs in mountainous regions
	consumption in high mountainous areas; 2) Natural gas consumption is fully subsidized in the Kazbegi and Dusheti municipalities.	policy: • Grants – households receiving TSA would receive a specific grant for purchasing and installing the required appliances; • Loan guarantees and interest rate subsidies –households that are not receiving TSA might apply for a subsidized loan from commercial banks. The interest rate would be fully subsidized by the government; • Awareness raising campaigns.	individual.
Economic	Currently, economic development in high mountainous areas is significantly hindered by poor access to energy sources and inhabitant's migration.	Option 1 would have significant economic impacts, divided into the positive and negative. The positive economic impact of the policy option is generated through increased access to energy that will mainly affect the two most important sectors in high mountainous areas: • Agriculture – Increased access to energy would create more opportunities in farming (e.g., unused farm resources might be utilized); • Tourism – Increased access to energy would encourage tourists to visit and stay longer in such areas. Thus, this would enhance development in the area and help strengthen the regional economy; • Access to energy can create more opportunities for off-farm diversification (e.g., agro-tourism activities); • In addition, there are increased employment opportunities generated through the need for the installation and maintenance of new appliances. On the negative side, there could be an opportunity cost associated with the allocation of financial resources on renewable energy sources.	The expected impacts are qualitatively similar to those discussed in Option 1.
Social	Energy insecurity has negative social impacts. There are two types of marginalized group in the high mountainous regions: 1. Those who have access to energy, but cannot afford it (state subsidies for electricity and natural gas consumption in high mountainous areas);	There are potentially both positive and negative social impacts associated with this policy option. On the positive side, socially vulnerable groups – households receiving TSA – would receive grants for purchasing and installing necessary appliances and the initial purchase of fuel to improve energy access. In addition, there are favorable effects on households that use wood as an energy source for cooking and space heating. They often have to travel long distances to collect firewood. Switching to alternative energy sources can increase HH time endowment as a result of the reduced time required for gathering fuel (the opportunity cost of using wood).	The expected social impacts are qualitatively similar to those discussed in Option 1, but Option 2 does not distinguish between households with and without TSA, which may lead to the fewer positive social impacts than in Option 1.

Impact	Option 0. Status quo	Option 1. Grants and interest rate subsidies for HHs in mountainous regions	Option 2. Lump sum payments to HHs in mountainous regions
	2. Those that have no access to energy. Energy insecurity also affects health in multiple ways. Firstly, unreliable energy sources lead to low-quality community healthcare services. Secondly, inhabitants in high mountainous areas may have deteriorating health due to the lack of heat appliances.	Increased access to energy would positively affect living standards and the health conditions of high mountainous inhabitants. Renewables contribute to reducing the use of fossil fuels and their associated air pollutant emissions, thus have a positive effect on human health. On the negative side, there is a risk of non-payment of a loan that would also influence the credit status of a borrower.	
Environmental	Currently, inhabitants in high mountainous areas overexploit the available resources, e.g., forest to meet heating demands. Besides which, the prevalence of illegal logging is extremely high.	This policy option is associated with several positive environmental factors. Firstly, increased access to affordable renewable energy sources might contribute to reduced firewood consumption and illegal logging. Secondly, the renewable energy sources offered are environmentally friendly and can contribute to lower CO_2 emissions.	The expected environmental impacts are qualitatively similar to those discussed in Option 1.

6.3 COST-BENEFIT ANALYSIS

The analysis is based on the assumption that economic trends are exogenous to the state interventions described within the options.

Option 0 – The status quo where provisions on energy access in mountain settlements remain unchanged

There are no quantifiable costs or benefits associated with the baseline scenario. Rather the focus is on the quantification of the incremental costs of Options 1 and 2, those assumed on the basis of the information collected.

Option 1 - Grants and interest rate subsidies for HHs in mountainous regions

In this option, individual households adopt alternative energy sources with the help of the government, where social workers act as intermediaries. This option does not assume any state support for non-residential users. Therefore, it is unlikely that private sector representatives will adopt alternative energy sources without state support. Consequently, there are no costs or benefits considered for the private sector in this option.

Quantified costs:

Households

- **Appliances installed, O&M, energy, and replacement** – HHs with TSA cover the energy, maintenance, and replacement costs of the respective appliances, where non-TSA HHs, in addition to these costs, cover installation of appliances. The costs vary by region and by appliance, from 450 GEL to 2,220 GEL per appliance (installed cost). The remainder of the costs are indicated in Table 15.

