ENABLING PV in Georgia

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List of Abbreviations

Acronym	Definition
"a"	Per Annum
€	Euro (currency)
ATS	Administrator of the Trade System
BM	Balancing Market
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditures
CFR	Financial Settlement Centre
CHPP	Combined Heat and Power Plant
DAM	Day-Ahead Market
DC	Direct Current
DFC	Discounted Cash Flow Analysis
DSCR	Debt Service Coverage Ratio
DSO	Distribution System Operator
ESCO	In this report: Electricity System Commercial Operator
EU	European Union
FDI	Foreign Direct Investment
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GEL	ISO-Code for the Georgian currency "Lari"
GHG	Green House Gas
GHI	Global Horizonal Irradiation
GIZ	German Corporation for International Cooperation GmbH
GNERC	Georgian National Energy and Water Supply Regulatory Commission
GTI	Global Tilted Irradiation
GWh	Gigawatt hours
HPP	Hydropower Plant
IPP	Independent Power Producer
kV	Kilovolts
kW(p)	Kilowatt (peak)
kWh	Kilowatt hours
LCOE	Levelized Costs of Electricity
m^2	Square Meters
MENR	Ministry of Energy and Natural Resources
MW(p)	Megawatt (peak)

Acronym	Definition
MWh	Megawatt hours
NCC	National Control Centre
PP	Power Plant
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable Energy
SME	Small and Medium-Sized Enterprise
SPP	Solar Power Plant
TPP	Thermal Power Plant
TWh	Tera-Watt Hour
TSO	Transmission System Operator
USD	US- Dollar (currency)
V	Volt
VAT	Value Added Tax
WACC	Weighted Average Cost of Capital
WPP	Wind Power Plant

1 Introduction to the Georgian Power Sector

Located at the eastern shore of the Black Sea, Georgia has historically played an important role in the Caucasus region. As part of the “Silk road” trading route, Georgia was an economic and cultural centre between Asia and Europe. Shortly after the Republic of Georgia was formed in 1918, the country became part of the Soviet Union in 1921. Independent since 1991, Georgia shares a border with Russia to the north, Turkey and Armenia to the south and Azerbaijan to the east [1]. As of 2018, the country stretches over a surface of 69,700 km^2 including the occupied territories of Abkhazia and the region of South Ossetia, and has a population of 3.7 million. The majority of the population (1.2 million) lives in the capital, Tbilisi [2][3]. In the last years, Georgia’s economy has suffered from several shocks, especially during the world financial crisis of 2008. The country has since recovered and has a steadily growing economy with an annually GDP growth rate between 4% and 5%. This growth is supported by the expansion of domestic consumption and export quotas. The main industrial sectors are agriculture and mining, but other sectors exist as well [1].

Figure 1: Map of Georgia

Source: Google maps, Georgia

1.1 Electricity Sector Overview

In 2019, Georgia’s total installed electrical capacity was 4,097 MW. It is mainly composed of thermal power plants (TPPs), hydropower plants (HPPs) and wind power plants (WPPs) [4][12]. Figure 2 shows the major shares of different power generation technologies in Georgia by source and the installed capacity of each type.

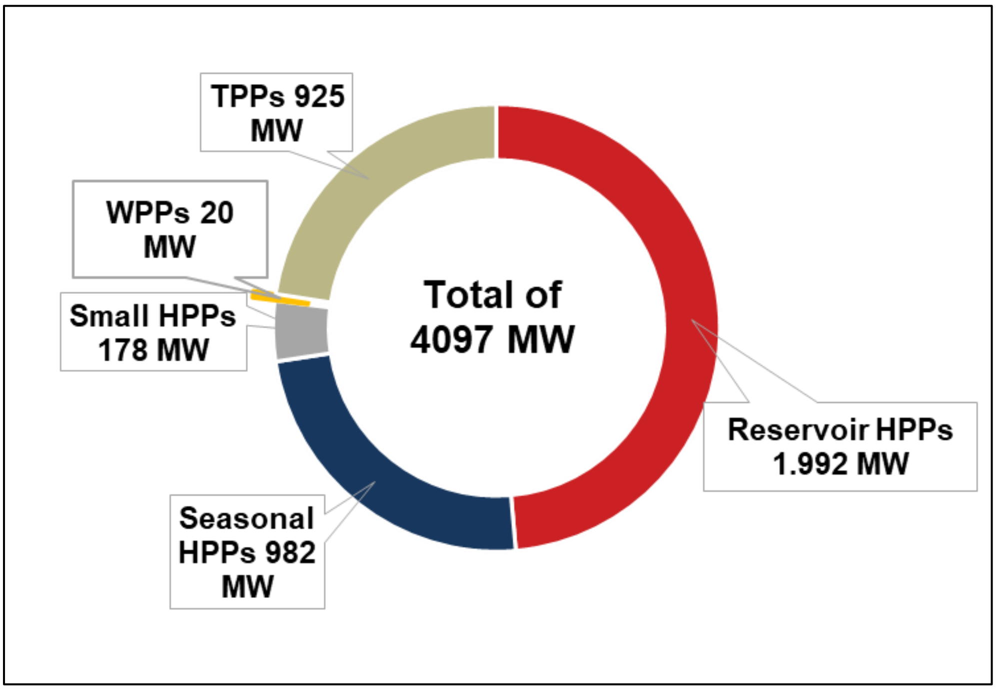
81% of the electricity in Georgia is generated by HPPs [6]. However, only about 60% of the existing HPP capacity is able to reach its energy generation potential due to deteriorated equipment [6]. Nine HPPs with an additional electricity production of 0.39 TWh/a were planned to go operational in 2019 or earlier, but this has been postponed for months or even years due to geological and legal issues as well as due to civil protests [7] [5].

The untapped potential of hydropower in the country is estimated to be up to 80 TWh/a, 75% of which could be economically attractive to develop [16]. Developing this capacity could boost Georgia's economy and increase the country's electricity exports generated by hydropower during the summer. Taking into consideration the electricity consumption of an entire year, however, Georgia is likely to stay a net importer. This is due to the growing electricity consumption per capita and a gap between generation and demand of electricity in the industry, which is to reach up to 3 TWh in 2025 [19]. Between 2016 and 2018 energy consumption in Georgia grew by 6%, while domestic generation increased by only 5%. This has forced the country to triple energy imports, putting increasing pressure on the Georgian power sector, and has made the country increasingly dependent on its neighbouring countries Russia, Azerbaijan, Turkey and Armenia [8] [7]. Commercial energy trading is conducted by a state-owned commercial institution called ESCO, "Electricity System Commercial Operator" [18]. It shall be noted that grid losses lead to a discrepancy of 1.92% between total grid injections and withdrawn power (equal to 258.15 GWh), which is lower than in neighbouring Russia where losses in grids reach up to 10% [10].

In early 2014, new modern high-voltage lines (500 kV) were installed throughout the country to enable the synchronization of the Georgian power grids with Russian and Armenian ones [18]. Therefore, Georgia is now able to export, import as well as transit electricity across borders and could potentially become a hub for electricity trade in the Caucasus region [58].

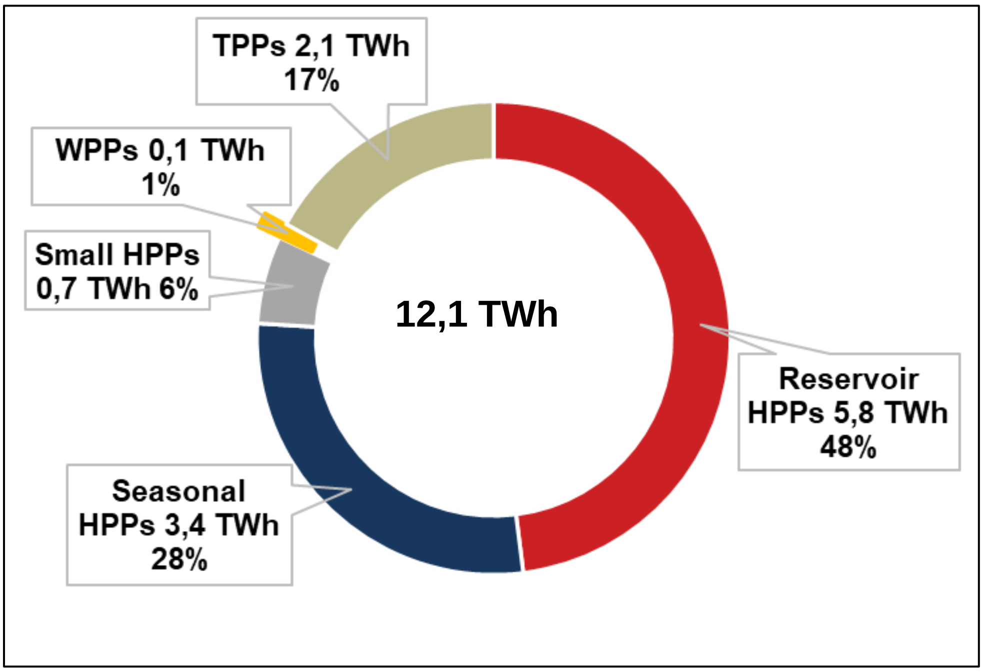
Besides wind and hydropower, Georgia is known to have a significant potential for two other renewable technologies: geothermal plants and solar energy. The potential for energy production (heat and power) with geothermal plants is said to be 3 TWh/a, the potential of solar energy is estimated to be 60-120 GWh/a [26].

Figure 2: Total installed power capacities in MW in Georgia by generation technology, 2019



Source: GSE 2019 [12]

Figure 3: Total annual generation in TWh and in % in Georgia by generation technology, 2019



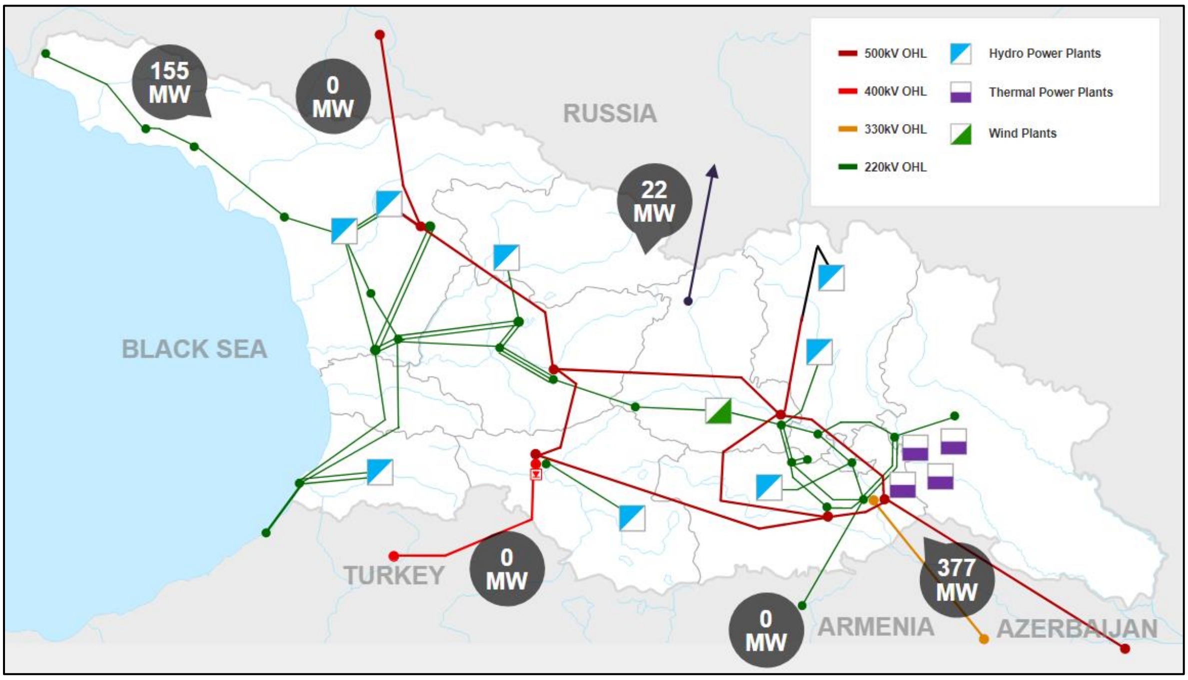
Source: TBC Capital, energy sector overview 2019 [34]

1.2 Grid Infrastructure

The Georgian transmission network has different voltage levels, varying from 6 to 500 kV, but most distributors (DSOs) operate networks with a voltage of 110 kV or less. As previously stated, Georgia, being a net importer of energy, is connected to the power systems of neighbouring countries through 110-500 kV power lines. In 2015, the “First Edition of the Grid Development Plan” was approved by the government, which ensures continuous improvement of the grids and the integration of new generation capacities. During the last years, the quality of the grids has indeed been significantly improved to manage growing domestic demand, reduce power outages and facilitate export and energy traffic (transit). [18][19]

Import and export of electricity is facilitated by the 220 – 500 kV power lines which are operated by the Transmission System Operator (TSO). Currently the maximum cross border transmission capacity is at 700 MW via 500 kV lines. Construction of additional power lines is already planned to increase energy trade between Georgia and its neighbours [18].

Figure 4: Georgia's Power supply and main high voltage infrastructure for energy trade



Source: JSC Georgian State Electrosystem (GSE-TSO), Power flow [11]

1.3 Off-Grid Energy Generation

Georgia has a well-developed power grid system and most settlements are connected to it. However, there are some remote villages which depend on off-grid electricity. The "USAID/Energy Program" supports the Regional Development and Infrastructure Ministry of Georgia in its objective to supply 87 mountainous villages with off-grid PV solutions. The goal is to equip 178 families with 1.5 kW PV-systems each until 2020 [37]. However, there is further potential for off-grid generation, e.g. agricultural areas could benefit from a better electricity supply.

1.4 Electricity Market Stakeholders

Georgian energy sector stakeholders include both private and state-owned companies that are producing, transmitting and distributing energy. The commercial activities of these companies are regulated by a state commission called GNERC (Georgian National Energy and Water Supply Regulatory Commission, see chapter 1.4.2). Activities, functioning and the economic relationship between all market participants are defined by the "Law of Georgia on Electric Energy and Natural Gas" [29]. and by the "Electricity (Capacity) Market Rules" [32]. All market participants are called "qualified enterprises" and their specific roles are described in detail in separate legislative acts.

The stakeholders of the electricity market can be grouped into several categories which are defined by the "Law of Georgia on Electricity and Natural Gas" [29]:

- Government (Ministry) and legislative bodies: Ministry of Energy and Natural Resources of Georgia (MENR), responsible for policies and facilitating investment projects
- Independent federal regulator: GNERC, issuing licenses and setting electricity rates
- Power generating companies/licensees: “Engurhesi”, JSE “Energo Pro-Georgia”
- Operators of regulated and semi-regulated power plants (see 1.4.3 for more details)
- Deregulated operators of power plants (see 1.4.3 for more details)
    - Small installed capacity (up to 13 MW)
    - Power plants built after August 1st, 2008
- National transmission and technical service operator: (TSO)-JSC “Georgian State Electro System”
- Regional distributers/licensees: JSC “Energo-Pro Georgia”, JSC “Telasi”
- Licensed dispatching companies
- Customers (retail or “direct” customers)
- Licensed importers and exporters /exporter licensees
- Federal Electricity System Commercial Operator (ESCO), a technical-commercial commission that has an exclusive right to conduct trading with the providers of guaranteed reserve sources (see 1.4.3) according to the “Electricity Market Rules”[32]

The roles and responsibilities of some of the key stakeholders are described in the following sections.

1.4.1 Ministry of Energy and Natural Resources (MENR)

The Ministry of Energy and Natural Resources of Georgia determines the overall energy policy and is responsible for the strategic planning and design of Georgia’s energy sector [38]. It is mainly responsible for the legislative framework of the energy sector and is monitoring its technical and economic conditions. Regarding the renewal of energy infrastructure, the MENR coordinates a state program targeting the capacity increase in selected areas of the energy sector (generation, transmission, etc.). Moreover, the ministry oversees the “deregulation” process of the Georgian electricity market. The implementation of RES as well as attracting foreign direct investments (FDI) in this sector is driven by the MENR as well.

1.4.2 GNERC

The Georgian National Energy and Water Supply Regulatory Commission (GNERC) is the national body responsible for the regulation of electricity, natural gas and water supply services. According to the “Law on Electricity and Natural Gas” [29], clauses 4 and 24, the commission has the following responsibilities:

- Issuance of licenses for energy-related operations (energy generation, transmission, dispatching, distribution as well as import and export-related operations)
- Establishment of rules and standards for energy-related operations

- Stipulation, calculation and regulation of the wholesale and retail electricity tariffs for energy-related operations
- Regulation and establishment of energy tariffs for the end consumers as well as a marginal tariff[1]. These tariffs are also defined by the Decree 33 “On the Tariffs of Electricity” [30].
- Control and monitoring of activities relating to mandatory certifications in the energy sector
- Protection of consumers from monopolistic prices, especially in areas without a competitive market

The legislative foundation for all powers and obligations of the Commission is stipulated in the “Law on Independent National Authorities”.

1.4.3 Electricity Producers

There are different types of electricity generating companies in Georgia. They can be distinguished in terms of power generation sources, installed capacity and the type of regulation that applies to them [22]. The true costs of electricity production vary by power plant and details are not made public. However, the GNERC sets a ceiling tariff, which sets an upper limit to the potential gross margins which producers can achieve by selling generated electricity on the wholesale market:

- Regulated power plants (s.a. “Enguri”, “Vardnilli”, “Krhhami-1”, “Krhami-2”) are operating under a license and sell their energy for fixed rates, both regulated by the GNERC.
- Semi-deregulated seasonal power plants (s.a. “Jinvalhesi”, “Vartsikhehesi” and “Rionhesi”) operate under licenses and tariffs determined by the GNERC.
- Guaranteed Capacity Sources (GCs) represented by TPPs (such as “Mtkvari Energetika”, “G Power”) operate under GNERC licences and sell energy based on direct contracts. They are bound to ceiling tariffs set by the GNERC and therefore secure the stability and reliability of the country’s energy system. Projections of monthly generation and energy trading volumes are conducted by ESCO. As of January 2020, there are five Georgian TPPs.
- The “Law on Electricity and Natural Gas”, Art. 2, defines “deregulation” as a right to engage in “tariff-free activity” and “transmit energy freely”. Deregulated plants are either smaller than 13 MW or were built after August 1st, 2008 (except thermal power plants categorized as company capacity sources). Such power plants have a generation licence and can sell electricity for a freely negotiated price, either on the wholesale market to ESCO, to the retail market, or to exporters (see 1.5).
- Micro-generation: power plants with less than 100 kW installed capacity per unit are defined as microgeneration. According to GNERC, the total installed power capacity of micro-generators was 153 kW in 2016.

