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ASSESSING BENEFITS FROM DEMAND RESPONSE (DR) PROGRAM IN THE DIFFERENT CLIMATIC ZONES OF GEORGIA ON THE EXAMPLE OF RESIDENTIAL PV INSTALLATIONS

Abstract:

We continue the series of investigations toward the market uptake measures of renewable energy systems for achievement of balance between electricity supply and demand in the local electricity market of Georgia. At present the research objective is to assess the benefits of residential customers living in the different climatic zones of Georgia with varied average annual solar radiation and willing to participate in the Demand Response (DR) program so called net-metering (NEM) for the purpose to figure out in which climatic zones of Georgia is more reasonable to make investments in small-scale solar PV plants.

For achieving the research objective, the total benefits/costs of residential customers (with the average monthly electricity consumption between 101 kWh and 301kWh) living in four different climatic zones of Georgia (Tbilisi, Batumi, Telavi, and Mestia) and willing to invest in small-scale solar PV installations with the installed capacity of 3,465 kW and sell excess electricity (capacity) to the grid, is estimated. Besides, the capacity factors for Tbilisi, Batumi, Telavi, and Mestia were determined to illustrate how location affects the actual output of small-scale PV plants.

During the study the following research hypothesis has been tested: "Residential customers can benefit from retail-rate net energy metering if they choose to participate in this program but their benefits depend heavily on the location where PV installations are applied."

Our cost-benefit analyses revealed that solar is often a solution suitable for the geographical needs of remote communities with higher potential of solar radiation.

Keywords:

Demand Response (DR), small-scale solar PV plants, net energy metering (NEM), renewable energy resources, Distributed Energy Resources (DER), Energy Balance, energy efficiency (EE).

JEL Classification: D19, M31, Q21

INTRODUCTION

According to International Energy Agency (IEA) annual report, "this is a pivotal time for renewable energy. Thanks to falling costs, technologies such as solar photovoltaics (PV) and wind are at the heart of transformations taking place across the global energy system. Their increasing deployment is crucial for efforts to tackle greenhouse gas emissions, reduce air pollution, and expand energy access". (International Energy Agency, p.3) Rooftop solar PV systems have spread rapidly throughout the globe thanks to supporting policies, such as net metering and fiscal incentives. According to IEA report 2019 (International Energy Agency, p.12) , "Some 100 million solar rooftop systems for homes could be operating worldwide by 2024. Residential systems are set to account for one-quarter of total distributed solar PV capacity by then, with deployment expanding rapidly in many countries owing to favorable policy designs and the economic attractiveness of distributed PV. The top five markets for residential PV installations per capita in 2024 are Australia, Belgium, California (United States), the Netherlands, and Austria".

Georgia can be among those countries dominating with residential solar PV installations if considering the big potential of solar energy possessed by the country and the declining costs of solar PV systems making the technology more economically attractive.

Georgia's geographical complexity determines the diversity of climate in its territory. In the majority of Georgia's regions annual duration of sunny days varies within 250-280 days, which equals to 1900-2200 hours a year. Annual solar radiation varies according to regions between 1250-1800 kWh/m^2. Overall, solar potential of Georgia is estimated at 108 MW, equivalent to 34 thousand tone of fossil fuel. Maximum solar radiation reaches 10kWh/m^2 in summer and 4-4.5kWh/m^2 in sunlit days of winter. Besides the solar energy, Georgia is also rich with its wind energy. According to special studies, theoretically wind energy supply in Georgia is 1.3 * 1012 kWh annually, while the potential of the wind with the speed over 4.0 m/s is almost 4,5 TWh annually. (Chomakhidze, 2018). It is also estimated that a total hydropower capacity in Georgia amounts to 15,000 MW with a total production potential of 50 TWh per year of which approximately 22% is currently utilized in terms of capacity. (Ministry of Economy and Sustainable Development of Georgia, 2019)