The government

- **Grants** – The government provides grants for the price of a respective appliance to HHs with TSA. The grants vary from 450 GEL to 2,220 GEL per appliance;
- **Interest rate subsidies** – The government pays the interest rate on loans for non-TSA HHs; with a five-year loan duration at an annual interest rate of 12.75%;[40]
- **Energy costs** – The government pays 50% of the annual energy expenses for all HHs in Mtskheta-Mtianeti to accelerate the adoption rate of alternative energy sources in the region;
- **Training social workers** – 2,000 GEL is spent annually on training social workers on alternative energy sources, energy security, and the sustainable use of natural resources;
- **Awareness raising campaigns** – 1,000 GEL is spent annually by the state for awareness raising campaigns that outline the importance of adopting alternative energy sources and on the sustainable use of natural resources;
- **Monitoring costs** – Five new employees are hired to perform monitoring activities; required to ensure the effective implementation of state policy. Each monitoring officer has a gross salary of 1,020 GEL.

Quantified benefits:

Households

- **Savings on wood purchase** – Given that energy efficient wood stoves consume 20% less wood, the wood consumption would reduce from 15 m^3 annually to 12 m^3. As 1 m^3 costs 100 GEL, the saving per 3 cubic meters of wood is 300 GEL per HH. This saving is thereafter multiplied by the number of HHs installing and using energy efficient stoves;
- **Grants** – The government provides grants to the price of a respective appliance to HHs with TSA. These grants vary from 450 GEL to 2,220 GEL per appliance;
- **Payments for gas consumption** – By using alternative energy sources, HHs avoid paying for gas. The average consumption of natural gas per HH varies by region, from 331 m^3 in Guria to 1,247 m^3 in Mtskheta-Mtianeti.[41] The consumption of gas is multiplied by the tariff and the number of HHs using alternative energy sources; it is assumed that the tariff rate is 0.57 GEL and increases 1% annually.

The government

- **Reduced CO_2 emissions** – Assuming that 1 m^3 wood contains 350-400 kg of carbon, when burnt it converts into 1,280-1,450kg of CO_2. Consequently, its average carbon footprint is 1.365 t/m^3. The current CO_2 emission price is 20 USD/ton, which amounts to 61 GEL, thus at 3 m^3 the price is 251 GEL. This price is multiplied by the number of HHs installing and using energy efficient wood stoves;
- **Gas infrastructure construction** – According to the USAID Energy *Cost estimation study of gas pipeline network and alternative systems for high-mountainous settlements of Georgia,* the weighted average cost of building a gas pipeline, per consumer, is 11,308 GEL. This figure is multiplied by the number of HHs adopting alternative energy sources. Therefore, the government saves financial resources on the construction of gas pipelines.

Option 2 – Lump sum payments to HHs in mountainous regions

In this option all households are treated equally, irrespective of their social status. There are no state grants provided in this option, however lump sum payments are provided to all HHs willing to adopt alternative energy sources.

Quantified costs:

Households

- **Appliances installed, O&M, energy, and replacement** – All HHs cover installation, energy, O&M, and replacement costs for the respective appliances; these costs vary by region and by appliance.

The government

- **Lump sum payments to HHs** – HHs receive a one-time lump sum payment from the state in the amount of 3,606 GEL, equating to the sum of the installation costs for an energy efficient

[40] These are the terms offered by a commercial bank, ProCredit Bank Georgia, which it offers its client Eco Loans.

[41] Gas consumption per HH is based on the *Cost estimation study of gas pipeline network and alternative systems for high-mountainous settlements of Georgia*, USAID Energy Program (2019).

wood stove (450 GEL), PV panels (2,220 GEL), and a solar water heater (936 GEL). The amount of the lump sum payment is higher in the region of Mtskheta-Mtianeti and equates to 4,000 GEL. It is assumed that the higher amount offered will accelerate alternative energy adoption rates in this region, in the Dusheti municipality in particular. It should be noted that in parts of Europe there is specific methodology for defining the amount of a lump sum payment for energy efficient alternatives, however in Georgia there is no such methodology, and therefore the amount is based on the assumption;

- **Training social workers** – Remains the same as Option 1;
- **Awareness raising campaigns** – Remains the same as Option 1;
- **Monitoring costs** – Remains the same as Option 1.

Quantified benefits:

Households

- **Savings on wood purchase** – Remains the same as Option 1.
- **Lump sum payments from the state** – All HHs receive a one-time lump sum payment from the state in the amount of 3,606 GEL, the sum of the installation costs for an energy efficient wood stove, PV panels, and a solar water heater;
- **Payments for gas consumption** – Remains the same as Option 1.

The government

- **Gas infrastructure construction** – Remains the same as Option 1;
- **Reduced CO_2 emissions** – Remains the same as Option 1.