In 2019, the Georgian power plant park consisted of seven regulated HPPs with an overall installed capacity of 2.049 MW. Moreover, there are 16 seasonal and 57 small hydropower

[1] In Georgia, the upper marginal tariff is the ceiling tariff or upper price/tariff limit

plants (total installed capacity 901 MW and 205 MW respectively), five TPPs of 901 MW and one WPP (20 MW) [25] [34].

According to the Ministry of Energy and the "Electricity System Commercial Operator" (ESCO), Georgia has 40 power generating companies, most of them private. The majority of these companies operates HPPs, only five of them operate TPPs. Four of those five companies hold a separate generation license for the provision of guaranteed capacity, namely the "International Energy Cooperation", "Georgian Power", "Mtkvari Energetika" and "Gardabani Power Plant" (which was formed by the "Georgian Oil and Gas Corporation") [56].

The largest company operating regulated HPPs, with a total installed capacity of 1.3 GW, is the state-owned "Enguri" (or "Engurhesi"). Enguri generates over a third of the electricity in Georgia [6] [8] [34]. There are also two large HPPs, "Khrami HPP-1" and "Khrami HPP-2" with a total installed power capacity of 227 MW, which belong to the Russian "Inter RAO". These HPPs operate on Georgian territory and are therefore included in the country's power balance [7]. The "Georgian Industrial Group" (GIG) owns different types of power plants with an overall capacity of 663 MW (approx. 16% of the total installed capacity of the market). The third largest share of capacity is held by the Czech "Energo-Pro Georgia", which manages 592 MW (approx. 15%) of Georgia's installed capacity. The abovementioned remaining energy producers hold less than 10% of the market. The following

Table 1: **Producers of electricity in Georgia**

Qualified Enterprise	Power Plant Company	Largest Power Plants	Installed Capacity (MW)
1	"Vardnili Hydroplant Cascade" Ltd	Vardnilhesi	220
2	"Mtkvari Energy" Ltd	Gardabani Energy Unit #9	300
3	"Eastern Energy Corporation" Ltd	Khadorhesi	24
4	"Georgian Water and Power" Ltd	Zhinvalhesi	130
5	"Engurhesi" Ltd	Engurhesi	1300
6	"G-Power" Ltd	Airturbine	110
7	JSC "Khramhesi-1" (Inter RAO)	Khrami-1	113
8	JSC "Khramhesi-2" (Inter RAO)	Khrami-2	110
9	"Vartsikhe 2005" Ltd	Vartsikhehesi	184
10	"International Energy Corporation of Georgia" Ltd	Tbilsresi	270
11	JSC "Energo-pro Georgia Generation"	Dzevruli	270
12	"Energy" Ltd	Larsihesi	19
13	"Georgia-Urban Enerji" Ltd	Paravanihesi	87
14	"Gardabani Thermal Power Plant " Ltd	Gardabani Thermal Power Plant	231
15	"Saknakhshiri" Ltd	Tkibuli Thermal Power Plant	13

gives an overview of all electricity producing companies and their most important power plants.

Table 1: Producers of electricity in Georgia

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7	JSC "Khramhesi-1" (Inter RAO)	Khrami-1	113
8	JSC "Khramhesi-2" (Inter RAO)	Khrami-2	110
9	"Vartsikhe 2005" Ltd	Vartsikhehesi	184
10	"International Energy Corporation of Georgia" Ltd	Tbilsresi	270
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14	"Gardabani Thermal Power Plant " Ltd	Gardabani Thermal Power Plant	231
15	"Saknakhshiri" Ltd	Tkibuli Thermal Power Plant	13

Qualified Enterprise	Power Plant Company	Largest Power Plants	Installed Capacity (MW)
16	JSC “Dariali Energy”	Dariali Hesi	108
17	“Qartli Wind Farm” Ltd	Qartli Wind Farm	21
18	“Achar Energy-2007” Ltd	Khelvachauri 1 HPP	47
		Kirnati HESI	27
19	“Adjaristsqali Georgia” LTD	Shuakhevi HESI	179
20	“Old Energy” JSC	Old Energy HESI	21
21	“Svaneti Hydro” JSC	Mestiachala 2 HPP	30
		MESTIACHALA 1 HPP	20
Total 32 PP with capacity (MW)			**4 026**

Source: ESCO, generation licensees [45]

1.5 Energy Transmission and Distribution

1.5.1 Energy Transmission and Dispatching Companies

Two licensed TSO's, "Georgian State Electro System" JSC (100% state-owned) and JSC "Sakrusenergo" (50% state-owned), transmit locally produced or imported energy to distribution companies, direct customers or neighbouring countries. These TSO's are not allowed to purchase or sell electricity. The licenses and rates these companies are bound to are set by the GNERC.

- "GSE" ("Georgian State Electrosystem" JSC) and its subsidiary "Energotrans Ltd." are electricity transmission system operators owning 141 power lines of 500/400/220/110/35 kV with a total length of 4,300 km and about 100 transformer substations [22]. "GSE" owns the major share (77.9%) of the transmission facilities in Georgia. The company also manages cross-border grids and provides transmission and exclusive dispatch services to about 50 companies [24]. As the major technical operator in Georgia, "GSE" ensures reliable power supply and technical maintenance of equipment and grids [22].
- "SakRusEnergo" JSC is a joint Russian-Georgian company. It owns the high-voltage 500 kV power lines.

The energy transmitted by the TSO's has the following destinations:

- 83% of the generated energy is transmitted to distribution companies
- 11% goes directly to customers
- 6% is exported.

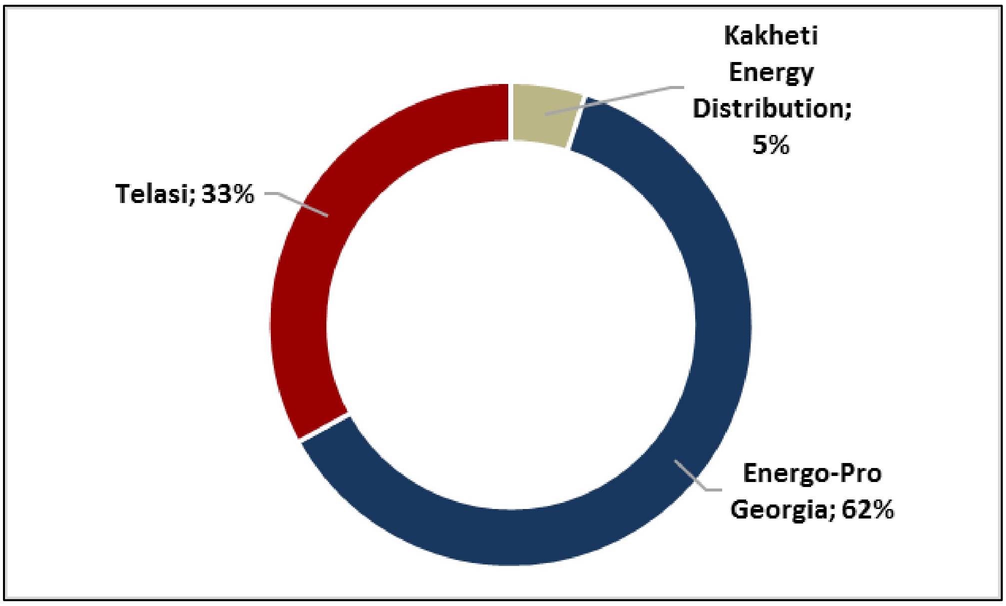
Georgia's "National Control (Dispatch) Centre" (NCC) is located at GSE headquarters in the center of Tbilisi. The NCC is equipped with modern technologies and metering systems, controls the operation of the Georgian power system and is important to the overall reliability of it. Due to access to real or near real time data from its substations, "NCC" is able to react quickly in the case of system failures or other emergency situations [22].

1.5.2 Distribution System Operators (DSOs)

All licensed Distribution System Operators (DSOs) in Georgia are privately owned and are players on the retail energy market. Distribution companies are buying energy on the wholesale market from other qualified enterprises based on direct contracts or through ESCO. DSOs are obliged to distribute electricity through their own grids from energy producers to consumers. Since 2017, access to the DSO grids is granted to third parties by the "Law on Electricity and Natural Gas" Art. 46[1]. Therefore, energy producers are now also able to sell electricity directly to retail or wholesale customers (direct customers or "eligible" customers) through the grids of distributor licensees [39]. DSOs typically own grids ranging from 0.4 kV (low voltage), medium (35-110 kV) to high voltage (110kV). The following 3 DSOs are the dominant players [22]:

- JSC “Energo-Pro Georgia”: The largest DSO in Georgia owns grids ranging from 0.4 to 110 kV. The company is active in all regions except in Tbsilisi and the Kakheti regions. Aside from distributing energy, Energo-Pro also produces electricity and provides technical services to its 850,000 customers.
- JSC “Telasi” is the second largest DSO, owning grids which range from low to high voltage (0.4 to 110 kV). The company delivers electricity to 416,500 customers. Other activities include technical, transit, billing and payment services to other service organizations.
- JSC “Kakheti Energy distribution” is an energy distributor servicing 117,058 customers. It is the only DSO active in the Kakheti region with grids ranging from 0.4 to 110 kV.

Figure 5: Market share of the DSOs in the retail market



Source: KPMG Power Sector Overview Georgia [22]

1.6 Other Stakeholders

Direct Customers

Direct customers (also called “eligible” customers) are defined by Decree 144 “On the approval of mandatory Criteria for the Direct Consumer of Electricity” and are mainly large institutional electricity consumers. Certain requirements have to be fulfilled, e.g. regarding the point of network connection (voltage level) or monthly consumption of electricity, to be considered a direct customer. Direct customers receive electricity through 35-110 kV grids and consume on average at least 5 million kWh per month. They may purchase energy via direct contracts with qualified energy producers such as the ESCO or generate their own electricity [33].

There are restrictions regarding energy trading capabilities of direct customers. They are only eligible to trade electricity (capacity volumes) on the wholesale market if the capacity does not exceed 1 MW (for 2017). Moreover, they cannot act as wholesale customers and retail customers at the same time. The number of direct customers has increased significantly during the year 2019 because non-residential customers that had previously bought electricity from the retail market were now granted the right to benefit from lower prices on the deregulated wholesale market.

Tariff Customers/Retail Customers

Retail or tariff customers form the second customer category in Georgia. They are regionally bound to DSOs and purchase electricity at a fixed rate set by GNERC. The Directives 2003/65/EC and 2009/72/EC, also known as the “3rd Package” state that tariff/retail customers are not allowed to switch energy suppliers (the only exception is that customers may purchase electricity from power plants < 13 MW). Due to attempts to harmonize Georgian legislature with EU directives, this directive is currently under revision. Since the “3rd Package” aims to unbundle power distribution and generation, it will have a major structural impact on the Georgian energy sector [49].

Electricity importers

According to the “Law on Electricity and Natural Gas” [29], an importer is “the one who […] receives energy from abroad and sells energy abroad, and/or consumes electricity (capacity)”. These activities are not subject to licensing. For all activities like registering with the dispatch licensee, selling the imported energy to qualified enterprises or own consumption, a direct contract is necessary. GNERC determines the upper marginal tariff for energy sold by electricity importers which is also based on direct contracts.

Electricity exporters

According to the “Law on Electricity and Natural Gas” [29], an exporter is “the one who sells electricity/capacity abroad at the point of delivery”. Exporting energy is not subject to GNERC licensing. Similar to importing, a direct contract is necessary for all activities like registering with the dispatch licensee or reselling energy for export and electricity transmission. On the wholesale market the exporter purchases electricity from another qualified energy producer or from ESCO.

1.6.1 Electricity System Commercial Operator (ESCO)

The “Electricity System Commercial Operator” (ESCO) plays a crucial role for the operation and development of the Georgian electricity market. ESCO is fully owned by the “JSC Partnership Fund”, a state-owned investment fund established in 2011.

ESCO is responsible for the uninterrupted and reliable power supply and plays hence a key role for the stability of the Georgian Electricity Power Sector. Among its duties as the commercial market operator are balancing electricity on the wholesale market (see 1.8.3), balancing guaranteed capacity and identifying electricity import/export needs. The share of balancing electricity trade on the wholesale market through ESCO is 20% to 30% and is based on direct contracts. The remaining electricity consumption is contracted by the DSOs. For direct customers, the energy producers sign bilateral contracts with large electricity consumers or distribution companies assisted by ESCO. The tariff of every commercial transaction depends on the status and the type of qualified energy stakeholder (regulated/deregulated, transmission, distributer) and is based on Decree 33. Every qualified enterprise pays a fee of 0.019 Tetri (0.06€ct) per generated, consumed, imported and exported kWh. The service fee finances ESCO and is also determined by Decree 33 (Art 5) [35].

ESCO operations are defined by the “Law on Electricity and Natural Gas” [29] and the “Order on the Approval of Electricity (Capacity) Market Rules” [32]. In brief, the main functions of ESCO are [22]:

- Purchase and sale of “balancing electricity (capacity)” and management of the electricity trade between Georgia and neighbouring countries
- Trade with guaranteed capacity in accordance with the “Law of Georgia on Power Industry and Natural Gas and Electric Power (Capacity)” and the “Market Rules”
- Inspection of meters used in wholesale trade
- Set up and operation of a unified data base on the volume of electricity traded on the wholesale market
- Submission of information on the final settlement between the consumers and energy sellers
- Support construction of new hydro power plants

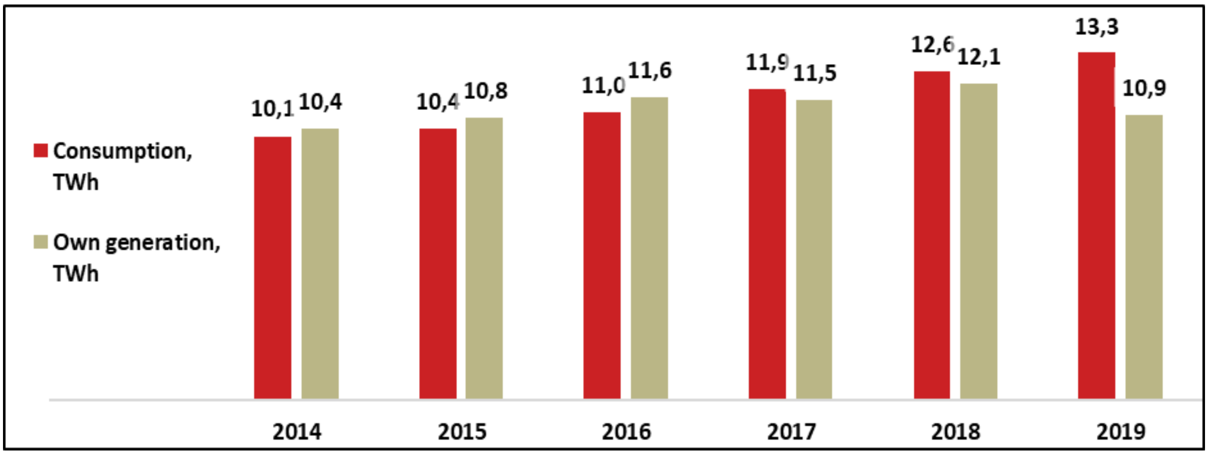
1.6.2 Electricity Generation and Demand

During the last decade, there has been a steady increase in energy demand and consumption in Georgia. In 2017 the consumption grew by 8% (compared to 2016) and reached 11,876 GWh in 2019 [44]. According to the information given by the Report “TBC Capital” [34], the growth in energy consumption was mainly driven by the tourism industry.

While Georgia had been a net electricity exporter between 2007 and 2011 [22], the country has for most years since 2012 become a net importer of electricity (see Figure 6). Major volumes are exported to Turkey, imports are mainly from Russian and Azerbaijan. Energy exports only occur during specific seasons and are expected to grow as soon as the new

HPPs, currently under construction, enter the market. However, even with the new HPPs, Georgia is unlikely to fully cover its demand with domestic generation. According to the estimations of "TBC Capital" the per capita consumption in Georgia increased by 5.4% in the past six years (CAGR) and has reached 2.87 MWh per capita in 2018. It is expected to grow further, reaching 3.67 MWh per capita in 2023 [34]. Simultaneously, the "Invest in Georgia"[2] information platform expects the energy deficit to reach 3 TWh by 2025 [18]. According to "Invest in Georgia", only 25% of Georgia's potential energy sources are being exploited, leaving much of the country's energy potential untapped. This potential includes mostly hydropower but also wind, PV, geothermal and biomass energy [18].

Figure 6: Domestic energy generation and consumption in Georgia in 2014-2019 in TWh



Source: eclareon 2020, based on ESCO 2020

Electricity generation remains a key challenge for the Georgian energy sector. Every year between September and April domestic electricity generation cannot meet demand and consumption. This deficit occurs due high electricity demand in the winter months, combined with the seasonal fluctuation of hydro generation (79% of total supply in 2017). These seasonal changes in generation are caused by Georgian climate and weather conditions: in winter glaciers form which then melt in summer and feed the rivers/discharge water into the hydro reservoirs, see Figure 7 [19]. During September and April, Georgia is therefore dependent on energy imports, primarily from Azerbaijan and Russia. In 2017, the volume of imported electricity from the two countries was 1,497 GWh [19]. In summer, when energy production exceeds demand, the surplus is exported to Turkey, Armenia and Russia. In 2017, Georgia exported 686 million kWh. In 2018, the electricity imports exceeded exports by a factor of 2.6 [48]. The installation of the new HPPs could help Georgia to cover more of the seasonal gap between energy generation and consumption as well as decrease its energy dependence from neighbouring countries.