Thus, Georgia has an immense untapped potential of wind, solar, geothermal, and hydro resources. The Georgian Government (GoG) has missed the target of 30% of energy consumed coming from renewable energy for 2020 defined by a National Renewable Energy Action Plan (NREAP) in compliance with Renewable Energy Directive No. 2009/29/EC because it was only approved in late 2019. The Georgian Government (GoG) set the 2030 targets and defined corresponding actions for achieving them. (International Energy Agency , 2020)

Under the EU-Georgia Association Agreement, which entered into force on July 1, 2016, GoG took the obligation of implementing the EU directives in energy sector and to comply with the requirements of the third energy package. The key priority of the energy policy is the utilization of the country's local indigenous renewable energy sources that could result in the production of an additional 20 TWh in the nearest future and significantly contribute to climate change mitigation in the country. (Ministry of Economy and Sustainable Development of Georgia, 2019) But prior to adding various Distributed Energy Resources (DER) in the form of rooftop solar PV panels, wind generation units, biomass generators, mini-hydro schemes and etc. to the national grid, residential and industrial customers must be convinced that the investments in DER could result in the larger savings on their electricity bills.

Our previous study, conducted in 2019 and aiming to assess the benefits residential customers can get from Demand Response (DR) Program so called net energy metering (NEM), already proved that the investments in small-scale solar PV projects are the real “money saving choice” for net metered residential customers of Georgia rather than the “money-making choice” because of fixed compensation structure (less than retail) applied to customer-produced solar energy.

At present the research objective is to:

1. assess the benefits of residential customers living in the different climatic zones of Georgia with varied average annual solar radiation and willing to participate in the Demand Response (DR) program so called net-metering (NEM) for the purpose to figure out in which climatic zones of Georgia is more reasonable to make investments in small-scale solar PV plants; and

2. test the following hypothesis: „Residential customers can benefit from retail-rate net energy metering if they choose to participate in this program but their benefits depend heavily on the location where PV installations are applied.”

Review of Literature

Upon working on the article both the local and the foreign scientific publication sources have been applied. The article after Demur Chomakhidze and Maia Melikidze, published in the Journal of Environmental Science and Renewable Resources in 2018, has been used to learn about the solar energy potential in the four different climatic zones of

Georgia; besides, the International Energy Agency's (IEA) latest market report "Renewables 2019 – Analysis and Forecast to 2024" has been used to obtain an authoritative information on where renewable technologies stand today and where they are headed in the next three years. It provides the analytical foundation for IEA work that helps countries navigate their clean energy transitions in secure and cost-effective ways; the paper - "Deployment, Investment, Technology, Grid Integration and Socio-Economic Aspects" from the International Renewable Energy Agency (IRENA) presents options to speed up deployment and fully unlock the world's vast solar PV potential over the period until 2050. (International Renewable Energy Agency, 2019) This paper was used to learn about technology trends in solar PV, about the market uptake measures of solar resources to prepare electricity grids for rising shares of solar PV, and growth needed in solar PV to achieve climate goals; from the series of newsletters, press releases, and articles published in the Utility Dive it became clear how the Demand Response (DR) has evolved in the recent years from an emergency-based program into a more holistic approach to grid management and became a resource for load forecasting and system planning. (Utility Dive, 2019) Besides the mentioned reports and papers, our study findings are based on: Georgian National Energy and Water Supply Regulatory Commission (GNERC) annual reports and resolutions about the integration of distributed solar to the national grid, annual reports of the Energy Policy Department at the Ministry of Economy and Sustainable Development of Georgia and Electricity Market Operator (ESCO). It is also proving very important to study energy consumption in buildings. The authors (Cermakova, K.; Hromada, E., 2022) found that household energy constitutes an important share of affordable housing. Unaffordable housing and inadequate household energy represent a new dimension of poverty. They have an important role to play in this context the role of life cycle costing (LCC) in the preparatory and implementation phase of residential projects (Vitasek, S., 2021). Experience from construction practice shows that the choice of variants, constructions, or equipment of buildings only on the basis of the lowest acquisition costs (lowest bid prices) is wrong. We are bringing new evidence from local customers in Georgia highlighting the importance of investment in renewable energy sources which have been confirmed as factor favoring economic growth (Pala, 2020) and price stability (Bednar, 2022).