A summary of the CBA results are presented in Table 17 below:

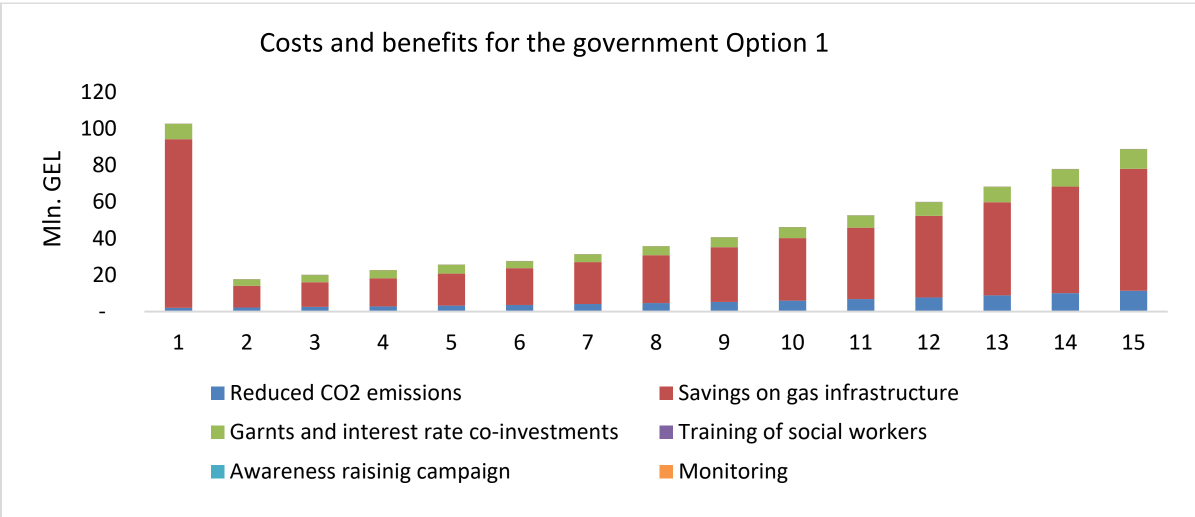
Table 17: The CBA Results

	Option 1	Option 2
NPV of net benefits, general (GEL)	109,496,029	146,644,235
NPV of net benefits, government (GEL)	255,895,479	211,869,888
NPV of net benefits, HHs (GEL)	(146,399,450)	(65,225,653)

As can be concluded from Table 17, both options have a positive general NPV of net benefits, which implies that both generate more benefits than costs for society. In general, Option 2 has a higher net benefit than Option 1, however the difference is not significant as the options differ only by the support schemes the state offers.

The NPV of net benefits for the government is also positive, this is explicable as avoiding gas pipeline construction generates high savings that overshadow the spending on grants, interest rates, and lump sum payments to HHs. The government has higher net benefits in Option 1 compared to Option 2 because the lump sum payments provided in the second option for each HH are higher than state spending per HH in Option 1.

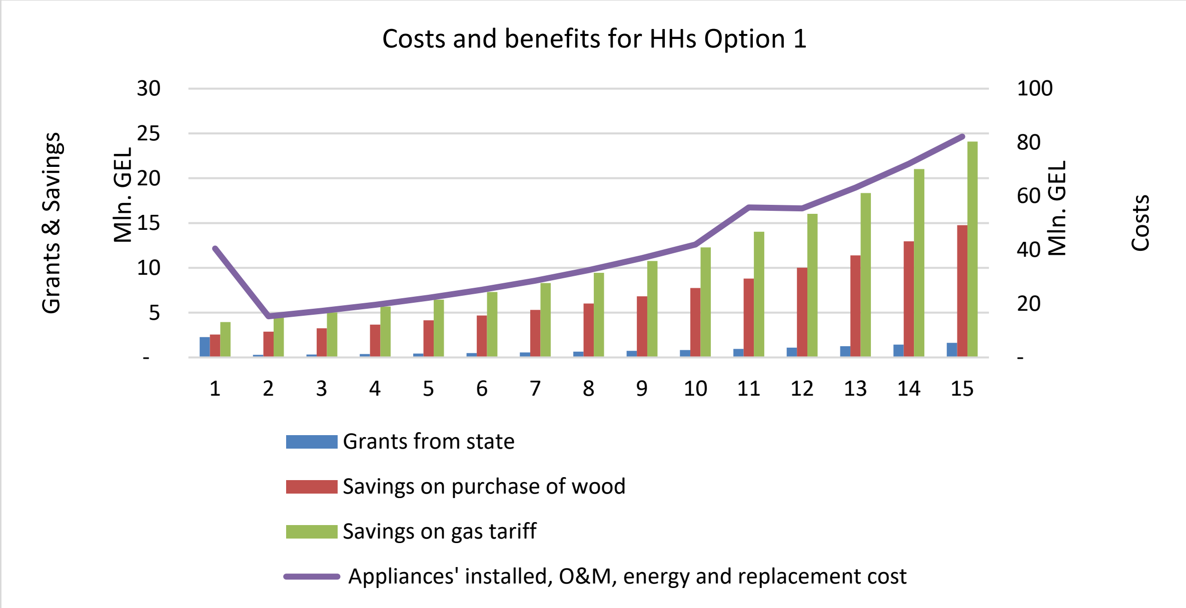
Figure 20: Costs and Benefits for the Government in Option 1



HHs, on the contrary, have a negative NPV as they have to incur the different costs related to the adoption of alternative energy sources. For instance, the greatest cost for HHs is on the wood needed for energy efficient stoves.