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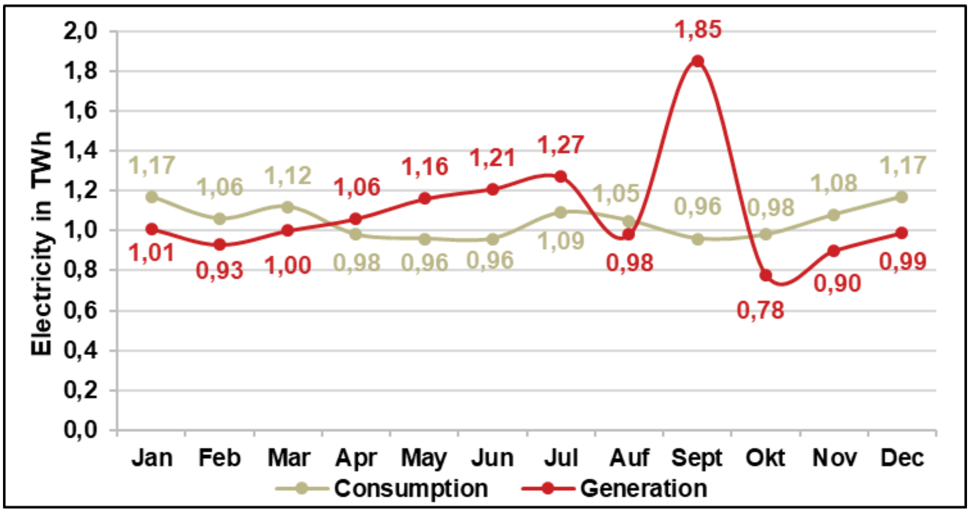
[2] Invest in Georgia is a website that is providing data, including energy data, with the aim of attracting FDI.

Figure 7: Seasonal impact of electricity generation and demand in TWh (month) in Georgia in 2018.



Source: TBC Capital, Energy Sector Overview, July 2019 [34]

1.7 Electricity Markets

1.7.1 Wholesale Electricity Market

According to Art 22 of the "Law on Electricity and Natural Gas" [29], the Georgian wholesale market is based on direct bilateral, short or long-term contracts balanced, supported, registered and scheduled by or through ESCO (see 1.4). As a mediator between electricity producers and consumers, ESCO plays an important role on Georgia's wholesale energy market (also see Figure 8).

Energy actors have to comply with the "Electricity Market Rules" [32], and are bound to tariffs (Decree 33) set by GNERC.

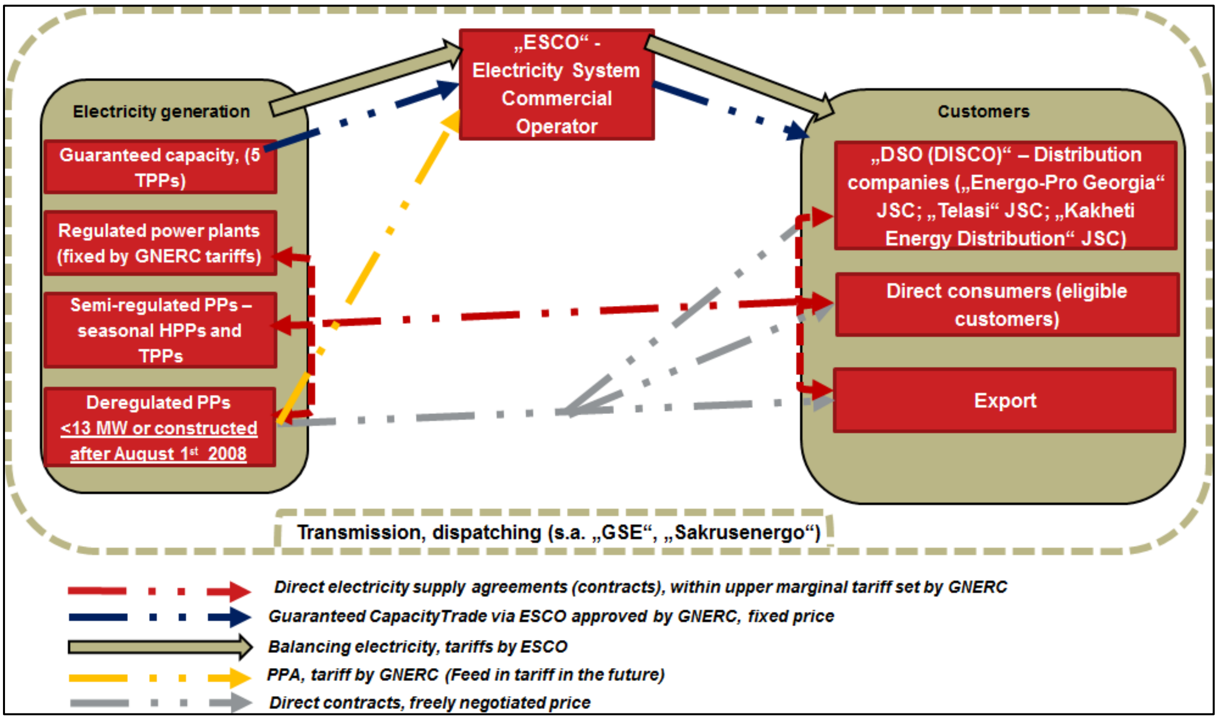
Producers of electricity and importers may sell electricity on the wholesale power market to any other of the following market players (or so-called qualified enterprises/customers):

- large direct electricity consumers (direct wholesale consumers, industrial customers)
- distribution licensees (companies / distribution companies (DISCOs or DSOs)) which are retailers purchasing electricity on the wholesale market
- ESCO ("Guaranteed Capacity" (GC)) or "Balancing Electricity" trading
- Grid operators (with the aim to compensate own grid losses)
- Direct customers (or so-called "eligible customers")

Moreover, electricity producers may directly export electricity and / or sell it to exporters.

HPPs smaller than 13 MW as well as other power plants built after the 1st of August 2008, fall into the category of deregulated plants. The operators of such plants are eligible to sell energy on both the wholesale and the deregulated retail markets. On the wholesale market, the energy is sold to the abovementioned qualified enterprises at freely negotiated rates (defined by the "Electricity Market Rules" Art. 36^1 and 36^2 [32]). At the same time, providers are able to sell electricity on the wholesale market to ESCO as "balancing electricity", via power purchase agreements (PPA) (see 1.8.3). ESCO in this case sells the electricity to all other consumers on the retail market, where it can be purchased by direct consumers at freely negotiated rates (as defined by the "Electricity Market Rules", Art. 36[1] and 36[2] [32]).

Figure 8: Schematic functioning of the Georgian wholesale electricity market



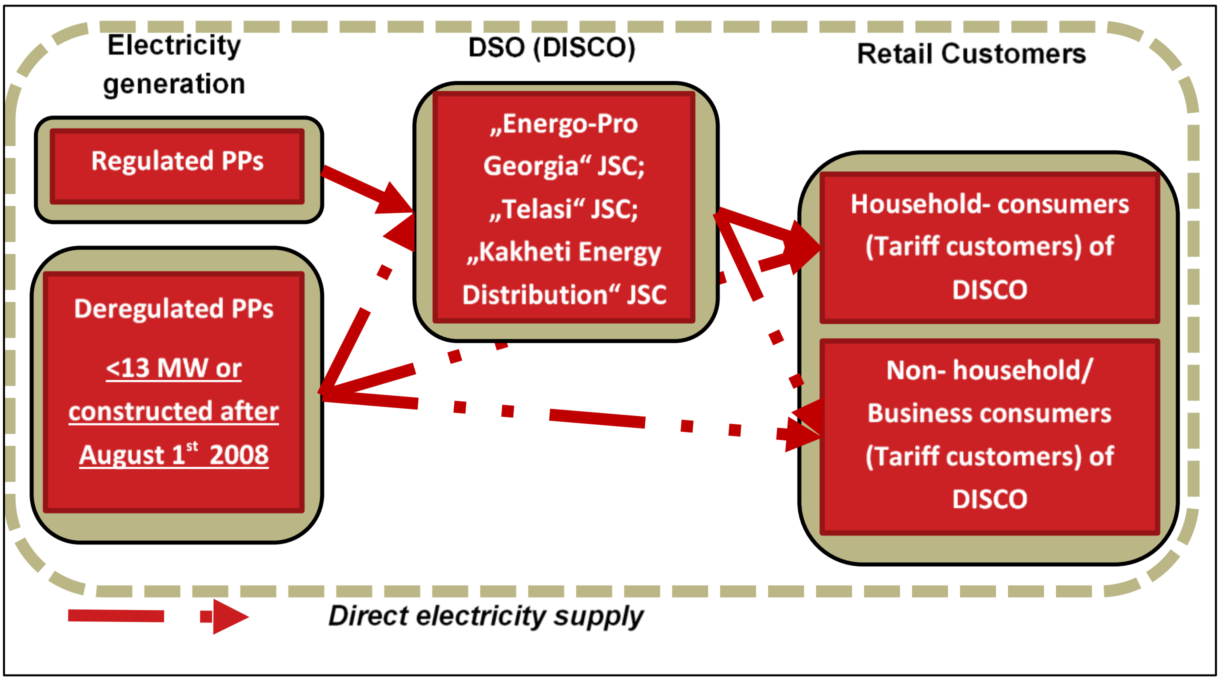
Source: eclareon 2020

1.7.2 Retail Electricity Market

Georgia's energy retail market needs further development as it is today still dominated to a large extent by three distribution companies, namely "Telasi", "Kakheti" and "Energo-Pro Georgia". Electricity distribution and supply activities have not yet been split. This constitutes a substantial barrier to the development of a competitive retail electricity market. All retail customers are supplied by abovementioned electricity distribution companies at regulated rates (since unbundling rules set by Directive 2009/73/E are not applied yet) which are defined by the Decree 33. Therefore, tariff/retail customers are bound to purchase electricity directly from these DSOs and cannot – as direct customers – purchase energy directly on the wholesale market at lower prices directly from energy producers. The currently ongoing legislative unbundling process, stimulated by the implementation of the EU directives, could change this situation and enable retail customers to change suppliers and therefore strengthen their position [49]. However, 'actual' unbundling (according to rules of the EU directive) may take several more years, approximately until 2025 [34].

Today, the only option of electricity trading without DSO participation is a model where a retail consumer purchases energy directly from a so-called 'small' power plant (under 13 MW installed capacity) under the terms of non-regulated direct agreements. However, this scheme is not yet widespread [29].

Figure 9: Scheme of the Georgian retail electricity market



Source: eclareon 2020

1.8 Electricity Tariffs on the Wholesale Market

There are several groups of electricity-related tariffs in Georgia: tariffs for balancing electricity, generation tariffs, import and export tariffs (regulated by GNERC) valid on the wholesale energy market or retail tariffs. There are two major types of costs that determine the rates, which all electricity-consumers (wholesale/direct or retail customers) have to pay indirectly, the generation costs and the costs for guaranteed capacity. These two types of costs are described in the following sections.

1.8.1 Guaranteed Capacity Trade (ESCO) and Costs

The guaranteed capacity is to serve the stability, security and reliability of the country's united electric energy system. It is provided exclusively by regulated thermal power plants on the wholesale market. The minimum volume of each producer of guaranteed capacity if fixed by the Georgian government in the "Law on Electricity and Natural Gas". In detail, the Decree 193 [31] determines the source of guaranteed capacity, the minimum volume to be provided and the periods of provision. Distribution licensees, direct customers and exporters are allowed to purchase the guaranteed capacity electricity volumes and trade them on the wholesale market via ESCO. The costs of guaranteed capacity are financed with this trade and a fee proportional to the traded volume is paid, as set by GNERC and specified by Decree 33.

1.8.2 Generation Costs

Electricity producers in Georgia are allowed to sell on the wholesale market and directly to ESCO as “balancing electricity” (see 1.8.3). As previously outlined, there are 4 major groups of electricity producers in Georgia: regulated power plants (PPs), semi-regulated PPs, guaranteed reserve sources (5 TPPs) and deregulated small PPs (see 1.4.3 for more details). Tariffs for electricity sold to ESCO are set by Decree 33 and the “Electricity Market Rules”. Generation tariffs depend on the technology used, the installed capacity, the date of commissioning and the producer’s license. Electricity producers are therefore allowed to sell electricity on the regulated market at a tariff set by GNERC (Decree 33) or on a deregulated market at freely negotiated tariffs.

The generation tariffs for regulated hydro power plants in Georgia vary between 1.3 Tetri/kWh and 4.1 Tetri/kWh for each plant. The long-term tariffs for HPPs (including large HPPs) are set at different ranges – from 2.3 Tetri/kWh up to 12.3 Tetri/kWh (all without VAT) [30]. Generation tariffs for TPPs are usually slightly higher: in 2019 they ranged from 8 to 12 Tetri/kW (without VAT) [34].

1.8.3 Balancing Electricity and Tariffs

The balancing electricity trade is based on direct contracts with standard conditions applying to all eligible enterprises. This is done so in order to meet the needs of customers and sellers (the enterprises) as well as balancing contracted volumes. All standard conditions of the direct contracts for the sale and purchase of electricity need to be approved by GNERC. Balancing electricity trade is a non-profit activity for ESCO.

Table 2: Balancing volumes and prices in Georgia (ESCO), 2019

Year 2019	BALANCING ELECTRICITY VOLUME	BALANCING ELECTRICITY PRICE
	MILLION KWh	Tetri/KWh
JANUARY	277	13,53
FEBRUARY	222	13,66
MARCH	287	13,46
APRIL	236	13,01
MAY	127	7,36
JUNE	148	7,24
JULY	192	13,60
AUGUST	213	14,29
SEPTEMBER	287	14,84
OCTOBER	303	14,69
NOVEMBER	288	15,45
DECEMBER	299	14,73

Source: ESCO, Website [46]

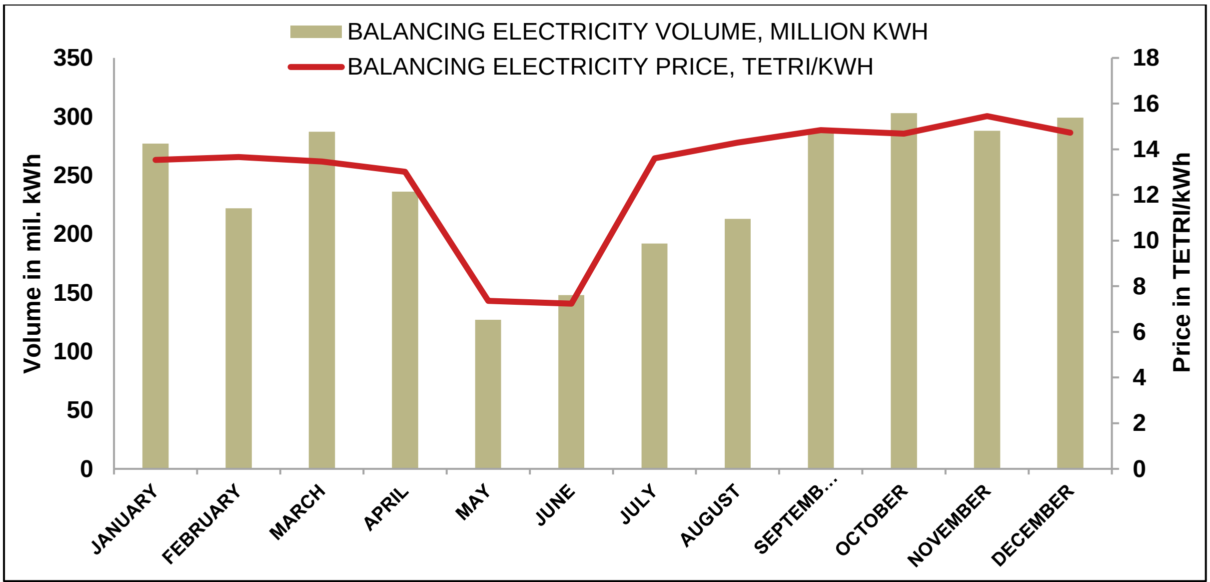
According to the Decree 33 [30] and the “Electricity Market Rules” [32], all electricity sales tariffs are determined as follows:

- For electricity generators the cost of balancing electricity sold to ESCO is set by GNERC.

- For semi-deregulated thermal power plants, the rates have an upper margin set by GNERC.
- For semi-deregulated HPPs, the tariff is set by GNERC at the lowest price of generation from May to August. From September to April it is set within an upper margin tariff.
- Small capacity power plants can sell their electricity on the wholesale market to ESCO via PPAs:
  - Between September and May at a regulated tariff within the upper marginal tariff.
  - Between May and September at the adjustable fixed tariffs which are kept low and can be compared to the generation tariffs for TPPs established by GNERC (stipulated by the "Electricity market rules", Art. 36[1]).

The sales tariff of balancing electricity established by ESCO is calculated based on the weighted average price of balancing electricity for all different purchased electricity volumes, each bearing specific tariffs according to the type of power plant (as listed above). In 2019, the weighted average tariff of balancing electricity in Georgia was 14.73 Tetri/kWh (ca. 5,6 €ct/kWh). The lowest tariff for balancing electricity in 2019 was in June – 7.23 Tetri/kWh, while the highest tariff per kWh was reached in November – 15.45 Tetri [41]. Figure 10 illustrates the fluctuations of balancing electricity tariffs in Georgia in 2019.

Figure 10: Balancing volumes and prices in Georgia (ESCO), 2019



Source: ESCO, Website [46]

1.8.4 Import and Export Tariffs

Import electricity tariffs are determined by Decree 33 and are lowest between May and August.