Methodology

For the purpose to achieve the research objective and to test the hypothesis generated on the basis of exploratory research conducted at the outset of the study, four significantly different locations were selected in Georgia considering their average annual duration of solar radiation:

1. Tbilisi (the capital of Georgia located in the Eastern Georgia 380-600m from the sea level);

2. Batumi (the second largest city of Georgia located on the Eastern coast of the Black Sea in Georgia's Southwest in a subtropical zone);

3. Telavi (the city is located on the foothills of the Tsiv-Gombori Range at 500–800 m (1,600–2,600 ft) above the sea level), and

4. Mestia (Urban-Type Settlement located in the Northwest Georgia at an elevation of 1,500 m (4,921 feet) in the Caucasus Mountains).

The secondary data have been gathered about the average annual duration of solar radiation for each of the selected locations and the industry experts' opinions were collected regarding the productivity of small-scale solar PV plants for each of the selected climatic zones.

In all four cases 8 units of Jinko Solar mono-facial module panels "Tiger Pro 60HC 445W" and Solis single-phase S5-GR1P(2.5-6)K 3,0kW solar inverter are considered.

Solar panels are selected because of their cost effectiveness, long lifespan, and availability in the local market. Jinko solar panels come with 12 year product workmanship warranty, 25 year linear power warranty, and have 0.55% annual degradation over 25 years ending with 84,8% guaranteed power performance. Solar panels meet the following standards' requirements: IEC61215 (2016), IEC61730 (2016). ISO9001:2015 (Quality Management System), ISO14001:2015: (Environment Management System), ISO45001:2018 (Occupational health and safety management systems). Solis single-phase inverter is selected because of its high efficiency (EU efficiency (ηEU) - 96,6%), reliability and availability in the local market. The most important functionality of 3,0kW Solis inverter is that it converts direct current, generated by solar panels, into standard 230 V/50Hz electric power. Solis inverter comes with 5 year standard warranty and 20 year optional upgrade and complies with the following safety/EMC standards: IEC/EN 62109-1/-2, IEC/EN 61000-6-2/-3.

When assembling residential solar PV plant many factors should be taken into account: monthly consumption of households, solar energy potential of location that determines the capacity factor of solar energy system, panel orientation (South), roof area, shade (light) and etc. In our particular cases it is reasonable to use solar panels with the capacity of 3,56 kW if considering that the average monthly consumption of households is between

101kWh and 301kWh. Since it is considered to use 8 units of solar panels each with the capacity of 445W, the installed capacity of small-scale solar PV plant will be 3,56 kW.

When calculating the solar system annual output, system losses must be considered because solar panel systems usually reach approximately 80% of their specified peak due to these “system losses“.

These system losses are the following:

1. Manufacturer’s Power Tolerance (0%). All panels have a power tolerance. In the case of mono-facial module panel “Tiger Pro 60HC 445W”, power tolerance is positive (0~+3%) that means there will be no losses because of power tolerance;
2. Temperature Loss (10%). Solar panels don’t like to be hot. Most solar panels lose their rated power if the panel temperature heats up above 25°C. The temperature coefficient of Pmax is 0,35%/°C that means for one extra °C of cell temperature heat above 25°C, the output of panel power will be decreased by 0.35%. In our particular case it would result in approximately 10% power loss;
3. Dirt (5%). When solar panels are mounted on roof, airborne particulates like dust will settle on the panels’ glass. These particulates block the amount of sunlight reaching the solar cells behind the glass reducing power. The reduction in power from particulates build up typically lies in the 5%-15% range. Let’s assume that in the case of proper maintenance of panels, the loss from dirt is only a 5%;
4. Wiring losses (voltage drops) (2%). All the solar panels on roof are interconnected with wires, then a long pair of DC wires connects the final solar panel to inverter. All these wires have a small electrical resistance, which means the electricity flowing through them will suffer a voltage drop. This will reduce power output proportionally, typically by around 2%;
5. Europ. Efficiency (ηEU) of inverter is 96.6%. The inverter’s efficiency directly affects system output. Since Solis single-phase S5-GR1P(2.5-6)K inverter’s efficiency is 96.6%, one can expect 3.4% losses of power output.