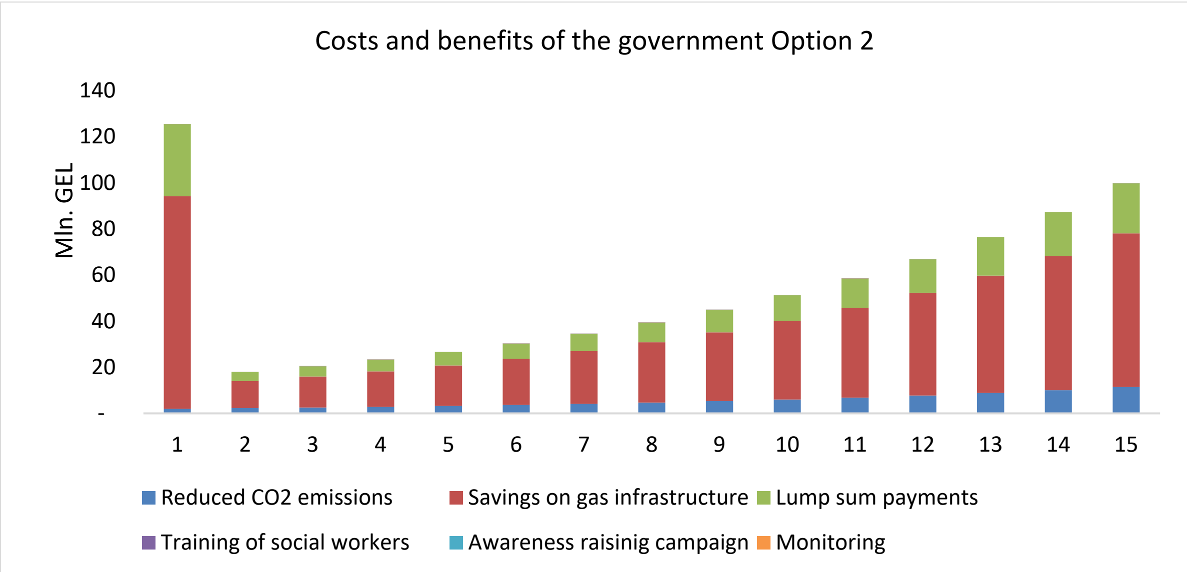
The categories of costs and benefits for HHs in Option 1 are presented in Figure 21:

Figure 21: Costs and Benefits for HHs in Option 1



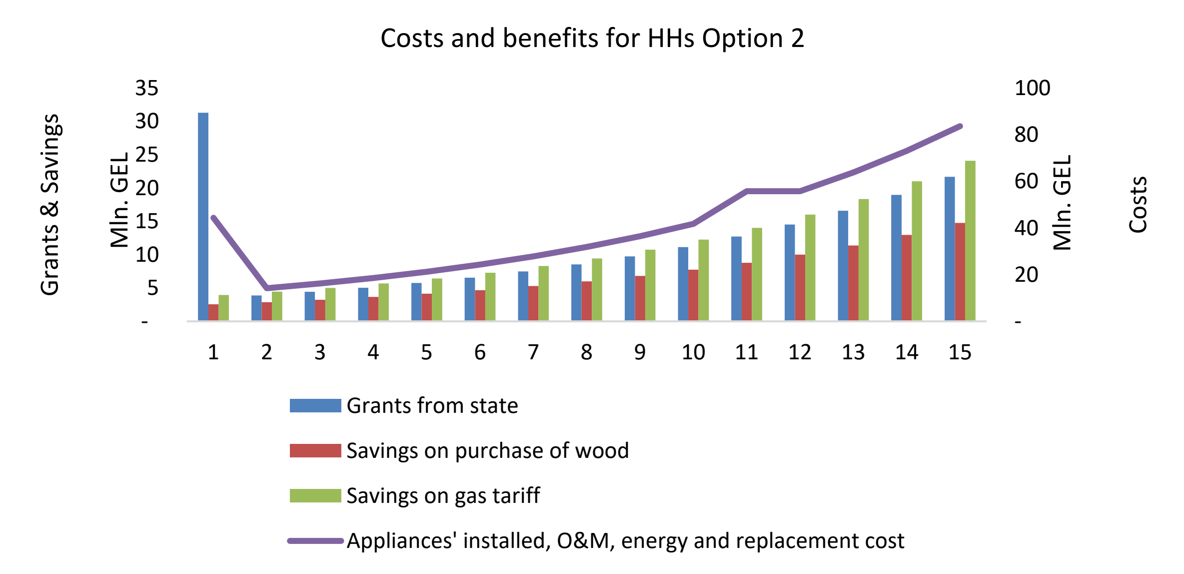
As in Option 1, savings on the construction of gas infrastructure represent the largest benefit for the government in Option 2 (Figure 22).