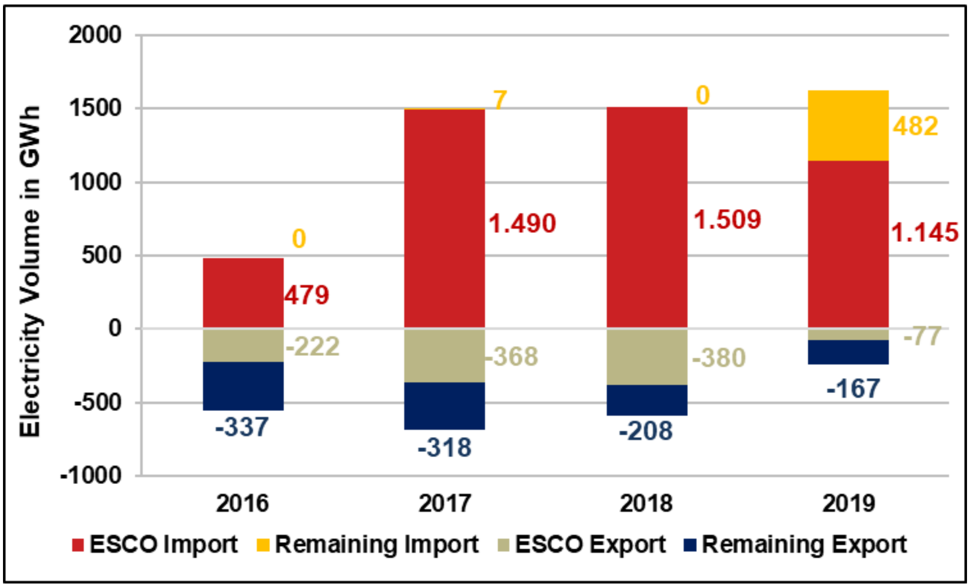
The import prices are based on short, medium, and long-term contracts. They are managed and registered by ESCO, according the organisation's objective to purchase balancing electricity and thereby ensuring the stability of the Georgian power system. In 2017 electricity import prices fluctuated between 3.5 USDct/kWh and 5.2 USDct/kWh (3.1 €ct/kWh and 4.4

€ct/kWh), while export prices fluctuated between 1.1 USDct/kWh and 4.5 USDct/kWh (1.0 €ct/kWh and 4.0 €ct/kWh) [19] [34].

Resolution N33 "On the Electricity Tariffs" determines the calculation of import tariffs using the Georgian currency Lari (GEL). Exports are deregulated and are therefore determined by electricity prices of the importing country. Turkey is the main importer of Georgian electricity [34]. The net price to export electricity from Georgia to Turkey has been fluctuating around 3.10 USD cents/kWh between 2015 and 2018. In 2018 the price was at 3.12 USDct/kWh [34]. Electricity exports, especially to Turkey, are an opportunity for each deregulated power plant in case electricity prices in the receiving country are relatively high. In 2018, Turkey was the major exporter of Georgian electricity (66% of all exports, followed by Russia and Armenia). For deregulated energy producers, the export activity is free of licensing and generation tariffs and export activities are free from VAT [34] [50].

To guarantee energy stability, ESCO has the exclusive right to issue a 'state of emergency' for import/export-contracts. Indicators for an imminent state of emergency are specified by the "Law of Georgia on State of Emergency". Indicators are, e.g. minimum voltages levels or minimum frequencies [32][29]. Imports can also be conducted via direct contracts between importers and DSOs, direct customers and exporters.

Figure 11: Imports and exports, 2016 - 2019



Source: ESCO data [47]

1.9 Tariffs for Retail Consumers

Retail consumers in Georgia include residential consumers as well as commercial and small industrial consumers. Tariffs for these groups are established by GNERC for each of the three major DSOs individually. The marginal tariffs are set by the Resolution N33 “On the Electricity Tariffs” by the Georgian National Energy and Water Regulatory Commission [30].

1.9.1 Tariffs for Non-residential Consumers

The retail tariffs for non-residential consumers (commercial or small industrial) depend on the voltage level and are set for the region of each DSO individually. Table 3 shows the current tariffs for non-residential consumers on the retail market for two of the three main DSOs of Georgia.

Table 3: Tariffs for non-residential electricity consumers in Georgia in 2020, including VAT

Voltage level	“Telasi” tariff		“Energo-Pro Georgia” tariff	
	Tetri/kWh	€ct/kWh	Tetri/kWh	€ct/kWh
220/380 V	21.32	6.66	21.08	6.57
3.3-10 kV	16.88	5.28	16.25	5.08
35-110 kV	16.11	5.04	14.86	4.65

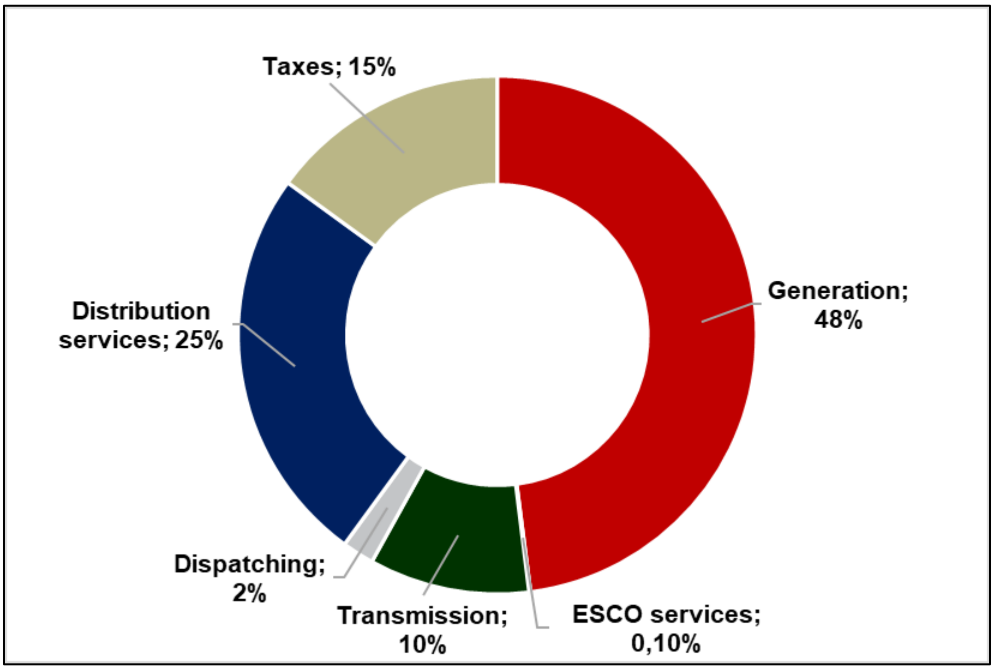
Source: “Telasi” JSC, 2020 [42]; “Energo-Pro Georgia” JSC, 2020 [43]

According to “TBC Capital”, the energy demand and consumption in Georgia is expected to grow [9][19][34]. Due to the current lack of sufficient generating capacities, this will lead to an electricity price increase for consumers.

1.9.2 Tariffs for Residential Consumers

The distribution of costs for residential consumers in Georgia is shown in the next graph:

Figure 12: Composition of the residential electricity tariff in Georgia



Source: eclareon 2020, based on "TBC Capital"2019. [34]

The residential electricity prices are determined by the amount of kWh consumed per month. The more electricity is consumed, the higher the price per kWh becomes. Therefore, residential tariffs for customers consuming less than 101 kWh/month can be even lower than the lowest ones for non-residential consumers. Tariffs are higher for residential consumers with rleativly high demand (more than 301 kWh). The marginal levels are determined by Decree 33, Art. 10.2 for each distributor. In comparison, residential tariffs are around 30% of the average prices per kWh in the EU, however, they are slightly higher than in Russia [51].

Table 4 Tariffs for residential electricity consumers in Georgia in 2020, with VAT

Voltage level	"Telasi" tariff		"Energo-Pro Georgia" tariff	
	Tetri/kWh	€ct/kWh	Tetri/kWh	€ct/kWh
Up to 101 kWh	14.54	4.66	14.24	4.45
101-301 kWh	18.56	5.95	18.21	5.69
More than 301 kWh	23.04	7.39	22.73	7.11

Source: "Telasi" JSC, 2020 [42]; "Energo-Pro Georgia" JSC, 2020 [43]

2 Regulatory and Business Framework

The major piece of legislation in the Georgian electricity sector is the **"Law on Electricity and Natural Gas**" [29]. It regulates the role and function of each market participant and is continuously updated. Renewable energy sources are described in the law as "all non-fossil and sustainable energy sources that are generated by, but not limited to: bio- and hydro powers, geothermal, solar, wind, and marine (including tidal, wave and thermal) energies". With respect to the integration of renewable energy sources, the Law stipulates the following points:

- Extension of the grid is promoted to facilitate the integration of RES
- Prioritised use of RES
- Art. 2 defines the deregulation along with the right to free-tariff activities and the right for free transportation and distribution.
- Art. 2 z defines a small power plant as a power plant not exceeding 13 MW.
- Art. 23 authorizes small power producers to sell directly to the DSO.
- Art. 46^1 grants third-party access to electricity transmission and distribution in networks.
- Art. 49 defines that all PP built after the 1^{st} of August 2008 are deregulated.

The Law regulates activities and relations of individual entrepreneurs, physical and legal persons in the areas of electricity system operation, wholesale electricity trading, electricity generation, transmission, dispatch, distribution, import, export and consumption. Likewise, the law sets rules for the supply of natural gas (import, export, transportation, distribution and consumption). Therefore, it ensures the functioning and development of the electricity sector (as well as the natural gas sector) in Georgia. Transit of electricity through Georgian territory is regulated by the provisions of this Law as well. Article 3 outlines the legal framework of the development of a ten-year network development plan. An updated version of the plan is published by the GSE each year.[3]

2.1 Regulations on Micro Generation and RES

In March 2016, Article 23 on "Micro Power Plants" was added to the "Law on Electricity and Natural Gas". By this definition, Micro Power Plants (MPP) in Georgia are those that do not exceed a capacity of 100 kW. They are owned by retail consumers and connected to distribution networks. Article 23 enables self-consumption business models for MPPs (such as PV), with the additional opportunity to deliver excess electricity to the distribution licensee, as well as the deduction of delivered electricity (net-metering). Several obligatory fees for electricity generators do not apply for the operation of an MPP, since its operation is not declared an "electricity generation activity" (Article 23 §2). Therefore, there is neither a market operator's service fee nor a dispatching service fee. Noteworthy is §7 of the Article, which gives the distribution, transmission and dispatch operators the legal right to limit the total capacity of

[3] http://www.gse.com.ge/communication/Publications/Ten-Year-Network-Development-Plan-of-Georgia

MPPs in Georgia. Further provisions regarding MPPs are determined by the “Electricity (Capacity) Market Rules”, published by ESCO.

Beside the “Law on Electricity and Natural Gas”, the Georgian government is working on a “Law of Georgia on Renewable Energy Sources” of which a draft from 2013 exists [57]. This draft defines several support schemes holding guarantees for investors regarding land ownership, feasibility studies and licenses. Article 4 of the draft is the national adaptation of the EU’s directive to develop National Action Plan for Energy from Renewable Sources. Despite the draft stage of the abovementioned Georgian law, this National Action Plan has been carried out and was published in 2017 under the name of National Sustainable Energy Action Plan of Georgia (NSEAP). The NSEAP outlines the potential for each RES (hydro, wind, biomass and solar) and how the government aims to exploit this potential. The goal is to integrate 130 MW of solar PV into the grid by the end of 2021. In 2017 GNERC introduced a new regulatory framework for “Net Metering in Georgia” [34][5]. As the framework enables all MPPs to benefit from net-metering schemes, it can be seen as a specific incentive for solar PV. By the end of 2018 there were 67 PV systems with a combined capacity of nearly 750 kW that operated under this net metering scheme. While this is still far from the 130 MW goal, the capacity installed in 2018 due to the net-metering incentive has multiplied by a factor of 2.7, allowing for a promising market outlook for residential PV.

It has to be noted, looking at the government’s solar PV activities, that there is no legal framework or governmental committee concerning solar PV only. This is also reflected in the NSEAP, where the support of solar PV is only listed as point 43 out of 48, with a small investment volume of 5 million EUR until 2030. The desired adoption of EU rules and regulations can be seen as a major driver for the development of the Georgian plan to promote RES.

2.2 Additional Decrees and Resolutions

There are also other Georgian laws with a potential impact on RES based energy generation, of which arguably the most relevant are the following:

- The Resolution No 10 “On Approving Network Rules”, based on the Article 5 (1) of the Law of “Georgia on Electricity and Natural Gas”, by GNERC, April 17, 2014 [10] is a standard Network Code, which applies to all market participants. Art. 87 defines a five-year plan to develop the distribution network in Georgia has to be implemented. This plan needs to take the implementation of renewable energies into account. Network rules (hereinafter – the Rules) set procedures, terms, principles and standards for the development, management, availability and secure utilization of transmission networks by electricity system participants and applicants.
- The Resolution No33 “On the Electricity Tariffs”, 4th December 2008 by GNERC [30], defines the generation tariffs for the each regulated tariff for production, transmission distribution, e.g. all tariffs are set by the GNERC.
- The Decree No144 "On the Approval of Mandatory Criteria for the Direct Consumers of Electricity" 25th March, 2019 [33], defines the classification of a “direct consumer” with respect to the voltage level a customer receives energy from and the minimum capacity a consumer receives from a licensee.

- Resolution No193 “Defining the Guaranteed Capacity and Guaranteed Capacity Sources in Electric Energy System of Georgia”, 10th July, 2010 [31], determines the guaranteed capacity sources by time, volume and minimum capacity (minimum guaranteed capacity in MW). As stipulated in the “Law on Electricity and Natural Gas” the sources are thermal power plants. (Art. 2, Paragraph 1).
- The Decree No214 “About the Approval and expressing interest in technical and economic study of the construction, ownership and operation of the power plants in Georgia” supports the construction of new power plants and is related the Decree No107 with the exemption that it is not establishing a “power purchase agreement or feed-in” but limits the size of financially supported power plants construction to 100 MW.
- Decree No107 State Program: “Renewable Energy 2008” about Approval of the Rule to Enable the Construction of Renewable Energy Sources in Georgia”. 18th April 2008, Government of Georgia [10] enables new (renewable) power plants to sell their generated electricity at a deregulated tariff or guaranteed purchase contract (PPA of 10 years), determined by the “Electricity System Commercial Operator” (ESCO) during the three-month winter period. In addition, it assures that RES construction will be supported by a Bank Guarantee of 100.000USD per each MW of installed capacity.

3 PV in Georgia

It can be assumed that there are no governmental plans to use solar PV as a backbone of Georgian electricity generation, although the solar irradiation in Georgia is quite high. Almost 100% of Georgian households have access to electricity. Direct governmental support for solar PV is only given to some parts of the population living in rural, mountainous and scarcely populated areas, which have no access to distribution networks. Development projects like “Light to Every Village” rely on solar PV to electrify these off-grid areas [49]. Nevertheless, two potential PV business cases were calculated for this report: utility-scale systems (due to decreasing PV LCOEs) and rural electrification with small off-grid PV. These two business cases will be discussed in the business case calculation section (chapter 4).

Global Horizonal Irradiation (GHI) in Georgia ranges from 1250 kWh/m² in the north-western region of the country, to 1400 -1450 kWh/m² in the central regions and can reach up to 1500 kWh/m² in the south[4]. With a median of local irradiation at 1370 kWh/m² and nearly 40% of the country’s territory above 1400 kWh/m², GSE’s goal to add 130 MW of solar PV by the end of 2021 exceeds the targets set in the NSEAP for PV of 108 MW, which is based on an outdated report from 2004. By 2030, the TSOs plan to increase the grid connected solar capacity to 520 MW.

The largest PV plant in operation is a 316 kW system on the Tiblisi International Airport, but other utility-scale PV plants are planned as well. Due to the decreasing global PV LCOE and the widespread availability of PV systems, the TSOs have taken interest in the technology. A 5 MW PV plant in Udabno is under construction after a Memorandum of Understanding (MoU) was signed between JSC "Georgian Energy Development Fund" (GEDF) and the Government of Georgia in 2016. The project is fully financed by the GEDF, “Georgian Solar Company” LLC and “Solar Power Georgia” LLC but is still not operational. In addition, several feasibility studies for solar PV are underway in the country. In 2017 the Government of Georgia signed a MoU with the JSC “Caucasian Solar Company” to develop feasibility studies for ten different Solar Power Plants (SPP) in Algeti, Gldani, Kaspi, Ksani, Marneuli, Saakadze as well as two locations each in Akhaltsikhe and Gardabani. All ten projects shall be utility-scale grid-connected SPPs with an average size of 50 MW per project. The responsible “Caucasian Solar Company” is owned by the JSC “Georgian Renewable Power Company”, which itself is a part of the Bank of Georgia Group PLC, a UK based holding. These studies were planned to be conducted within 18 months; however, the results have not yet been published (March 2020). Another factor points to the promising prospects of large utility-scale PV potential in Georgia: The “European Bank for Reconstruction and Development” (EBRD) issued a tender in 2019 to find consultants to advice the GDEF in four areas [59][34][49][60][61][62].

- Selecting a site for a 50 MW SPP project
- Design of a competitive auction or bidding process for SPP projects
- Providing technical, financial and legal assistance for solar auctions
- Preparing documents for national solar energy tenders.

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[4] https://globalsolaratlas.info; GHI country data Georgia

Besides utility-scale systems, another use for PV systems is gaining momentum. The “Light to Every Village” program started to supply mountainous areas with solar panels in 2014. This project is to be picked up again after the Georgian Government’s announced the “Mountain Development Strategy 2019-2023” in 2019. 178 households in 87 villages in the regions Mtskheta-Mtianeti, Shida Kartli, Samtskhe-Javakheti, Racha-Lechkhum-Kvemo Svaneti, Kakheti and Imereti will be supplied with small SPPs. The systems will have a size of 1,5 kWp each. The project is fully funded by the government with a budget of nearly 22 million €. The PV-related part of the project is managed by the Tiblisi based IT-company “United Global Technology” UGT [63][64].

The Georgian industry has started to engage in PV in 2017 and the market seems to have developed quickly. Solar companies like “Sun House” LLP report massive growth in the number of PV systems installed each year since 2017. Since the market is very young, regulatory mechanisms need to be created and implemented. The GDEF’s effort to implement an auction system is a first step towards enabling PV in Georgia, but should be accompanied by appropriate legislation and a regulatory framework (e.g. feed-in-tariffs, PV-hybrid systems) [65].

3.1 Value Chain

Due to Georgia’s brief history of solar power, the country’s PV value chain is yet to be developed. There are few sources regarding production of upstream PV components but the opening of a 500 MW module manufacturing site by the German company AE Solar sticks out. The factory was built after state support such as exemptions from a number of taxes and duties were granted [65]: The manufacturing site was opened in May 2019 in the city of Kutaissi and will mostly not serve the Georgian but international PV markets. AE Solar chose Georgia because of the country’s strategic location, its free trade agreements with the EU, India and China as well as duty preferences with the USA, post-Soviet nations, Turkey and other countries. Moreover, as another reason for choosing Georgia it was stated that “Labor and electricity costs in Georgia are low.”