Hence, the total system losses amount to 20.4%. Thus, the expected peak capacity of small-scale power plant will be 2.83 kW.

Ultimately, the costs related to the acquisition and installation of small-scale solar PV plants for those households participating in the NEM program and having average monthly electricity consumption between 101kWh and 301kWh, as well as their savings on electricity bills and the payback period of investments made in small-scale solar PV plants designated for installation in the selected climatic zones have been estimated. Besides, the capacity factors for Tbilisi, Batumi, Telavi, and Mestia were determined to illustrate how location impacts the actual output of small-scale PV plants. If assuming that small-scale solar PV plant were to run non-stop, 24/7 at peak capacity of 2.83 kW, it would have generated 24790.8 kWh (24h x 365 days x 2.83 kW= 24790.8 kWh). Consequently, the capacity factors for each of the selected locations were determined by dividing average annual generation of solar PV plant by the maximum energy generated by solar PV plant with the installed capacity of 3.56 kW.

It is also relevant to mention that the residential electricity rates in Georgia are fixed. Households living in Tbilisi and having electricity consumption between 101kWh and 301 kWh are charged GEL .22053 including the VAT for consumed per kilowatt hour; the households leaving outside Tbilisi (the Capital of Georgia) and having electricity consumption between 101kWh and 301 kWh, are charged GEL.21707 including the VAT for consumed per kilowatt hour. Weighted average price paid to the net metered customers for exported to the grid power is also fixed and amounts to GEL.18 including the VAT.

Analysis and Findings

In the selected four locations (Tbilisi, Batumi, Telavi, and Mestia) an average annual and daily duration of solar radiations are following:

1. Tbilisi – average annual duration of solar radiation amounts to 2019 solar hours. Average daily duration of solar radiation amounts to 5,6 hours; the most shortest duration of solar radiation is fixed in December (on average 3,0 hours a day), and maximum – in June and July (on average 8,3 hours a day);

2. Batumi - average annual duration of solar radiation amounts to 1932 solar hours. Average daily duration of solar radiation amounts to 5,3 hours; the most shortest duration of solar radiation is fixed in January (on average 3,2 hours a day), and maximum – in June (on average 7,8 hours a day);

3. Telavi - average annual duration of solar radiation amounts to 2040 solar hours. Average daily duration of solar radiation amounts to 5,6 hours; the most shortest duration of solar radiation is fixed in December and January (on average 3,0 hours a day), and maximum – in July (on average 9,0 hours a day);

4. Mestia - average annual duration of solar radiation amounts to 2280 solar hours. The most shortest duration of solar radiation is fixed in November, December, and January (on average 3,0 hours a day), and maximum – in July (on average 9,0 hours a day).

Respectively, annual generation of electricity (capacity) in four different locations (Tbilisi, Batumi, Telavi, and Mestia) in the case of application of small-scale solar PV plants with the expected peak capacity of 2,83 kW are presented in the Table 1:

Table 1.

Annual Generation of Electricity (Capacity) in four Locations: Tbilisi, Batumi, Telavi, and Mestia (kWh)

#	Location	The Average Annual Duration of Solar Radiation (Solar Hours)	Annual generation of Electricity (kWh)
1	Tbilisi	2019	5714
2	Batumi	1932	5468
3	Telavi	2040	5773
4	Mestia	2280	6452

The cost-benefit analyses of net metered households living in four different climatic zones of Georgia (Tbilisi, Batumi, Telavi, and Mestia), and whose average monthly consumption of electricity is between 101kWh and 301kWh, are presented in the tables below (see Table 2, Table 3, Table 4, and Table 5). In all four cases small-scale solar PV plants with the expected peak capacity of 2,83 kW are applied.

The results of cost-benefit analysis held for net metered households living in Tbilisi, are summarized in the Table 2.

Table 2.

