ELECTRICITY DEMAND FORECASTING MODEL
FINAL REPORT

USAID GOVERNING FOR GROWTH (G4G) IN GEORGIA

15 January 2018

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### ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ANN</td>
<td>Artificial Neural Networks</td>
</tr>
<tr>
<td>ARIMA</td>
<td>Autoregressive Integrated Moving Average</td>
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<tr>
<td>AYPEG</td>
<td>Association of Young Professionals in Energy of Georgia</td>
</tr>
<tr>
<td>BAU</td>
<td>Business as Usual Scenario</td>
</tr>
<tr>
<td>CAGR</td>
<td>Compound Annual Growth Rate</td>
</tr>
<tr>
<td>CGE</td>
<td>Computable General Equilibrium</td>
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<tr>
<td>CSO</td>
<td>Civil Society organization</td>
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<tr>
<td>DSO</td>
<td>Distribution System Operator</td>
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<tr>
<td>EEC</td>
<td>Energy Efficiency Center</td>
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<tr>
<td>ESCO</td>
<td>Electricity System Commercial Operator</td>
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<td>ESCO</td>
<td>Electricity System Commercial Operator</td>
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<td>G4G</td>
<td>Governing for Growth in Georgia</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GEOSTAT</td>
<td>National Statistics Office of Georgia</td>
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<td>GNERC</td>
<td>Georgian National Energy and Water Supply Regulatory Commission</td>
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<td>GSE</td>
<td>Georgian State Electro System</td>
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<tr>
<td>GW</td>
<td>Gigawatt</td>
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<tr>
<td>GWh</td>
<td>Gigawatt hour</td>
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<tr>
<td>HH</td>
<td>Households</td>
</tr>
<tr>
<td>HPP</td>
<td>Hydro Power Plant</td>
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<tr>
<td>IEA</td>
<td>International Energy Agency</td>
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<tr>
<td>IMF</td>
<td>International Monetary Fund</td>
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<tr>
<td>JSC</td>
<td>Joint Stock Company</td>
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<tr>
<td>KW</td>
<td>Kilowatt</td>
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<tr>
<td>kWh</td>
<td>Kilowatt hour</td>
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<tr>
<td>LEAP</td>
<td>Long-range Energy Alternatives Planning</td>
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<tr>
<td>LEDS</td>
<td>Low Emission Development Strategy</td>
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<td>MAED</td>
<td>Model for Analyses of Electricity Demand</td>
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<td>MARKAL</td>
<td>Market Allocation Model</td>
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<tr>
<td>MoE</td>
<td>Ministry of Energy</td>
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<tr>
<td>MoESD</td>
<td>Ministry of Economy and Sustainable Development</td>
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<tr>
<td>MoIA</td>
<td>Ministry of Internal Affairs</td>
</tr>
<tr>
<td>MW</td>
<td>Megawatt</td>
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<tr>
<td>MWh</td>
<td>Megawatt hour</td>
</tr>
<tr>
<td>NEEAP</td>
<td>National Energy Efficiency Action Plan</td>
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<tr>
<td>OLS</td>
<td>Ordinary least square technique</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaics</td>
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<tr>
<td>TW</td>
<td>Terawatt</td>
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<tr>
<td>TWH</td>
<td>Terawatt hour</td>
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<tr>
<td>TYNDP</td>
<td>Ten Year Network Development Plan</td>
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<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
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<tr>
<td>WB</td>
<td>World Bank</td>
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<tr>
<td>WEG</td>
<td>World Experience for Georgia</td>
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1. EXECUTIVE SUMMARY

Energy Efficiency Center Georgia (EEC), under the G4G grant project “Electricity Demand Forecasting Model,” developed a user-friendly electricity demand forecasting tool in order to improve the decision making process in the Georgian energy sector using internationally recognized and scientifically proven methodologies as well as empirical analysis. The expected outcomes of the project were to develop not only an electricity demand forecasting tool and a 10-15-year electricity demand forecast for Georgia, but also and of no less importance, to identify challenges associated with the demand forecasting process and provide recommendations addressing those challenges supporting further improvements to the existing model.