In 2013, the company “Ergon Solair” LLP also planned to establish module production in Kvemo Kartli, south of Tiblisi, but there is no confirmation on whether the plan was eventually realised. The only active part of the value chain is the installation of PV systems – data on operation and maintenance is not available. [67]

Companies active in the solar power industry are: “JSC Caucasus Sun Company”, “Solar Energy Georgia Ltd.”[5] and the self-proclaimed leading solar installer LLC “Sun House”[6]. “Sun House” offers PV solutions for off-grid and on-grid projects. On its website, the company states it has installed 548 off-grid systems with a cumulated capacity of 240 kW and an on-grid capacity of 347 kW (45 systems). Depending on the location, “Sun House” charges 1200 € to 1500 € per installation of 1 kW. [65][67]

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[5] https://www.solar.ge/

[6] http://sunhouse.ge/en/

3.2 Incentives

There are no government subsidies exclusively for solar power in place. However, PV benefits from MPP incentives (chapter 2), especially net metering, which is allowed since 2016.

According to the "Law on Electricity and Natural Gas" (Art. 49[3]) every new producer is considered "deregulated" and will face a liberalized, deregulated market characterized by the absence of a tariff-regulation and no costs for distribution.

Georgia currently has RES specific RES legislation comparable for example to the German Renewable Energy Law ("Erneuerbare Energien Gesetz", EEG) Since 2013 different sources have stated that a law on RES is imminent, but so far no law has been introduced. Despite the absence of a central legislative act on the promotion of solar power there are still some indirect support mechanisms RES investors should be aware of - some of which are actually aimed at micro generation. [50]

Incentives aimed at micro generation:

- Owners of micro power plants can sell electricity to distribution companies at the weighted average price for purchased electricity.
- Self-consumption is exempt from taxes.
- Electricity generated above self-consumption levels can be supplied to the grid and then re-supplied upon request for self-consumption.
- PPA for 20% of annually generated electricity for 10 years for domestic suppliers.

Other relevant incentives:

- Investors are free to choose clients on an open market and negotiate tariffs
- No fees for distribution and transmission ("Law on Electricity and Natural Gas", Art. Art. 2)
- Exceptional right for PPs up to 13 MW to sell electricity to any retail customer ("Law on Electricity and Natural Gas", Art. 23[4])
- All PPs <13 MW of installed capacity do not require a generation license ("Law on Electricity and Natural Gas", Art. 2 (z,f))
- Network access is legally granted and prioritised for RES and an application procedure needs to be conducted online via the GNERC-website [40]. ("Law on Electricity and Natural Gas", Art. 46[1])
- No fee required for the connection to transmission grids [50].
- No license is required for electricity export and newly built PPs prioritized connection to new grids and selling the energy to Turkey at freely negotiated prices (and not under the tariffs set by GNERC or ESCO) ("Market Rules", Art 14[12])
- Generation and export activities are exempted from VAT [50]
- The government approved new rules on the expression of interest to install a power plant, technical and economic feasibility studies, construction, ownership and the operation of power plants in Georgia (Decree #214)

In addition, by Decree 214, the Government of Georgia offers two different bank guarantees for investments in all kinds of power plants, including investments in large PV arrays: The "Preconstruction Guarantee" at 5,000 USD/MW aims to help market participants in the phase of interest expression, e.g. with conducting feasibility studies. The second guarantee is the "Construction Guarantee" at 100,000 USD/MW for PPs up to 100 MW and 50,000 USD/MW for PPs larger than 100 MW. As the name suggests, this guarantee is given for the construction phase of PP-projects.

3.2.1 Opportunities on the Wholesale Market

Investors planning to become an IPP have to negotiate with ESCO. They can freely negotiate tariffs with ESCO for "balancing electricity"- trade. As of 2020, GNERC sets an upper marginal tariff of approximately 16,5 Tetri/kWh (5,2€ct/kWh).

With regards to potential customers for an IPP operated PV systems, the following 2 groups seem to be most promising:

- Direct customers: This group of customers consumes a high volume of electricity, leading to higher electricity tariffs. Therefore, these customers might be interested in independent SPPs.
- Export: Investments in new IPPs for export purposes is a highly promoted option for foreign direct investment.

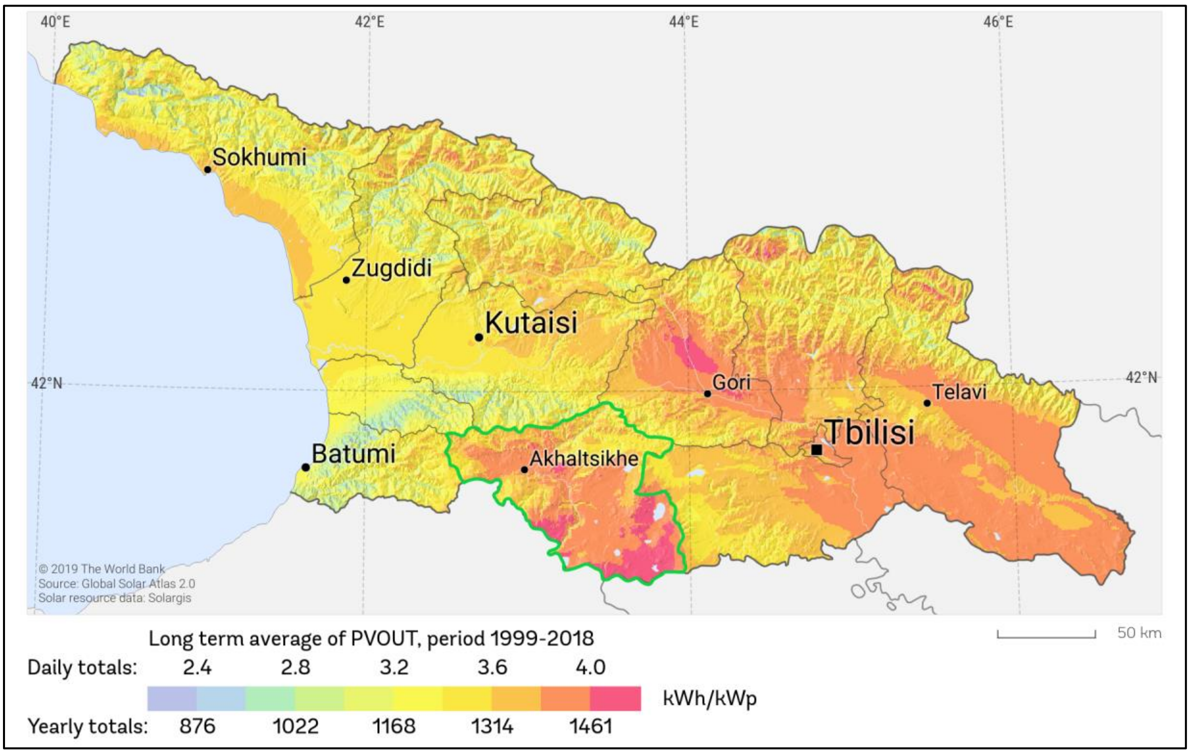
3.2.2 Opportunities on the Retail Market

Retail tariffs for residential customers increase with higher electricity consumption. Therefore, the benefits of net-metering and/or self-consumption may prove as an incentive for customers reach a lower tariff bracket. However, besides in rural areas, the majority of Georgians (nearly 100%, according to the Energy governance in Georgia Report [49]) is already connected to the grids and the low electricity tariffs in Georgia (far below 0,1 €/kWh) reduce the utility of self-consumption business models.

4 Selected PV Business Cases

The southern region Samtskhe-Javakheti with its capital Akhaltsikhehas been chosen as the location for both business cases. This region has a high PV power potential (PVOUT), as shown in Figure 13. Using the "Global Solar Atlas" tool [69], the PVOUT in this area of the region has been evaluated (see Annex 1 for the corresponding report). The area has a potential of 1,325 kWh/kWp to 1500 kWh/kWp (the average is 1427 kWh/kWp), with a GHI of 1391 kWh/m² to 1526 kWh/m².

Figure 13: Photovoltaic Power Potential in Georgia



Source: Solar Resource Map of Photovoltaic Power Potential in Georgia obtained from the "Global Solar Atlas 2.0, the free, web-based application is developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilising Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP) [69]

4.1 Rural Electrification

A few mountainous areas in Georgia still do not have a connection to an electricity distribution network. In the past six years, the Georgian government funded two separate programs that aim to electrify these villages through solar PV. In the latest program (2019 – 2023) 178 households are going to be supplied with 1,5 kWp systems. This business case presumes, that there still is a market for rural electrification via small-scale PV systems in the future: either for households still not supplied, or supplied consumers that could use a system larger than 1,5 kW. In addition, many agricultural processes could benefit from a higher available capacity. A 1,5 kWp system (in the specific area) is able to supply a household with around 2000 kWh/a. The average electric power consumption per capita in Georgia, however, was around 2700 kWh/a in 2014, and is likely to increase as the trend of previous years indicates [69]. Therefore, it is likely, that there is a need (and a market) for the further supply off-grid communities with small PV-systems. It has to be noted that the benefits of having electricity in contrast to no electricity supply at all cannot easily be represented in terms of monetary figures. Therefore, the business case calculates the savings in contrast to the most common electricity generation in rural and 'underdeveloped' regions: a diesel genset. To further add value to the customer, the rural business case is split in a calculation with, and one without storage.

The calculations of both cases (with and without storage) are based on an 1,5 kWp system in the rural area of Samtskhe-Javakheti (part of the "Mountain-Development Strategy"). The optimum tilt of panels in the examined area is 32-36° (also see globalsolaratlas data in the Annex). The investment costs for a separate diesel genset are not integrated in the calculation. This report aims to showcase the economic opportunity PV offers, even if a basic supply system or a backup genset is in place.

4.1.1 Without Storage

The profitability analysis for an off-grid PV system for self-consumption with a diesel backup unit is presented below.

Figure 14: Project overview - PV system for self-sufficiency without storage (eclareon; 2020)

Project Overview

PV Project			
PV System Size		kWp	1,5
Specific System Cost		GEL/kWp	5.136
PV Battery Size		kWh	-
Specific Battery Costs		GEL/kWh	-
Total System Cost		GEL	7.704
Fixed Operation Costs		GEL p.a.	154
Variable Operation Costs		GEL/kWh	-

PV Generation			
Global Tilted Irradiation (GTI)		kWh/qm/a	1700
Performance Factor		%	84%
Specific Yield		kWh/kWp/a	1.428
Degradation		% p.a.	0,70%

Investment			
Project Duration		Years	25
Equity		GEL	3.980
Debt (Gearing)	50%	GEL	3.852
Loan Tenor		Years	10
Interest Rate		%	10,50%
Discount Rate		%	15,00%
Inflation Rate		%	3%

PV Business Model		
Direct PV Consumption	%	80%
PV Consumption via Battery	%	-
Battery Losses	%	-
Effective fuel costs	GEL/liter	2,6
Diesel Generation Costs	GEL/kWh	0,85
Fuel cost escalation	% p.a.	4%

Results		
Net-Present Value	GEL	3.358
Project IRR	%	20%
Equity IRR	%	24%
Amortization - discounted payback period	Years	8,61
Undiscounted payback period	Years	4,95
LCOE (no subsidy)	GEL/kWh	0,61
Min DSCR**	x	2,11 x
Min LLCR***	x	2,39 x

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

As mentioned in 4.1 the PV systems are self-consumption systems. Therefore 20% of the generated electricity is considered a loss that occurs, e.g. when a PV system generates electricity which cannot be used efficiently at times when there is no or less electricity needed.

The 80% used lead to revenue based on the substitution of an existing backup system (diesel genset). Since in the calculation the genset is already in place, only fuel costs are taken into account. In the period from January 2020 to April 13th the average diesel fuel price in Georgia has been 2,56 GEL/litre (~0,74 EUR/ litre) [9].

In case the PV systems are professionally planned and constructed (32-36° tilt angle) a Global Tilted Irradiation (GTI) of 1700 kWh/m²/a leads to the above-mentioned range of PVOUT at 1427 kWh/kWp/a. Due to the bank guarantee for PP projects (see chapter 3.2) the investment is calculated with a debt gearing of 50%, a payback tenor of 10 years and a WACC of 12,8%.

Results

The results are shown in Figure 15 and Figure 16. In the first ten years the payback tenor of the debt capital lowers the Equity Cash Flow, but the whole-time revenues are higher than debt service and O&M costs. Therefore, the long-term economic viability of this investment is shown in Figure 16. The amortization, using discounted cashflows, takes place within the first nine years. This might be considered a fairly long period from the point of view of the investors. However, due to the durability of the PV system the Project IRR and the Equity IRR are above 20%.

Figure 15: Equity capital cash flows – off-grid PV system for self-sufficiency without storage (eclareon, 2020)

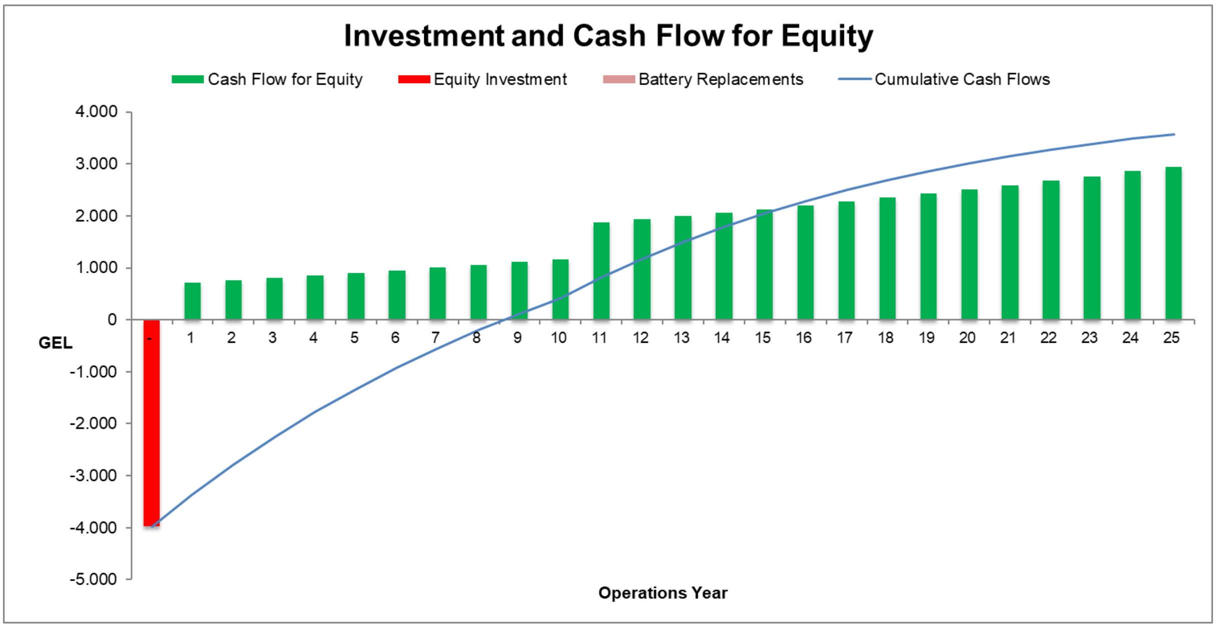
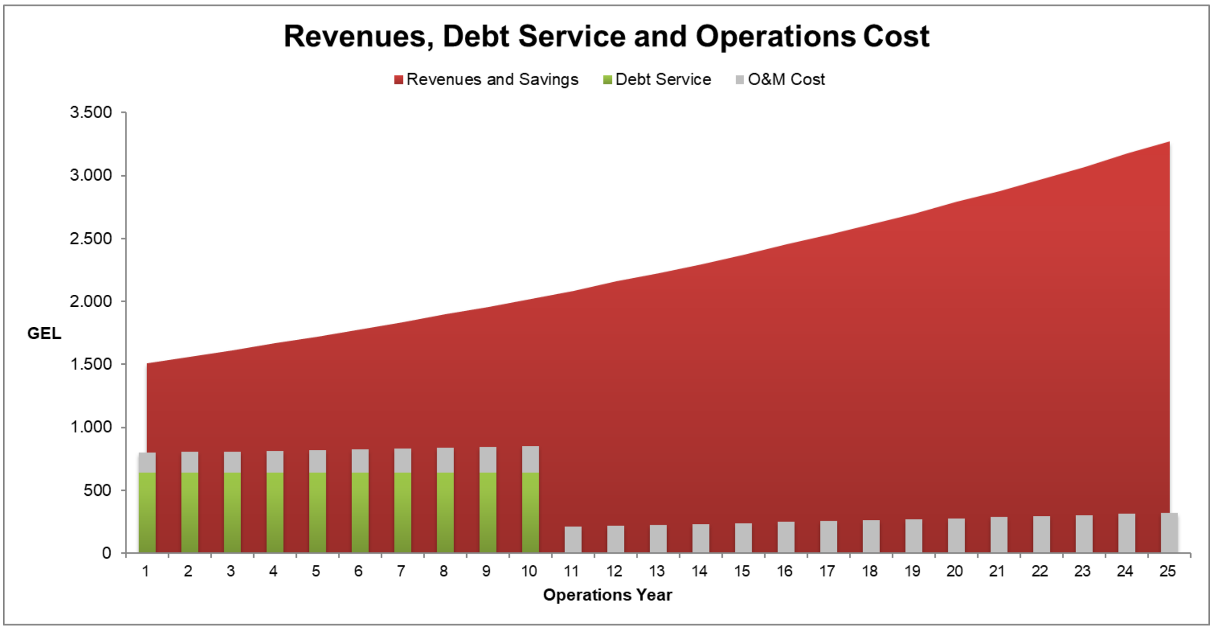


Figure 16: Project cash flows off-grid PV system for self-sufficiency without storage (eclareon; 2020)



Sensitivity Analysis

The sensitivity analysis shows how the two leading economic indicators for an investment, the amortization period (amortization) and the internal rate of return on equity (Equity IRR) change when certain parameters in the framework conditions are altered. It becomes clear which individual assumptions have a particularly strong influence on the profitability of the investment (high sensitivity). This has to be considered carefully during the planning phase.