The Cost-Benefit Analysis (CBA) for Tbilisi's Net-Metered Households

Location:	Tbilisi	
Exchange Rate: $1= GEL 3.0076 (03.06.2022)		
The quantity of solar panels, Jinko Solar	8	
The quantity of inverter, Solis	1	
Installed capacity of solar system	3.56 kW	
Expected capacity of solar system	2,83 kW	
Inverter capacity	3,0 kW	
Inverter EU efficiency: 96,6%		
The cost of Solar Panel (USD)	1610	
The cost of Inverter (USD)	557	
The cost of installation and adjustment of small-scale solar PV plant	650	

Total cost of acquisition and installation of small-scale solar PV plant (USD)		**2817**
Average monthly consumption of electrical power, kWh	291	
Average annual consumption of electrical power, kWh	3500	
Residential electricity rate of customers with electricity consumption from 101kW.h to 301 kWh including the VAT (USD)	0.07332	
Average annual cost of consumed power, kWh (USD)	256.62	
Annual savings on electricity bills, kWh (USD)		**256.62**
The annual generation of small-scale solar PV plant, kWh	5714	
Weighted average price paid to net metered customers for exported to the grid power, kWh (USD)	0.05985	
Exported power to the grid, kWh	2214	
Credits received from exported to distribution system operator (DSO) power by the end of the year, (USD)		**132.51**
Total customer benefits (savings) (USD)		**389.13**
Payback period		**7.2**

Note: It is customary to use inverters with 30% less capacity than solar panels.

As it was mentioned above, the installed capacity of small-scale solar PV plant is 3,56kW. For adjustment of the small-scale solar PV plant 8 units of Jinko Solar mono-facial module panels “Tiger Pro 60HC 445W” and 1 unit of Solis single-phase S5-GR1P(2.5-6)K 3,0kW solar inverter with the capacity of 3,0 are considered. Since the small-scale solar PV plant consists of 8 units of panels each with the capacity of 445 watt, the installed capacity of solar PV system amounts to 3,56 kW. If considering system losses that amount to 20.4%, the expected peak capacity of solar PV system is 2,83 kW. Since the households’ average annual consumption of electricity is 3500kWh, with $.07332 fixed electricity rate applied in Tbilisi, the households’ annual savings on their electricity bills amount to $256.62 (3500kWh X $.07332=$256.62). If considering the annual duration of solar radiation in Tbilisi (2019 hours), the annual generation of solar PV plant equals to ~5714kWh (2019 hX2,83kW=5714kWh). The credit, received by net-metered households for the extra power (2214kWh) generated and exported to the Distribution System Operator (DSO) JSC “Telasi” by the end of the year at weighted net-metering rate of $.05985, amounts to $132.51 (2214kWh X $.05985=$132.51). Thus, the net-metered households’ total annual benefit amounts to $389.13 ($256.62+$132.51=$389.13).

Since the cost of investments carried by net-metered households is $2817, the number of payback years is 7.2 ($2817/$389.13=7.2 years).

In the case of Batumi the installed capacity of small-scale solar PV plant is again 3,56kW. For adjustment of the small-scale solar PV plant 8 units of Jinko Solar mono-facial module panels "Tiger Pro 60HC 445W" and 1 unit of Solis single-phase S5-GR1P(2.5-6)K 3,0kW solar inverter with the capacity of 3,0 are considered. Since the small-scale solar PV plant consists of 8 units of panels each with the capacity of 445 watt, the installed capacity of solar PV system amounts to 3,56 kW. If considering system losses that amount to 20.4%, the expected peak capacity of solar PV system is 2,83 kW. Since the households' average annual consumption of electricity is 3500kWh, with fixed electricity rate of $.07217 applied in Batumi, the households' annual savings on their electricity bills amount to $252.60 (3500kWh X $ .07217 =$252.60). If considering the annual duration of solar radiation in Batumi (1932 hours), the annual generation of small-scale solar PV plant equals to ~5468kWh (1932hX2,83kW=5468kWh). The credit, received by net-metered households for the extra power (1968kWh) generated and exported to the Distribution System Operator (DSO) JSC "Energo-Pro Georgia" by the end of the year at weighted net-metering rate of $.05985, amounts to $117.78 (1968kWhX$.05985=$117.78). Thus, the net-metered households' total annual benefit amounts to $370.38 ($252.60+$117.78=$370.38). Since the cost of investments carried by net-metered households is $2817, the number of payback years is 7.6 ($2817/$370.38=7.6 years).