Figure 22: Costs and Benefits for the Government in Option 2



For HHs in Option 2 the costs related to the purchase and maintenance of appliances is the most significant expense, as in Option 1 (Figure 23).

Figure 23. Costs and Benefits for HHs in Option 2



Given that the operational costs for wood stoves remain high, the government might consider offering subsides.

Sensitivity analysis

The following modifications to the base model have been considered in the sensitivity analysis:

- Low and high discount rates – the average real discount rate considered in the model is 9.6%, the real interest rate on a 10-year government bond. Assuming that interest rates are normally distributed with a standard deviation of 2.1%, the upper and lower bound discount rates are 13.8% and 5.5%, respectively.[42]
- Lower adoption rates – In the main model, after 15 years 100% of potential users adopt alternative energy sources, while in the sensitivity analysis the adoption rate is reduced to 60%.
- A higher adoption rate in year 1 – While in the main model 15% of HHs adopt alternative energy sources in year 1, in the sensitivity analysis the adoption rate is 25% in the first year.

The results for all the modifications are summarized below in Table 18.

Table 18: Summary of the Sensitivity Analysis

	Low discount rate (dr=5.5%)		High discount rate (dr=13.8%)	
	Option 1	**Option 2**	**Option 1**	**Option 2**
NPV general (GEL)	139,291,202	189,028,133	90,131,728	118,891,030
NPV government (GEL)	338,580,103	281,965,783	202,515,762	166,567,761
NPV HHs (GEL)	(199,288,901)	(92,937,650)	(112,384,034)	(47,676,731)
	Lower adoption rate of technologies after 15 years (60%)		**Higher adoption rate of technologies in year 1 (25%)**	
	Option 1	**Option 2**	**Option 1**	**Option 2**
NPV general (GEL)	68,146,367	101,078,470	155,031,666	194,447,712
NPV government (GEL)	157,885,034	132,597,903	298,581,551	243,593,460
NPV HHs (GEL)	(89,738,667)	(31,519,434)	(143,549,885)	(49,145,748)

The results of the analysis are robust to modifications and in all the suggested scenarios the general NPV is positive, as well as the governmental NPV, however, it remains negative for HHs.

[42] The upper and lower bounds were calculated using the following formula: 9.6 (mean value) +/-1.96*2.1 (standard deviation). The standard deviation was calculated for the period 6.01.2015-10.07.2020.

7. MULTICRITERIA ANALYSIS

In accordance with the objective of improving access to alternative energy in mountainous regions, the options have been compared based on a set of criteria developed by the research team. In addition to the NPV, the following criteria have been used to evaluate the two potential alternatives:

1. Increased energy security to all existing and potential users in the mountainous regions of Georgia – The capability of the policy option to achieve this objective;
2. Increased access to energy – The capability of the policy option to achieve this objective;
3. Affordability of energy sources to all existing and potential users in mountainous regions – The capability of the policy option to achieve this objective;
4. Environmental sustainability and a reduction in CO_2 emissions – The capability of the policy option to achieve this objective;
5. Compliance with EU Directives and the 2030 Agenda for sustainable development – The capability of the policy option to achieve this objective;
6. Feasibility – The ease of realization and actual implementation of the policy option;
7. Mitigating conflicts of interests – The capability to eliminate disagreements between stakeholders;
8. Systemic efficiency – The potential to utilize existing capital and human resources;
9. Minimization of risks;
10. Maximization of the potential benefits.

Table 19 summarizes the results of the multicriteria analysis, where pluses, minuses, and zeroes are used to assess the options against a given criterion: pluses indicate a synergy between the criterion and the option's impact; minuses are used when there is a trade-off between the criterion and the option's impact; and zero (0) is used if there is no impact.

Table 19: Comparison of the Options

Evaluation criteria	Option 1. Grants and interest rate subsidies for HHs in mountainous regions	Option 2. Lump sum payments to HHs in mountainous regions
NPV of net benefits (GEL)	109,496,029	146,644,235
Increased energy security	+	+
Increased access to energy	+	+
Affordability of energy source	++	+
Environmental sustainability and reduction in CO_2 emissions	++	++
Compliance with EU directives	++	+
Feasibility/ease of realization	--	-
Mitigated conflict of interests	-	-
Systemic efficiency	+	+
Minimization of risks	+	++
Maximization of the potential benefits	++	+

In monetary terms, Option 2 is superior as the NPV is slightly higher than in the first option. However, Option 1 has a lower NPV due to the HH high costs compared to those in Option 2 (in which all HHs are treated equally and provided with a lump sum payment).

Both options were compared by their capability to achieve the policy objectives. The first criterion refers to the supply side problems of increased energy security for all users in mountainous regions. Compared to the status quo, the options have equivalent positive impacts in terms of energy security: the inhabitants of high mountainous regions may improve access to diversified energy sources.