Figure 17: Specific Yield – off-grid PV system for self-sufficiency (eclareon; 2020)

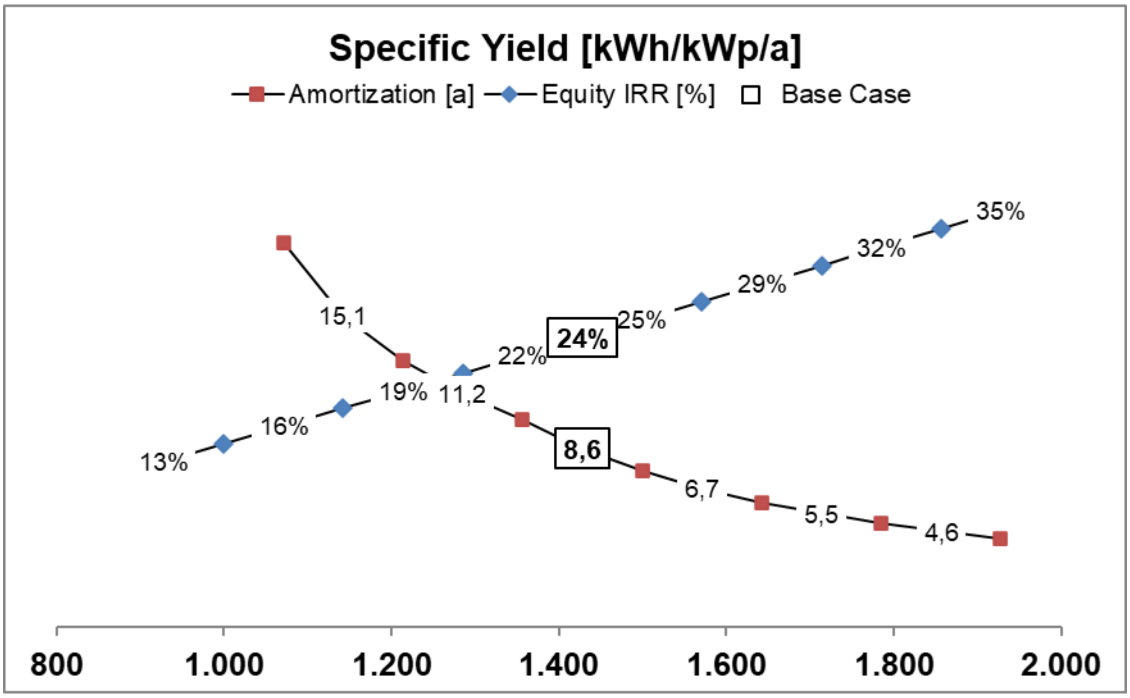


Figure 18: System price – off-grid PV system for self-sufficiency (eclareon; 2020)

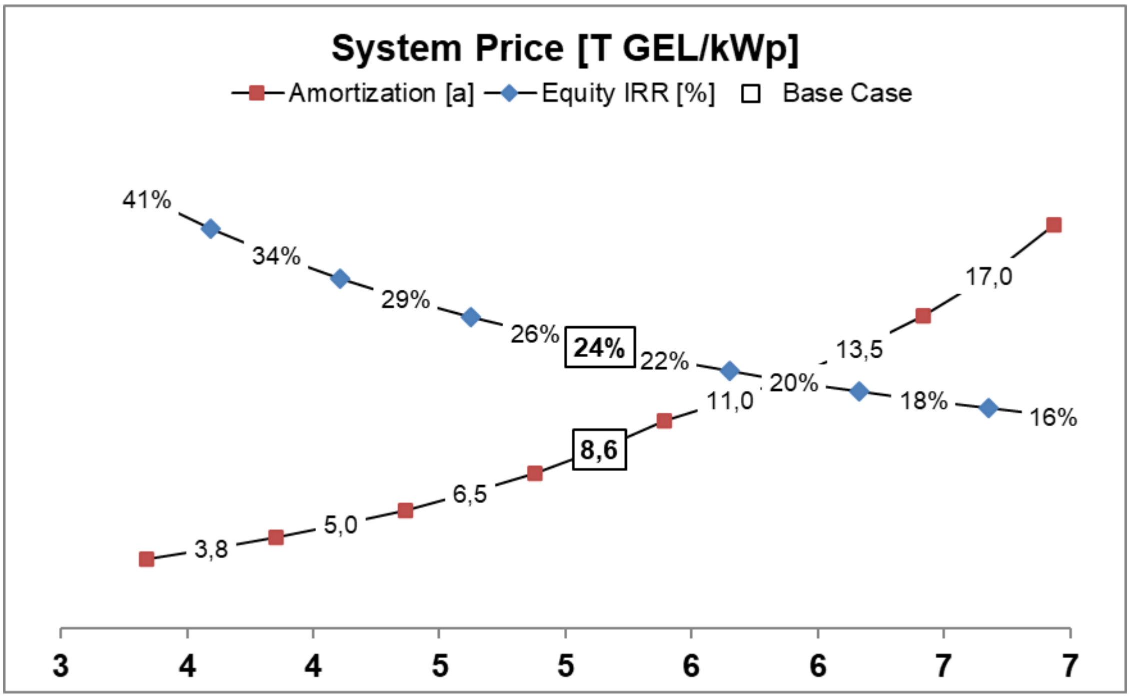
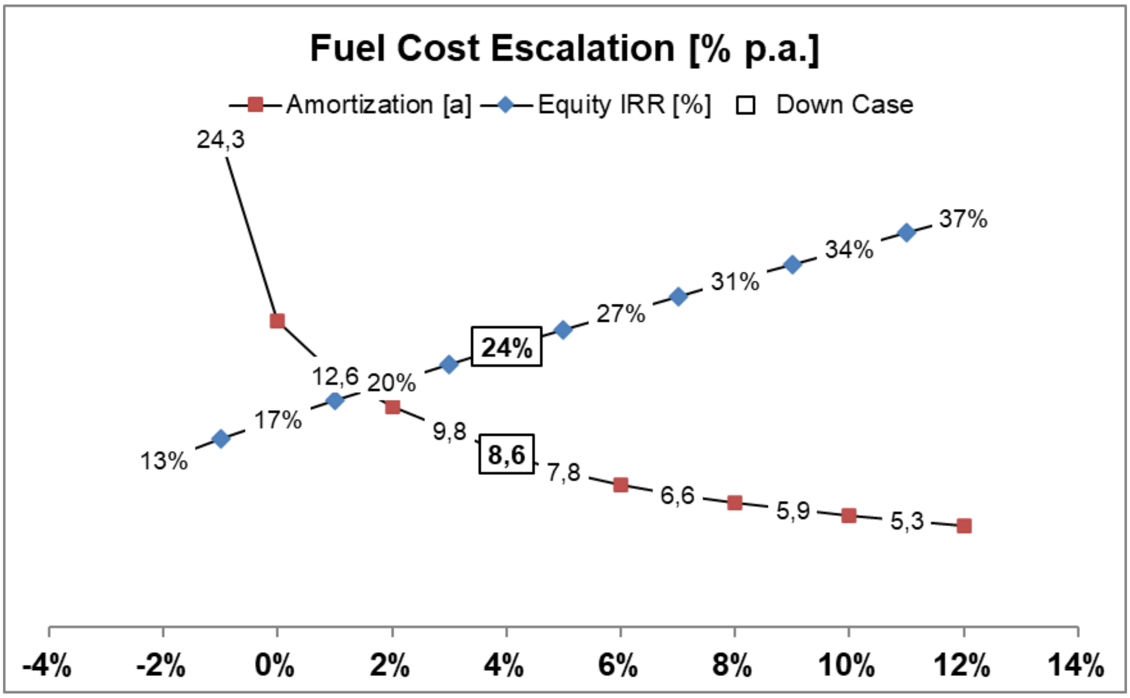


Figure 19: Fuel cost escalation – off-grid PV system for self-sufficiency (eclareon; 2020)



4.1.2 With Storage

A profitability analysis for an off-grid PV system for self-consumption with storage and a diesel backup unit is presented below.

Figure 20: Project overview - PV system for self-sufficiency with storage (eclareon; 2020)

Project Overview

PV Project			
PV System Size		kWp	1,5
Specific System Cost		GEL/kWp	5.136
PV Battery Size		kWh	1,3
Specific Battery Costs		GEL/kWh	1.483
Total System Cost		GEL	9.619
Fixed Operation Costs		GEL p.a.	192
Variable Operation Costs		GEL/kWh	-

PV Generation		
Global Tilted Irradiation (GTI)	kWh/qm/a	1.700
Performance Factor	%	84%
Specific Yield	kWh/kWp/a	1.428
Degradation	% p.a.	0,70%

Investment			
Project Duration		Years	25
Equity		GEL	4.969
Debt (Gearing)	50%	GEL	4.809
Loan Tenor		Years	10
Interest Rate		%	10,50%
Discount Rate		%	15,00%
Inflation Rate (Intial year)		%	3%

PV Business Model		
Direct PV Consumption	%	75%
PV Consumption via Battery	%	22%
Battery Losses	%	20%
Effective fuel costs	GEL/liter	2,6
Diesel Generation Costs	GEL/kWh	0,9
Fuel cost escalation	% p.a.	4%

Results		
Net-Present Value	GEL	2.535
Project IRR	%	17%
Equity IRR	%	20%
Amortization - discounted payback period	Years	11,72
Undiscounted payback period	Years	5,67
LCOE (no subsidy)	GEL/kWh	0,82
Min DSCR**	x	0,52 x
Min LLCR***	x	1,81 x

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

The main difference between this business case and the one without storage outlined in the previous chapter, is the opportunity storage offers to optimize the consumption pattern of the customers. In the abovementioned case 20% of the generated electricity were considered a loss due to inefficient generation and consumption schemes. In this case the loss is minimized to 3% by storing unused electricity. Only power that is generated during a time of no consumption and a fully charged battery will be lost (except efficiency losses). 75% of the produced energy will be consumed on site and 22% will be stored. Therefore, in the model a 1,3 kWh battery is installed, which leads to higher investment costs. Again, the genset is already in place, therefore only the fuel costs are taken into account to calculate revenues. It is calculated with the diesel fuel prices in the period of January 2020 to April 13th, which averaged 2,56 GEL/litre (~0,74 EUR/ litre) [9].

In case the PV systems are professionally planned and constructed (32-36° tilt angle) a Global Tilted Irradiation (GTI) of 1700 kWh/m²/a leads to the abovementioned range of PVOUT at 1427 kWh/kWp/a, as in the previous model. Due to the bank guarantee for PP projects (see chapter 3.2) the investment is calculated with debt gearing of 50%, a payback tenor of 10 years and a WACC of 12,8%.

Results

The results are shown in Figure 21 and Figure 22. In the business case it weas assumed that the lead-acid battery needs to be replaced after eight and after 16 years. In the first ten years the payback tenor of the debt lowers the Equity Cash Flow, but at all times the revenues are higher than the debt service and the O&M costs of the system. Therefore, the long-term economic viability of this investment is shown in Figure 21. The amortization, using discounted cashflows, takes place within the first twelve years. The Project IRR is at 17% and the Equity IRR is at 20%. This investment alternative is less economically viable than the business case without storage, but it still leads to a reasonable amortization period - considering the lifetime of a PV-system is up to 25 years. Again, it has to be noted that the opportunity costs between access and no access to electricity are not easily presented in monetary values and that the consumers undoubtedly benefit from installing a battery (97% of the generated energy is used compared to80 % without storage).

Figure 21: Equity capital cash flows – off-grid PV system for self-sufficiency with storage (eclareon, 2020)

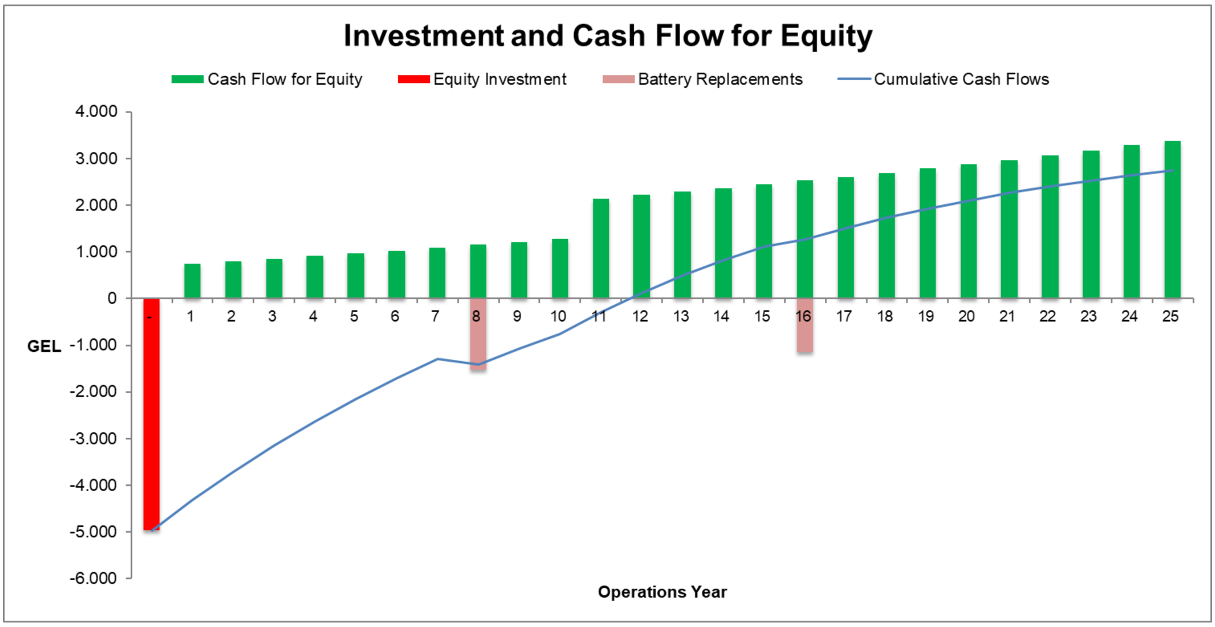
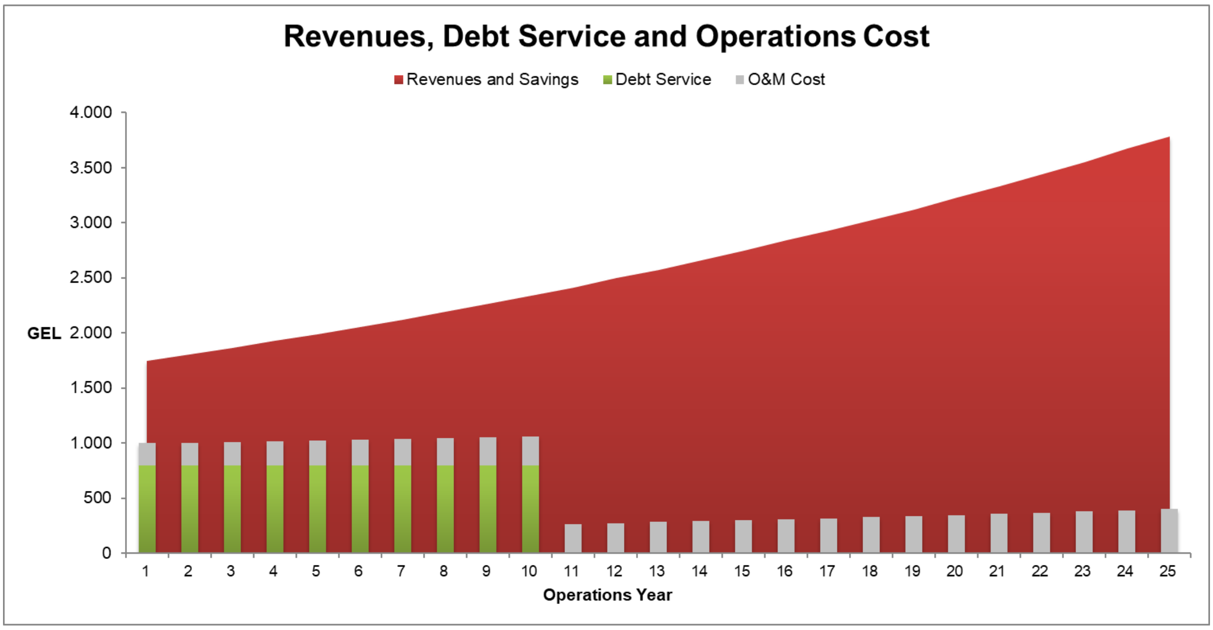


Figure 22: Project cash flows off-grid PV system for self-sufficiency with storage (eclareon; 2020)



Sensitivity Analysis

The sensitivity analysis shows how the two leading economic indicators for an investment, the amortization period (amortization) and the internal rate of return on equity (Equity IRR) change when certain parameters in the framework conditions are altered. It becomes clear which individual assumptions have a particularly strong influence on the profitability of the investment (high sensitivity). This has to be considered carefully during the planning phase of an investment.