The results of cost-benefit analysis held for net metered households living in Batumi, are presented in the Table 3.

Table 3

The Cost-Benefit Analysis (CBA) for Batumi's Net Metered Households

Location:	Batumi	
Exchange Rate: $1= GEL 3.0076 (03.06.2022)		
The quantity of solar panels, Jinko Solar	8	
The quantity of inverter, Solis	1	
Expected capacity of solar system	2,83 kW	
Inverter capacity	3,0 kW	
Inverter EU Efficiency (96.6%)		
The cost of Solar Panel (USD)	1610	
The cost of Micro-inverter (USD)	557	
The cost of installation and adjustment of small-scale solar PV plant	650	
Total cost of acquisition and installation of small-scale solar PV plant (USD)		**2817**

Average monthly consumption of electrical power, kWh	291	
Average annual consumption of electrical power, kWh	3500	
Residential electricity rate of customers with electricity consumption from 101kW.h to 301 kWh including the VAT (USD)	0.07217	
Average annual cost of consumed power, kWh (USD)	252.60	
Annual savings on electricity bills, kWh (USD)		**252.60**
The annual generation of small-scale solar PV plant, kWh	5468	
Weighted average price paid to net metered customers for exported to the grid power, kWh (USD)	0.05985	
Exported power to the grid, kWh	1968	
Credits received from exported to distribution system operator (DSO) power by the end of the year, (USD)		**117.78**
Total customer benefits (savings) (USD)		**370.38**
Payback period		**7.6**

Note: It is customary to use inverters with 30% less capacity than solar panels.

In the case of Telavi the installed capacity of small-scale solar PV plant is again 3,56kW. For adjustment of the small-scale solar PV plant 8 units of Jinko Solar mono-facial module panels “Tiger Pro 60HC 445W” and 1 unit of Solis single-phase S5-GR1P(2.5-6)K 3,0kW solar inverter with the capacity of 3,0 are considered. Since the small-scale solar PV plant consists of 8 units of panels each with the capacity of 445 watt, the installed capacity of solar PV system amounts to 3,56 kW. If considering system losses that amount to 20.4%, the expected peak capacity of solar PV system is 2,83 kW. Since the households’ average annual consumption of electricity is 3500kWh, with $.07217 fixed electricity rate applied in Telavi, the households’ annual savings on their electricity bills amount to $252.60 (3500kWh X $.07217 =$252.60). If considering the annual duration of solar radiation in Telavi (2040 hours), the annual generation of small-scale solar PV plant equals to ~ 5773kWh (2040hX2,83kW=5773kWh). The credit, received by net-metered households for the extra power (2273kWh) generated and exported to the Distribution System Operator (DSO) JSC “Energo-Pro Georgia” by the end of the year at weighted net-metering rate of $.05985, amounts to $136.04 (2273kWhX $.05985=$136.04). Thus, the net-metered households’ total annual benefit amounts to $388.64 ($252.60+$136.04=$388.64). Since the cost of investments carried by net-metered households is $2817, the number of payback years is 7.2 ($2817/$388.64=7.2 years). (See the table 4)