Equally, the options both have similar positive impacts regarding access to energy: more inhabitants in mountainous areas may obtain access to energy. This is most notably the case in high mountainous regions where the building of a natural gas infrastructure is not physically viable. Thus, the inhabitants in such areas would benefit from access to various decentralized solutions for renewable energy.

Considering the affordability criterion, Options 1 and 2 are also encouraging: renewable energy from the suggested sources provide competitively priced energy (especially compared to natural gas). As Option 1 has a strong emphasis towards socially vulnerable groups, it outperforms the second option in this criterion.

Option 1 and 2 may both have significant positive influences in terms of environmental sustainability and a reduction in CO_2 emissions. Firstly, due to the lack of accessible energy, inhabitants in high mountainous areas overexploit available resources (e.g., forests). Further access to affordable renewable energy might therefore contribute to a reduction of wood consumption for heating. Secondly, the renewable energy sources offered are environmentally friendly and contribute to a reduction in CO_2 emissions. As both policies involve identical technologies, these impacts remain equivalent.

Considering compliance with EU Directives, the first option outperforms the second as it places strong emphasis on socially vulnerable groups: households receiving targeted social assistance (TSA) would receive a grant for the purchase and installation of the required appliances and the initial purchase of fuel to improve their energy access.

In feasibility terms, both options appear difficult to implement compared to the status quo. While specific constraints are associated with each policy option. For instance, Option 1 has two components: grants and loan subsidies, thus involving banks in the policy implementation process, which could be difficult to plan and realize. Whereas Option 2 utilizes lump sum payments to HHs that would require the development of a proper methodology, which makes the implementation process problematic.

Regarding mitigated conflict of interests, both options recommend abandoning the current support schemes for the populations of high mountainous areas. This change might consequently lead to social tension in such areas. Accordingly, both options could have the same negative effect on the mitigated conflict of interests compared to the status quo.

In terms of systemic efficiency, both options have the potential to utilize the existing capital and human resources; where they each consider the local context and specific characteristics of every targeted area.

Concerning the minimization risks, the second option outperforms the first. The risks associated with Option 1 relate to loan repayments and long-term appliance use. Besides which, the grant program represents an additional effort for social workers.

When considering the maximization of potential benefits, both options have the potential to avoid any inefficiency associated with the implementation of commercially unfeasible gas supply projects. However, Option 1 outperforms 2 as it reaches every social group in mountainous areas based on their social vulnerabilities. In addition, a grant program implemented with the support of social workers would provide decentralized assistance and consider the individual needs of a household. Moreover, the loan program creates certain incentives for the more sustainable use of appliances, as costs are partially incurred by the household.

In summary, Option 2 outperforms 1 in monetary terms, however Option 1 better satisfies criteria related to energy source affordability, compliance with EU Directives, and the maximization of potential benefits. Therefore, the options are approximately equivalent and the final option selection becomes dependent on the extent of state support to HHs.

Both of the options recommend a uniform energy policy to ensure access to energy in high mountainous regions. It is advisable that the current preferential treatment for certain municipalities of subsidies and exemptions from payments (e.g., Kazbegi, Dusheti, Mestia) be eliminated, and the same approach be applied across all municipalities.

The suggested options each address the issues of energy security, equity, and environmental sustainability. The relevant alternative energy sources selected for each respective region ease the distribution of energy supplies, while the recommended options focus on energy equity via the provision of state support schemes for HHs. Moreover, the schemes proffered would reduce HH costs during the process of adopting alternative energy sources. The alternative energy sources considered in the analysis are also more environmentally friendly than the currently supply.

8. MONITORING AND EVALUATION PLAN

In order to track the progress and evaluate the impact of a development policy, it is important to monitor how the indicators of the policy objectives (reviewed in section 4) change. The indicators are divided into four categories – these indicators ensure:

I. Energy security in the mountainous regions of Georgia;
II. Affordability of energy to all existing and potential users in mountainous regions;
III. Environmental sustainability and reduced CO_2 emissions;
IV. Compliance with EU Directives and the 2030 Agenda for sustainable development.

Table 20: Progress Indicators Towards Meeting the Objectives

Indicator	Frequency	Responsible for monitoring
Ensure energy security in the mountainous regions of Georgia		
Investments in rural energy efficiency, as a percentage of GDP and the amount of foreign direct investment in financial transfers for infrastructure and technology in sustainable development services.	Annually.	MoESD
% of HH and enterprises using alternative energy sources.	TBD.	MoESD and MRDI
The percentage of TSA and non-TSA HHs obtaining information on state programs for alternative energy sources.	To be measured during the first year of the intervention.	MoESD
The number of social workers trained; Change in the pre- and post-test scores for trained social workers.	Y.[29]	MoESD
Ensure affordable energy to all existing and potential users in mountainous regions		
% of TSA HHs receiving grants for adopting alternative energy sources; % of non-TSA HHs receiving loan guarantees and interest rate subsidies for adopting alternative energy sources; % of enterprises receiving subsidies for providing communities with energy supply services; % of HHs and enterprises receiving investment subsidies.	Annually.	MoESD and MRDI
Ensure environmental sustainability and reduced CO_2 emissions		
% of population with access to reliable and modern energy services.	Annually.	MoESD and MRDI
% share of renewable energy on the market.	Annually.	MoESD
Ensure compliance with EU Directives and the 2030 Agenda for sustainable development		
The energy supply policy is adapted to local needs and justification for subsidies is documented.	Achieved by year X.	MoESD and MRDI
An amount of foreign investment is mobilized into clean energy research and technology.	Annually.	MoESD