Figure 23: Specific Yield – off-grid PV system for self-sufficiency with storage (eclareon; 2020)

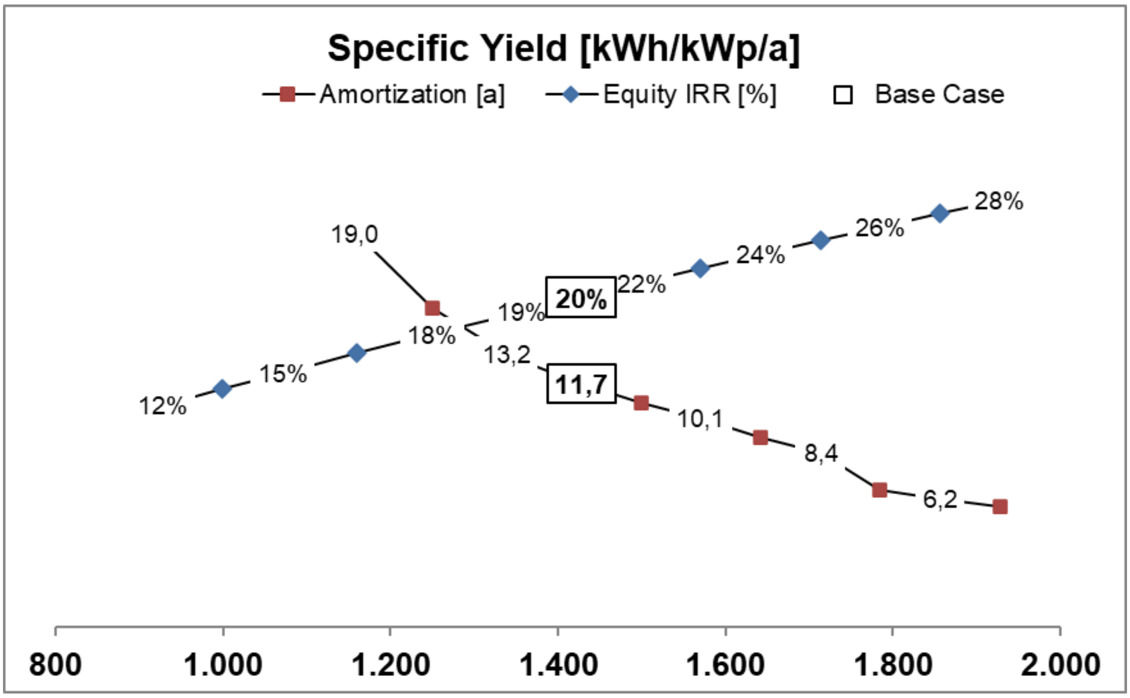


Figure 24: System price – off-grid PV system for self-sufficiency with storage (eclareon; 2020)

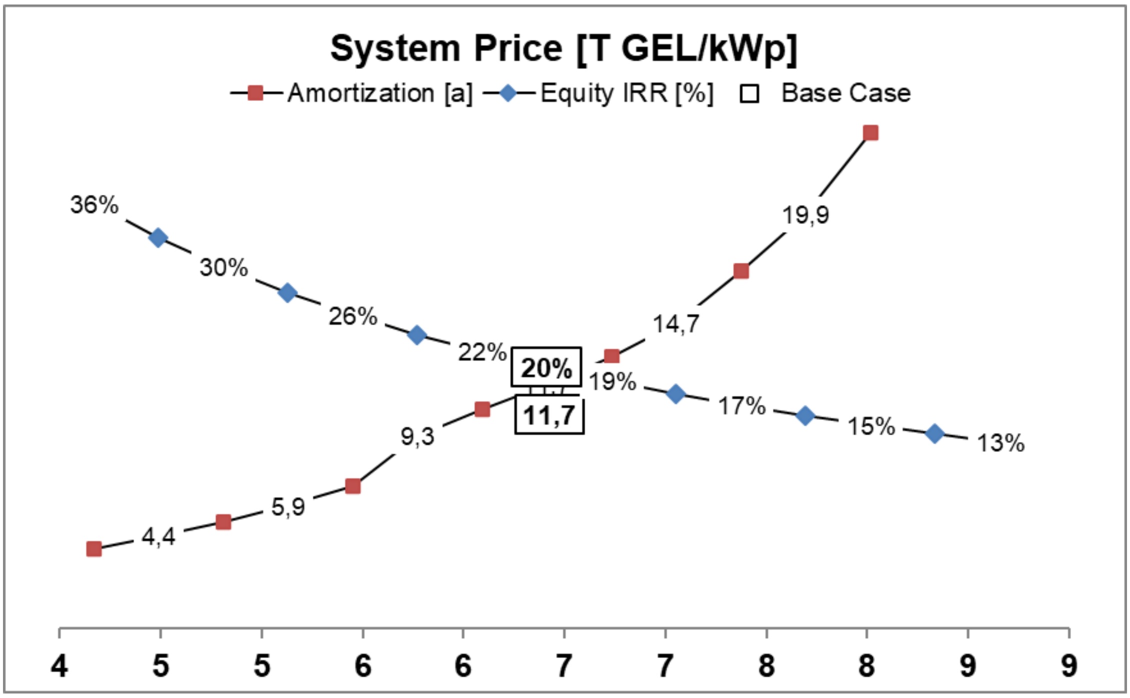
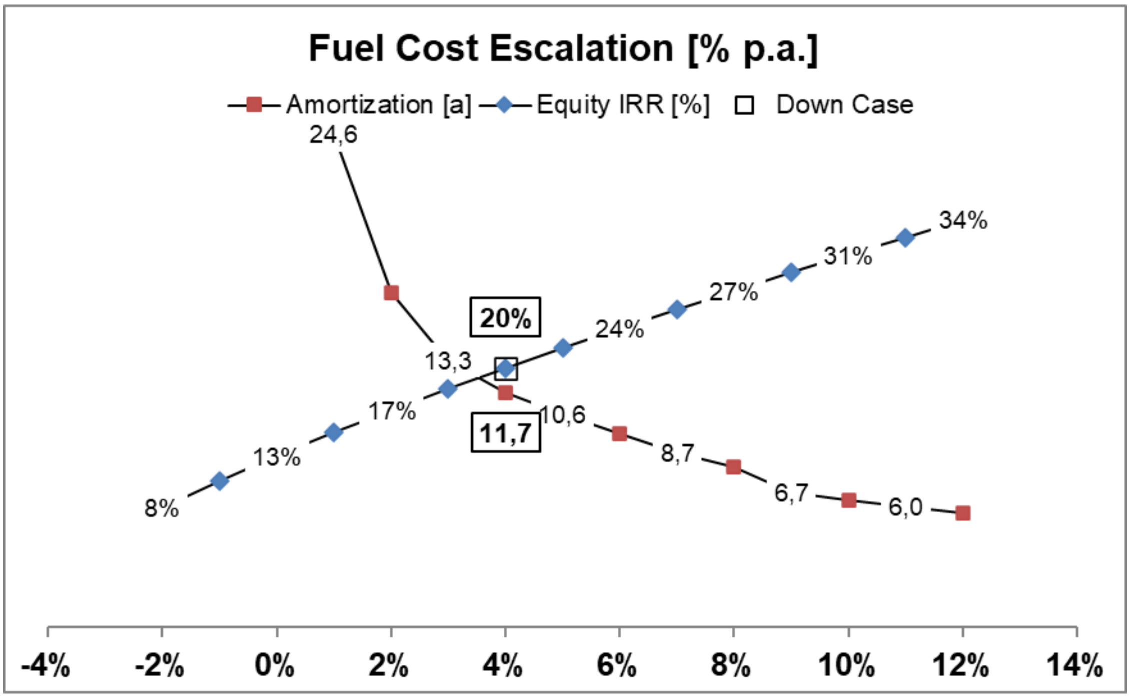


Figure 25: Fuel cost escalation – off-grid PV system for self-sufficiency with storage (eclareon; 2020)



4.2 Utility-Scale System

A profitability analysis for a 5 MW grid connected utility-scale PV system is presented in this following chapter.

Figure 26: Project overview – grid-connected PV system, PPA utility scale (eclareon; 2020)

Project Overview

PV Project			
PV System Size		kWp	5.000
Specific System Cost		GEL/kWp	3.100
Investment Subsidy		GEL	-
Total System Cost		GEL	15.500.000
Fixed Operation Costs		GEL p.a.	310.000
Variable Operation Costs		GEL/kWh	-

PV Generation		
Yield	kWh/qm/a	1.700
Performance Factor	%	84%
Specific Yield	kWh/kWp/a	1.428
Degradation	% p.a.	0,70%

Investment			
Project Duration		Years	25
Beneficial tariff payments		Years	15
Equity		GEL	7.955.113
Debt (Gearing)	50%	GEL	7.750.000
Loan Tenor		Years	10
Interest Rate		%	9,50%
Discount Rate		%	15,00%
Inflation Rate		%	3%

PV Business Model			
Beneficial tariff	100%	GEL/kWh	0,42
Targeted capacity factor		%	14,00%
Avg. capacity factor achieved		%	15,42%
Fees		GEL/kWh	-
Retail electricity market price		GEL/kWh	0,14
Undersupply Penalty		GEL/kWh	-
Inflation Adjustment		%	-
Calculatory average capacity premium		GEL/kWp/a	561

Results		
Net-Present Value	GEL	443.595
Project IRR	%	13,73%
Equity IRR	%	15,90%
Amortization - discounted payback period	Years	14,42
Undiscounted payback period	Years	6,28
LCOE (no subsidy)	GEL/kWh	0,37
Min DSCR**	x	1,76 x
Min LLCR***	x	1,93 x

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

This business case aims to evaluate the economic efficiency for a large utility-scale PV power plant. The estimates are again based on the same southern region Samtskhe-Javakheti, just as the two previous cases. The size of 5 MW was chosen since there are several feasibility studies being processed in Georgia trying to find a suitable location for a SPP of this capacity.

The theoretical absence of PV specific PPAs inhibits national and international investments in new power plants, because they cannot compete with the low cost of electricity generation of old and amortized hydro power plants. Although the Georgian government abolished PPAs in 2018, ESCO published a list of PPAs on their website where new entries have been added to the list up to October 2019. In this business case a PPA was used to show the importance of these incentives for solar power plants.

Even with a fixed PPA for a period of 15 years and further 10 years of deregulated market participation, the investment costs are too high. Therefore, a PPA of 0,42 GEL/kWh (~0,12 EUR/kWh), which is around twice the amount of regular PPAs in Georgia [68], is needed. Similar to chapter 4.1 the calculation was based on a debt gearing of 50%, a payback tenor of 10 years and a WACC of 12,8%.

Results

The results are shown in Figure 27 and Figure 28. Even with a PPA of 0,42 GEL/kWh, the investment reaches amortization, based on discounted cashflows, after approx. 14 years. A PPA of 40 GEL/kWh would lead to no amortization at all. Moreover, Figure 28 shows a drop in revenues as soon as the PPA expires, as well as the payback tenor. It becomes evident that under the current economic and legal conditions, a PV system in the utility sector, which has to be competitive on the wholesale electricity market, is not economically feasible at the moment. As soon as the parameters are adjusted to the actual market prices, the net present value of the investment falls far below zero.

In order to make the PV utility-scale segment more attractive, the Georgian government would need to create legal conditions that render such investments financially viable. A PPA in the range of around 0.42 GEL/kWh could most likely allow to pay the investment but a discounted payback period of more than 14 years may not be attractive for most investors.

Figure 27: Equity capital cash flows – grid-connected PV system, PPA utility scale (eclareon, 2020)

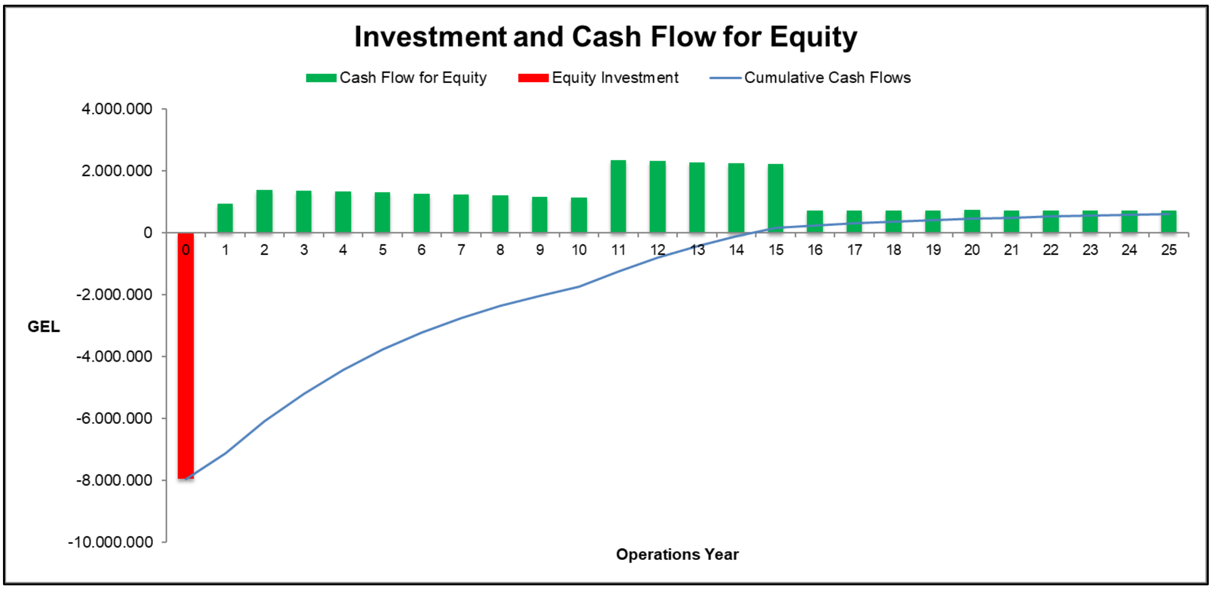
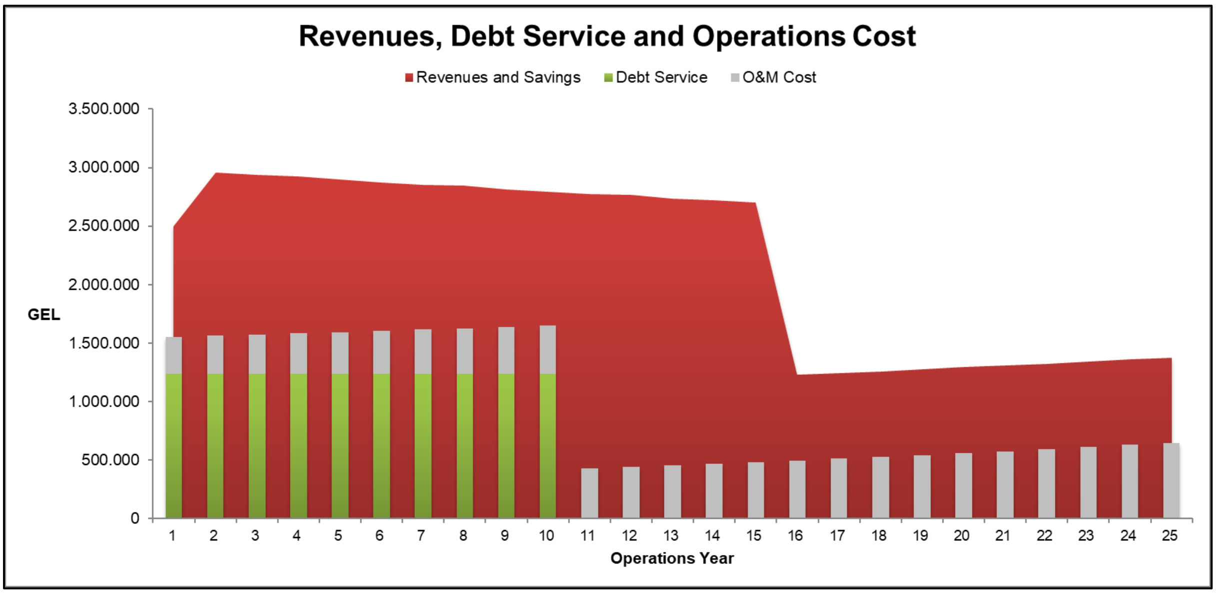


Figure 28: Project cash flows – grid-connected PV system, PPA utility scale (eclareon; 2020)



Sensitivity Analysis

The sensitivity analysis shows how the two leading economic indicators for an investment, the amortization period (amortization) and the internal rate of return on equity (Equity IRR) change when certain parameters in the framework conditions are altered. It becomes clear which individual assumptions have a particularly strong influence on the profitability of the investment (high sensitivity). This has to be considered carefully during the planning phase of an investment.

Figure 29: Specific Yield – grid-connected PV system, PPA utility scale (eclareon; 2020)

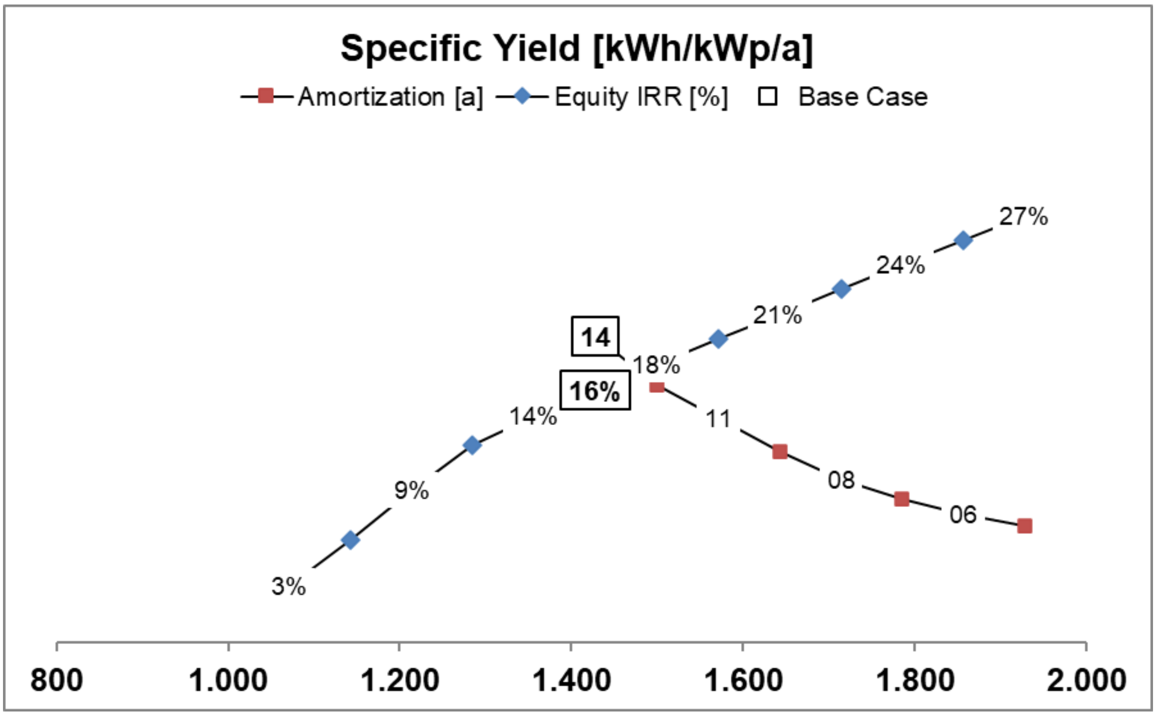


Figure 30: System price – grid-connected PV system, PPA utility scale (eclareon; 2020)