Table 4

The Cost-Benefit Analysis (CBA) for Telavi's Net Metered Households

Location:	Telavi	
Exchange Rate: $1= GEL 3.0076 (03.06.2022)		
The quantity of solar panels, Jinko Solar	8	
The quantity of inverter, Solis	1	
Expected capacity of solar system	2,83 kW	
Inverter capacity	3,0 kW	
Inverter EU Efficiency (96.6%)		
The cost of Solar Panel (USD)	1610	
The cost of Micro-inverter (USD)	557	
The cost of installation and adjustment of small-scale solar PV plant	650	
Total cost of acquisition and installation of small-scale solar PV plant (USD)		**2817**
Average monthly consumption of electrical power, kWh	291	
Average annual consumption of electrical power, kWh	3500	
Residential electricity rate of customers with electricity consumption from 101kW.h to 301 kWh including the VAT (USD)	0.07217	
Average annual cost of consumed power, kWh (USD)	252.60	
Annual savings on electricity bills, kWh (USD)		**252.60**
The annual generation of small-scale solar PV plant, kWh	5773	
Weighted average price paid to net metered customers for exported to the grid power, kWh (USD)	0.05985	
Exported power to the grid, kWh	2273	
Credits received from exported to distribution system operator (DSO) power by the end of the year, (USD)		**136.04**
Total customer benefits (savings) (USD)		**388.64**
Payback period		**7.2**

Note: It is customary to use inverters with 30% less capacity than solar panels.

In the case of Mestia the installed capacity of small-scale solar PV plant is again 3, 65kW. For adjustment of the small-scale solar PV plant 8 units of Jinko Solar mono-facial module panels “Tiger Pro 60HC 445W” and 1 unit of Solis single-phase S5-GR1P(2.5-6)K 3,0kW solar inverter with the capacity of 3,0 are considered. Since the small-scale solar PV plant consists of 8 units of panels each with the capacity of 445 watt, the installed capacity of solar PV system amounts to 3,56 kW. If considering system losses that amount to 20.4%, the expected peak capacity of solar PV system is 2,83kW. Since the households' average annual consumption of electricity is 3500kWh, with

$.07217 fixed electricity rate applied in Mestia, the households' annual savings on their electricity bills amount to $252.60 (3500kWhX$.07217 =$252.60). If considering the annual duration of solar radiation in Mestia (2280 hours), the annual generation of small-scale solar PV plant equals to ~ 6452kWh (2280hX2,83kW=6452kWh). The credit, received by net-metered households for the extra power (2952kWh) generated and exported to the Distribution System Operator (DSO) JSC "Energo-Pro Georgia" by the end of the year at net-metering rate of $.05985, amounts to $176.68 (2952kWhX$.05985=$176.68). Thus, the net-metered households' total annual benefit amounts to $429.28 ($252.60+$176.68=$429.28). Since the cost of investments carried by net-metered households is $2817, the number of payback years is 6.6 ($2817/$429.28=6.6 years). The results of cost-benefit analysis held for net metered households in Mestia, are presented in the Table 5.

Table 5

The Cost-Benefit Analysis (CBA) for Mestia's Net Metered Households

Location:	Mestia	
Exchange Rate: $1= GEL 3.0076 (03.06.2022)		
The quantity of solar panels, Jinko Solar	8	
The quantity of inverter, Solis	1	
Expected capacity of solar system	2,83 kW	
Inverter capacity	3,0 kW	
Inverter EU Efficiency (96.6%)		
The cost of Solar Panel (USD)	1610	
The cost of Micro-inverter (USD)	557	
The cost of installation and adjustment of small-scale solar PV plant	**650**	
Total cost of acquisition and installation of small-scale solar PV plant (USD)		**2817**
Average monthly consumption of electrical power, kWh	291	
Average annual consumption of electrical power, kWh	3500	
Residential electricity rate of customers with electricity consumption from 101kWh to 301 kWh including the VAT (USD)	0.07217	
Average annual cost of consumed power, kWh (USD)	252.60	
Annual savings on electricity bills, kWh (USD)		**252.60**
The annual generation of small-scale solar PV plant, kWh	6452	
Weighted average price paid to net metered customers for exported to the grid power, kWh (USD)	0.05985	

Exported power to the grid, kWh	2952	
Credits received from exported to distribution system operator (DSO) power by the end of the year, (USD)		**176.68**
Total customer benefits (savings) (USD)		**429.28**
Payback period		**6.6**

Note: It is customary to use inverters with 30% less capacity than solar panels.