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APPENDICES

Table A1: Average Monthly Wind Velocity (meters/second)

	Location	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1	Anaklia	2,8	2,8	2,8	2,5	2,0	1,7	1,6	1,6	1,6	2,0	2,8	2,5	2,2
2	Akhalkalaki	3,7	3,7	3,8	3,6	3,1	2,7	2,7	2,8	2,2	2,1	2,7	3,2	3,0
3	Batumi airport	7,2	6,4	4,7	3,8	3,0	3,1	2,8	3,1	3,2	4,6	5,7	7,3	4,6
4	Bolnisi	1,8	2,0	2,2	2,5	2,3	2,5	2,5	2,5	2,2	1,9	1,6	1,7	2,1
5	Gagrian Range	4,2	3,8	3,6	3,3	2,8	2,0	1,7	2,0	2,4	2,8	3,2	3,5	2,9
6	Gardabani	1,5	2,2	2,5	2,7	2,4	2,6	3,1	2,4	2,1	1,8	1,0	1,0	2,1
7	Goderdzi Pass	7,1	7,0	5,8	5,4	4,7	4,6	4,3	4,2	4,5	4,8	5,2	6,0	5,4
8	Gori	3,2	4,0	4,9	5,1	4,6	4,3	4,6	4,3	4,2	3,5	3,4	2,9	4,1
9	Dmanisi	3,5	3,6	3,4	2,8	2,4	2,2	2,4	2,3	2,2	2,6	2,6	3,2	2,8
10	Dighomi	3,7	3,9	4,6	4,5	4,4	4,0	5,2	4,0	3,3	2,7	2,9	3,1	3,9
11	Efremovka	3,9	4,0	3,9	3,2	3,0	2,5	2,8	2,9	2,4	2,6	2,9	3,4	3,1
12	Vaziani	4,2	4,3	4,5	3,8	3,5	3,6	4,5	3,8	3,7	3,9	2,3	2,8	3,7
13	Tbilisi airport	5,4	6,8	6,4	6,4	5,9	6,3	7,2	5,8	5,6	5,1	4,1	4,4	5,8
14	Kapandiba	7,5	6,5	4,6	4,6	4,2	4,0	3,6	3,7	4,3	6,3	6,7	7,9	5,3
15	Korbouli	3,4	4,9	4,6	3,6	2,5	1,8	1,4	1,6	1,4	2,0	3,9	3,4	2,9
16	Mamisoni Pass	6,6	6,7	6,2	5,2	4,4	4,7	4,8	4,6	4,8	5,6	5,5	6,2	5,4
17	Marneuli	1,6	2,0	2,2	2,3	2,0	1,9	1,9	1,8	1,7	1,5	1,2	1,2	1,8
18	Martkofi	4,4	6,5	4,9	4,3	4,0	3,8	4,1	4,7	4,7	4,3	4,0	2,9	4,4
19	Mta Sabueti	8,8	9,2	9,6	10	8,9	8,3	7,9	8,8	9,4	9,7	10,6	9,1	9,2
20	Mukhrani	3,3	4,4	4,7	4,6	4,0	3,7	4,0	3,2	3,2	3,0	2,8	2,6	3,6
21	Radionovka	4,9	5,5	4,2	3,8	3,4	3,3	3,8	3,6	3,2	3,5	4,1	4,4	4,0
22	Rustavi	4,4	6,0	5,3	4,9	5,2	5,4	6,0	4,9	4,5	4,2	3,1	3,4	4,8
23	Samgori reservoir	6,8	8,0	6,5	6,4	6,5	7,0	8,0	7,0	6,8	6,2	5,4	5,9	6,7
24	Samtredia	3,2	3,4	3,6	3,4	2,8	2,3	1,8	1,8	1,8	2,3	3,6	3,6	2,8
25	Skra	3,9	4,6	5,8	5,8	4,7	4,3	4,7	4,3	4,5	4,0	4,3	3,4	4,5
26	Tkibuli	2,9	2,7	3,2	3,2	2,6	2,2	1,8	2,6	2,8	2,4	3,6	3,3	2,8
27	Udabno	4,3	5,3	4,3	4,2	3,9	3,7	4,1	3,5	3,4	3,2	3,4	3,8	3,9
28	Tskhratskaro	6,8	6,8	6,3	5,6	5,0	4,3	5,0	4,7	4,5	4,0	5,3	6,0	5,4
29	Poka	5,1	4,4	4,4	3,7	3,3	3,2	3,3	3,3	3,4	3,5	3,5	4,6	3,8
30	Poti port	5,2	5,3	5,0	4,3	3,6	3,2	3,2	2,1	3,2	4,0	4,9	5,3	4,3
31	Kutaisi	5,6	5,6	5,9	5,7	4,6	3,7	3,0	3,4	3,6	4,8	7,2	6,7	5,0
32	Kazbegi alpine	7,0	7,5	7,4	7,0	6,1	4,8	5,0	5,4	6,4	7,1	6,6	6,8	6,4
33	Shiraki	1,1	1,4	1,6	1,4	1,3	1,2	1,2	1,3	1,1	1,1	1,0	0,8	1,2
34	Charnali	3,9	4,4	3,4	2,8	2,4	2,0	2,0	2,3	2,3	2,7	3,7	3,8	3,0
35	Tskhinvali	3,2	3,9	4,7	5,2	4,7	4,6	4,4	4,2	4,2	3,8	3,0	2,6	4,0
36	Tsalka	2,7	2,7	2,4	2,0	2,0	1,8	1,7	1,4	1,5	1,7	1,6	2,2	2,0
37	Tsipa	4,0	3,9	4,2	4,2	3,7	3,2	3,0	3,3	3,6	3,7	4,8	4,2	3,8
38	Tsnori	0,7	1,2	1,3	1,3	1,2	1,2	1,1	0,9	0,9	0,7	0,7	0,5	1,0
39	Kharagauli	2,2	2,5	3,1	2,8	2,2	1,9	1,7	2,0	2,3	2,7	3,7	3,1	2,5
40	Khashuri	2,8	2,8	3,5	4,2	3,5	3,4	3,5	3,7	3,5	2,8	2,9	2,4	3,2
41	Khulo	2,8	2,9	2,8	2,8	2,5	2,4	2,2	2,2	2,2	2,4	2,6	2,8	2,6
42	Djvari	6,9	6,3	4,6	4,4	3,8	2,8	2,2	2,7	3,5	5,4	6,4	7,8	4,7
43	Djvari Pass	2,2	2,4	2,2	1,8	1,9	2,0	1,9	2,0	2,0	2,0	1,9	2,2	2,0