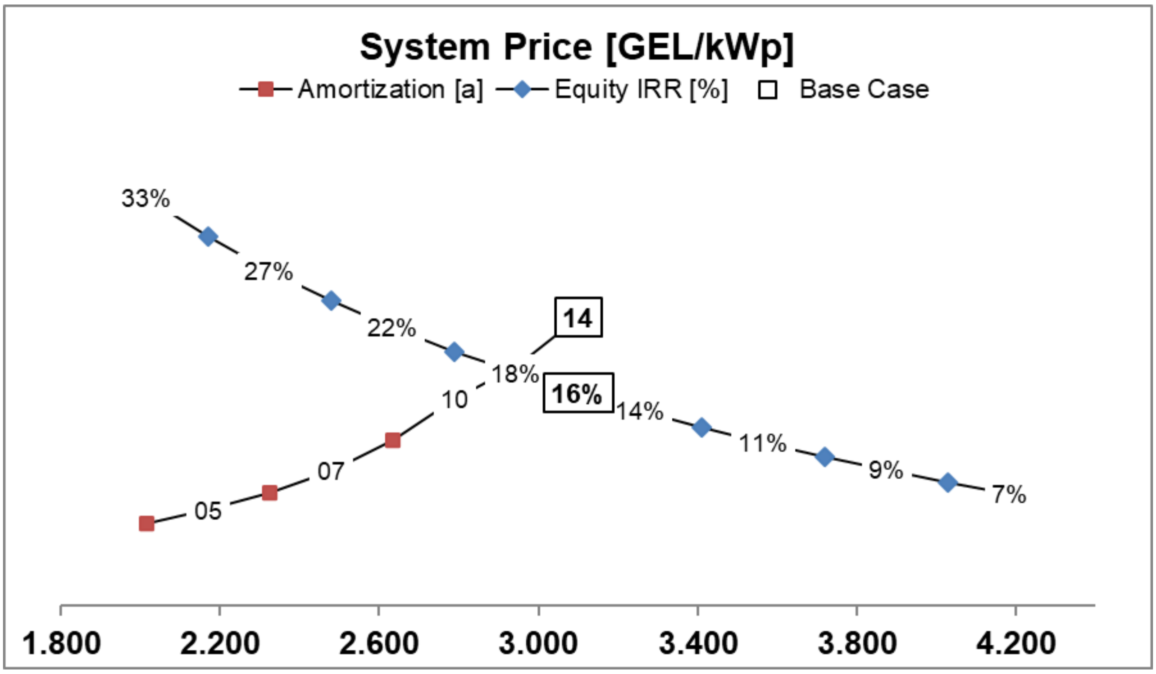
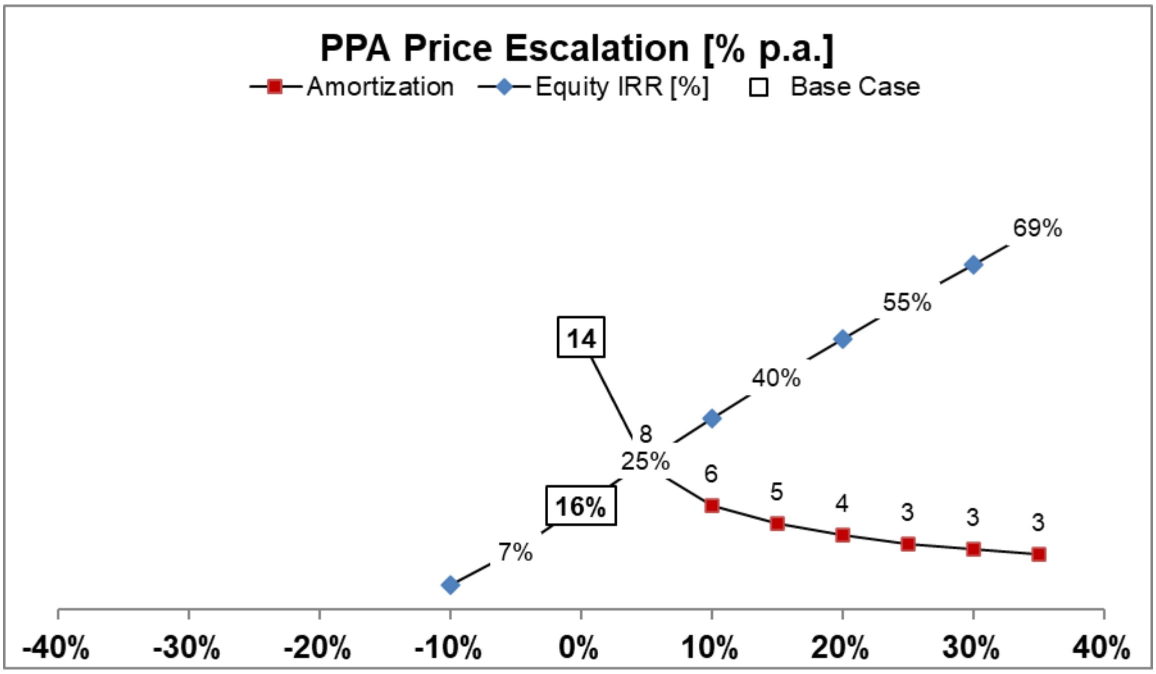


Figure 31: Fuel cost escalation – grid-connected PV system, PPA utility scale (eclareon; 2020)



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Annex

Annex 1: Global Solar Atlas Report on Samtskhe-Javakheti (southern and central) [69]

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

User-defined area

Area: 3326.23 km²
Perimeter: 243.71 km

Report generated: 7 Apr 2020, 13:24

AREA INFO

Map data (min-max range) — Per day

Specific photovoltaic power output	PVOUT	3.63 —	4.11	kWh/kWp
Direct normal irradiation	DNI	3.33 —	4.18	kWh/m²
Global horizontal irradiation	GHI	3.81 —	4.18	kWh/m²
Diffuse horizontal irradiation	DIF	1.70 —	1.77	kWh/m²
Global tilted irradiation	GTI	4.32 —	4.87	kWh/m²
Optimum tilt of PV modules	OPTA	32 —	36	°
Air temperature	TEMP	0.9 —	7.6	°C
Terrain elevation	ELE	1132 —	2559	m

Map

User-defined area 1 / 6

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

PVOUT - AREA ANALYSIS

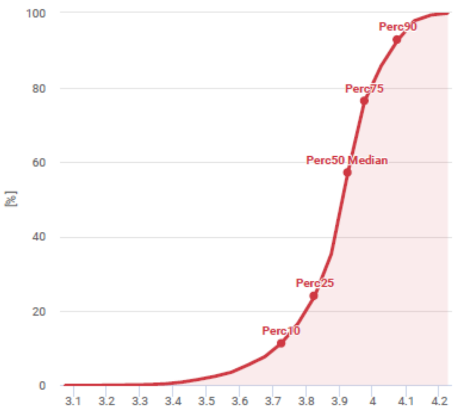
Statistics

Specific photovoltaic power output

Average	3.91	kWh/kWp
Maximum	4.11	kWh/kWp
Percentile 90	4.08	kWh/kWp
Percentile 75	3.99	kWh/kWp
Percentile 50 (Median)	3.93	kWh/kWp
Percentile 25	3.85	kWh/kWp
Percentile 10	3.73	kWh/kWp
Minimum	3.63	kWh/kWp

Cumulative distribution function

Specific photovoltaic power output



Distribution

Specific photovoltaic power output

less than 3.60	3.6	%
3.60 – 3.80	13.1	%
3.80 – 4.00	59.7	%
more than 4.00	23.6	%
	100.0	%

DNI - AREA ANALYSIS

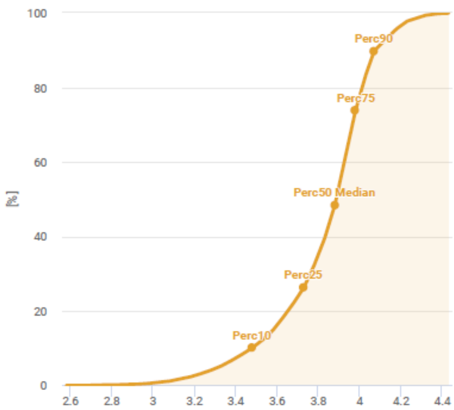
Statistics

Direct normal irradiation

Average	3.85	kWh/m²
Maximum	4.18	kWh/m²
Percentile 90	4.09	kWh/m²
Percentile 75	4.00	kWh/m²
Percentile 50 (Median)	3.90	kWh/m²
Percentile 25	3.72	kWh/m²
Percentile 10	3.48	kWh/m²
Minimum	3.33	kWh/m²

Cumulative distribution function

Direct normal irradiation



Distribution

Direct normal irradiation

less than 3.20	2.3	%
3.20 – 3.40	4.4	%
3.40 – 3.60	8.1	%
3.60 – 3.80	17.5	%
3.80 – 4.00	41.6	%
4.00 – 4.20	21.9	%
more than 4.20	4.2	%
	100.0	%

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

GHI - AREA ANALYSIS

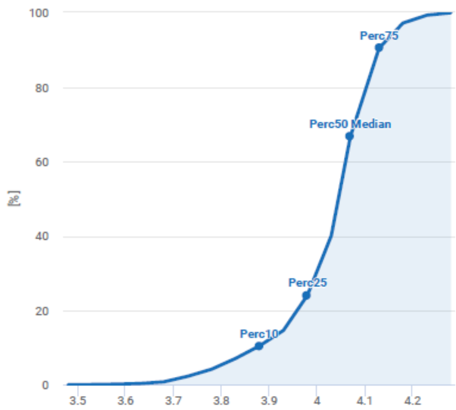
Statistics

Global horizontal irradiation

Average	4.04	kWh/m²
Maximum	4.18	kWh/m²
Percentile 90	4.14	kWh/m²
Percentile 75	4.11	kWh/m²
Percentile 50 (Median)	4.07	kWh/m²
Percentile 25	4.00	kWh/m²
Percentile 10	3.89	kWh/m²
Minimum	3.81	kWh/m²

Cumulative distribution function

Global horizontal irradiation



Distribution

Global horizontal irradiation

less than 3.80	4.2	%
3.80 – 4.00	19.8	%
4.00 – 4.20	73.2	%
more than 4.20	2.8	%
	100.0	%

DIF - AREA ANALYSIS

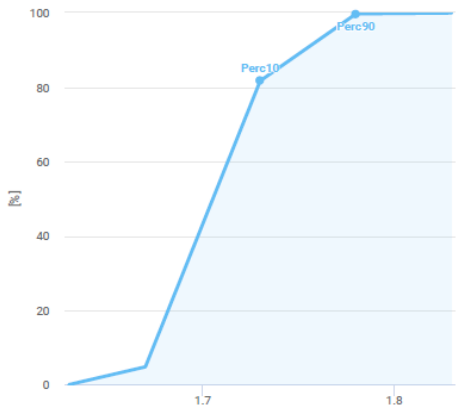
Statistics

Diffuse horizontal irradiation

Average	1.73	kWh/m²
Maximum	1.77	kWh/m²
Percentile 90	1.76	kWh/m²
Percentile 75	1.74	kWh/m²
Percentile 50 (Median)	1.73	kWh/m²
Percentile 25	1.72	kWh/m²
Percentile 10	1.71	kWh/m²
Minimum	1.70	kWh/m²

Cumulative distribution function

Diffuse horizontal irradiation



Distribution

Diffuse horizontal irradiation

less than 2.00	100.0	%
	100.0	%

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

GTI - AREA ANALYSIS

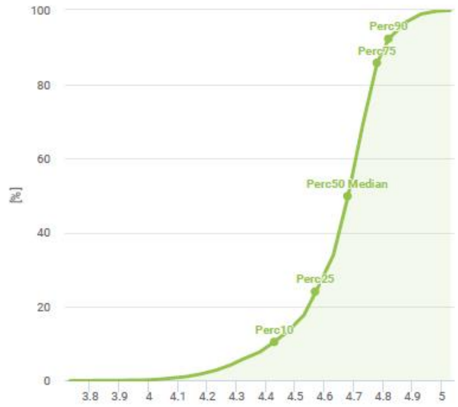
Statistics

Global tilted irradiation

Average	4.66 kWh/m²
Maximum	4.87 kWh/m²
Percentile 90	4.82 kWh/m²
Percentile 75	4.76 kWh/m²
Percentile 50 (Median)	4.69 kWh/m²
Percentile 25	4.60 kWh/m²
Percentile 10	4.43 kWh/m²
Minimum	4.32 kWh/m²

Cumulative distribution function

Global tilted irradiation



Distribution

Global tilted irradiation

less than 4.20	1.9 %
4.20 – 4.40	5.9 %
4.40 – 4.60	16.2 %
4.60 – 4.80	61.9 %
more than 4.80	14.1 %
	100.0 %

OPTA - AREA ANALYSIS

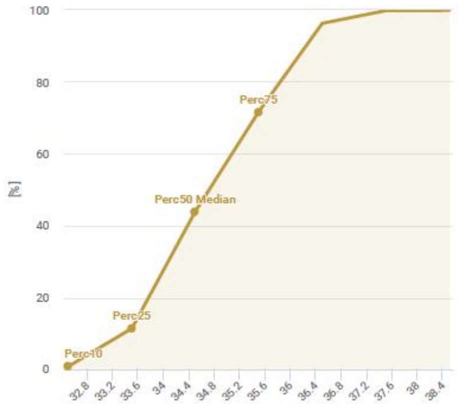
Statistics

Optimum tilt of PV modules

Average	35 °
Maximum	36 °
Percentile 90	36 °
Percentile 75	35 °
Percentile 50 (Median)	34 °
Percentile 25	33 °
Percentile 10	33 °
Minimum	32 °

Cumulative distribution function

Optimum tilt of PV modules



Distribution

Optimum tilt of PV modules

less than 34	11.4 %
34 – 35	32.6 %
35 – 36	27.8 %
36 – 37	24.6 %
more than 37	3.6 %
	100.0 %

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

TEMP - AREA ANALYSIS

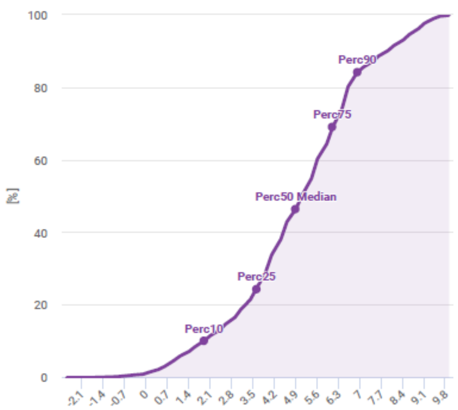
Statistics

Air temperature

Average	4.8 °C
Maximum	7.6 °C
Percentile 90	6.9 °C
Percentile 75	6.2 °C
Percentile 50 (Median)	4.9 °C
Percentile 25	3.6 °C
Percentile 10	1.8 °C
Minimum	0.9 °C

Cumulative distribution function

Air temperature



Distribution

Air temperature

less than 1.0	4.7 %
1.0 – 2.0	5.5 %
2.0 – 3.0	6.4 %
3.0 – 4.0	12.4 %
4.0 – 5.0	17.6 %
5.0 – 6.0	17.9 %
6.0 – 7.0	19.8 %
7.0 – 8.0	6.0 %
8.0 – 9.0	6.1 %
more than 9.0	3.6 %
	100.0 %

ELE - AREA ANALYSIS

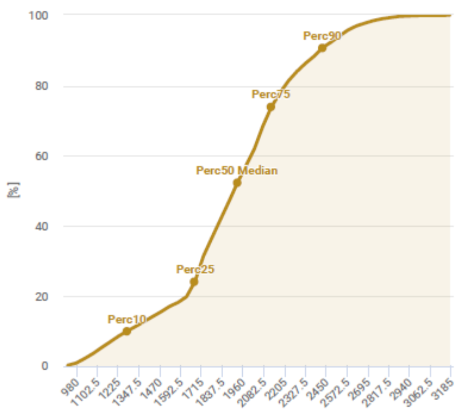
Statistics

Terrain elevation

Average	1915 m
Maximum	3188 m
Percentile 90	2421 m
Percentile 75	2147 m
Percentile 50 (Median)	1919 m
Percentile 25	1693 m
Percentile 10	1296 m
Minimum	936 m

Cumulative distribution function

Terrain elevation



Distribution

Terrain elevation

less than 1200	6.9 %
1200 – 1400	5.8 %
1400 – 1600	5.4 %
1600 – 1800	18.5 %
1800 – 2000	20.5 %
2000 – 2200	20.8 %
2200 – 2400	10.4 %
2400 – 2600	7.5 %
2600 – 2800	3.2 %
more than 2800	1.0 %
	100.0 %

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

GLOSSARY

Acronym	Full name	Unit	Type of use
DIF	Diffuse horizontal irradiation	kWh/m², MJ/m²	Average yearly, monthly or daily sum of diffuse horizontal irradiation (© 2019 Solargis)
DNI	Direct normal irradiation	kWh/m², MJ/m²	Average yearly, monthly or daily sum of direct normal irradiation (© 2019 Solargis)
ELE	Terrain elevation	m, ft	Elevation of terrain surface above/below sea level, processed and integrated from SRTM-3 data and related data products (© 2019 SRTM team)
GHI	Global horizontal irradiation	kWh/m², MJ/m²	Average annual, monthly or daily sum of global horizontal irradiation (© 2019 Solargis)
GTI	Global tilted irradiation	kWh/m², MJ/m²	Average annual, monthly or daily sum of global tilted irradiation (© 2019 Solargis)
GTI_opta	Global tilted irradiation at optimum angle	kWh/m², MJ/m²	Average annual, monthly or daily sum of global tilted irradiation for PV modules fix-mounted at optimum angle (© 2019 Solargis)
OPTA	Optimum tilt of PV modules	°	Optimum tilt of fix-mounted PV modules facing towards Equator set for maximizing GTI input (© 2019 Solargis)
PVOUT_total	Total photovoltaic power output	kWh, MWh, GWh	Yearly and monthly average values of photovoltaic electricity (AC) delivered by the total installed capacity of a PV system (© 2019 Solargis)
PVOUT_specific	Specific photovoltaic power output	kWh/kWp	Yearly and monthly average values of photovoltaic electricity (AC) delivered by a PV system and normalized to 1 kWp of installed capacity (© 2019 Solargis)
TEMP	Air temperature	°C, °F	Average yearly, monthly and daily air temperature at 2 m above ground. Calculated from outputs of ERA5 model (© 2019 NOAA and NASA)

ABOUT

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