As it is mentioned in the research methodology, the capacity factors for Tbilisi, Batumi, Telavi, and Mestia were also determined to illustrate how location impacts the actual output of small-scale PV plants. If assuming that small-scale solar PV plant were to run non-stop, 24/7 at an expected peak capacity of 2.83 kW, it would have generated 24790.8 kWh (24h x 365 days x 2.83 kW= 24790.8 kWh). Consequently, the capacity factors for each of the selected locations were determined by dividing average annual generation of solar PV plant by the maximum energy generated by solar PV plant with the installed capacity of 3.56 kW. The results are summarized in the table 6.

Table 6

The Capacity factors for each of the Selected Locations

Location	Annual Generation of Solar PV Plant (kWh)	Maximum Output of Solar PV plant (kWh)	Capacity Factor (%)
Tbilisi	5714	24790.8	23
Batumi	5468	24790.8	22
Telavi	5773	24790.8	23
Mestia	6452	24790.8	26

Conclusions

On the basis of results obtained from the cost-benefit analyses carried out for the purpose of assessing the benefits households can receive from Demand Response (DR) program NEM and illustrating how location affects the actual output of small-scale PV plants, it is possible to make the following conclusions:

1. Residential customers in Georgia can save money on their utility bills every year by making excess electricity with their rooftop solar panel systems and sending it back to the grid if they are involved in retail-rate net energy metering program but the benefits of net metered customers depend heavily on the locations where small-scale PV installations are applied. Since the average annual generation of

small-scale solar PV plant with the capacity of 3,56 kW is higher in Mestia (6452kWh) as compared to the average annual generations obtained in Tbilisi, Batumi, and Telavi, that automatically results in more annual benefits ($429.28) for households living in Mestia and participating in demand response (DR) program.

2. Hence, investments in small-scale solar PV plants are more reasonable in the mountainous regions of Georgia, like Mestia, having the higher solar energy potential (the average annual radiation of solar in Mestia is 2280 hours) in terms of less payback period of invested capital than in all other geographic-climatic zones discussed above.

Based on the above mentioned, the research hypothesis staying that "Residential customers can benefit from retail-rate net energy metering if they choose to participate in this program but their benefits depend heavily on the location where PV installations are applied", is also supported.

Thus, speaking in more general terms, NEM is a good reason to make the money-saving choice and go solar sooner rather than later, and that a solar is often a solution suitable for the geographical needs of remote communities like Mestia.

Additional benefits will be associated with the healthy environment. If many DER's will be added to the electrical grid of Georgia, it would be possible for GoG to meet the EU directives in energy sector - to generate an additional 20 TWh in the nearest future and significantly contribute to climate change mitigation.

But is should be mentioned that according to our estimate, the generation of 1.0kW power using small-scale PV installations would cost somewhere $791 to Georgian households. It means that only premium segment, particularly those people who care about environment, can afford themselves to own such a system but these households constitute only the small portion of Georgia's population.

Problem Solution

This particular research serves as an additional prove to the already established viewpoint that the proliferation of small-scale solar systems requires strong support from the side of government. Policymakers must tire-down market barriers to entry for distributed energy resources (DERs) to connect consumers with more affordable and cleaner resources and in this way help utilities better manage the grid and reduce harm to the environment and public health. Particularly, households willing to invest in small-scale PV installations should be released from custom fees. Other monetary incentives include: long-term low interest financing, cash rebates and etc. in order to incentivize households' participation in the NEM program. If the fiscal incentives will be offered to those residential electricity customers of Georgia having monthly consumption between 101kWh and 301kWh and above[1], the number of households, willing to invest in DER, will be increased and it will be the huge contribution in solving the problem of peak demand for electricity, especially, in winter period. And if no peak demand in electricity occurs, distribution system operators (DSOs) will be reluctant, under the regulatory pressure, to lower their retail electricity rates and it will be the overall social benefit for Georgia's electricity customers in the form of lower electricity bills.

Net Energy Metering (NEM) is just the first step in reaping benefits from residential demand response (DR) as a resource of more efficiently matching supply with load.

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