	Location	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
44	Yaglija Ridge	3,4	3,5	4,3	4,5	4,8	6,3	6,5	4,6	3,9	4,0	2,6	3,6	4,3
45	Lisi	2,5	3,4	4,5	3,4	3,9	5,3	4,3	3,3	2,5	2,5	2,3	2,3	3,3
46	Chorokhi	7,9	3,8	5,7	4,3	5,1	4,8	4,3	4,7	5,7	8,1	9,7	8,1	6,0

Table A2. Mean Wind Speed and Power Density

	Location	Mean wind speed (meters/second)	Mean power density (W/m^2)
1	Anaklia	2,00	66,0
2	Akhalkalaki	2,92	94,0
3	Batumi airport	4,01	162,0
4	Bolnisi	1,87	28,0
5	Gagrian Range	2,77	120,0
6	Gardabani	1,69	113,0
7	Goderdzi Pass	5,28	404,0
8	Gori	3,87	179,0
9	Dmanisi	2,87	100,0
10	Dighomi	4,06	286,0
11	Efremovka	3,12	86,0
12	Vaziani	3,19	369,0
13	Tbilisi airport	5,39	971,0
14	Kapandiba	4,81	289,0
15	Korbouli	3,44	74,0
16	Mamisoni Pass	5,33	345,0
17	Marneuli	1,63	29,0
18	Martkofi	4,22	573,0
19	Mta Sabueti	9,34	1476,0
20	Mukhrani	3,49	338,0
21	Radionovka	4,61	228,0
22	Rustavi	4,16	493,0
23	Samgori reservoir	4,03	296,0
24	Samtredia	2,71	233,0
25	Skra	4,63	385,0
26	Tkibuli	2,51	191,0
27	Udabno	3,00	257,0
28	Tskhratskaro	5,18	297,0
29	Poka	3,42	92,0
30	Poti port	4,14	243,0
31	Kutaisi	4,34	638,0
32	Kazbegi alpine	7,23	1023,0
33	Shiraki	0,95	16,0
34	Charnali	3,68	122,0
35	Tskhinvali	3,40	190,0
36	Tsalka	1,76	74,0
37	Tsipa	3,61	234,0
38	Tsnori	0,68	11,0
39	Kharagauli	2,17	124,0
40	Khashuri	3,11	214,0
41	Khulo	2,35	20,0
42	Djvari	4,06	447,0
43	Djvari Pass	2,12	32,0
44	Yagluja Ridge	4,22	174,0
45	Lisi	3,38	186,0
46	Chorokhi	5,14	319,0

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