The project was divided into five milestones with the first three milestones focused on assessing data availability for performing modelling, review of existing electricity long-term demand projects applied in Georgia and consultation with main stakeholders for providing feedback on the selected model and planning the next steps.

The assessment of existing data revealed that there is not available data on hourly loads by customer groups in Georgia. Therefore, EEC constructed a model that can capture all relevant customer groups influencing peak demands for hourly, daily and seasonal perspectives and applied demand proxies of different customer groups based on scientific literature and publicly available sources.

According to Georgian electricity sector stakeholders, the existing electricity demand forecasting models are simple and do not incorporate comprehensive demand forecasting analyses. At the same time, forecasting of hourly peak loads is not conducted. Therefore, improving the electricity demand forecasting capacities of stakeholders and implementation of comprehensive demand forecasting tools are necessary for proper planning of Georgian electricity sector development.

Under this grant project, the Long-range Energy Alternatives Planning (LEAP) Georgia model was constructed in a way to enable forecasting of monthly electricity demand as well as producing monthly peak loads. Additionally, a bottom-up approach was used in order to create a tool for evaluating energy efficiency scenarios. In total, five scenarios are discussed in the report. The baseline scenario describes how the system might evolve without implementation of any new policies. It takes into account past trends and functional relationships between demand drivers and end-uses. The energy efficiency scenario is based on results and targets provided in the draft National Energy Efficiency Action Plan (NEEAP). The comparison between baseline and energy efficiency scenarios demonstrates the impact of certain energy efficiency policies on the demand. The customer-owned generation scenario was developed to forecast the impact of micro power plants on demand. Finally, as real gross domestic product (GDP) growth is one of the main determinants of electricity usage in the country, two additional scenarios with high and low GDP growth were developed to observe the impact of changes in GDP on electricity demand.

The forecast shows that total electricity demand will increase from 10.6 TWh in 2015 to 18.9 TWh in 2030 in the BAU scenario. In other scenarios: a 10% deviation from baseline GDP growth rate results in a 0.8 TWh increase in the case of a high GDP growth rate and a 0.7 TWh decrease in the case of a low GDP growth rate for year 2030 as compared to the business as usual (BAU) scenario. The energy efficiency scenario shows that electricity demand decreases by 2.3 TWh in 2030 as compared to the BAU scenario, while in the customer owned generation scenario electricity demand decreased by 0.1 TWh in 2030 compared to the BAU scenario.
2. BACKGROUND

During the last decade, electricity demand in Georgia has increased around 4-5% annually. However, the process of harmonization of Georgian legislation with the Energy Community acquis leads to different policies to be in place and implemented (e.g. initiatives such as development of the NEEAP, obligations related to renewable sources) which leads to drastic changes affecting demand on electricity. The effect of the policies needs to be analyzed properly to respond to any future challenges.

Electricity demand forecasting is an important topic for a country and is a foundation for planning of generation capacity and its technical specifications, as well as for stimulating mechanisms.

The project was designed to effectively address the main questions and issues presented by the “Electricity Demand Forecasting Model” project. The main outputs of the project are:

- Assessment of existing electricity demand related datasets, as well as analysis of energy end-use data from different surveys. The assessment of data availability and transparency provides information about the existing datasets and determines what data is missing for the purposes of building a comprehensive forecasting model and provides recommendations for filling this gap. The assessment will serve as a guide for the interested parties (decision makers, civil society organizations (CSOs), investors) about the available data and on the other hand will provide recommendations for improvement (including applying international experience on specific data collection by responsible parties).

- Exploration of the methods/models which are currently available in Georgia and the most relevant ones used internationally is another aim of the project. The most widely used models are determined and overviewed in Appendix C of the report. Based on the assessment of the models and comparing their data requirements with the available data, the LEAP software was chosen as the most suitable tool to produce an electricity demand scenario-based forecast in Georgia for the next 10-15 years. The forecast includes monthly peak loads and energy sales, forecasted network losses and total system monthly peak and energy sales. EEC built a model in LEAP software and increased the capacity of Georgian CSOs and decision making bodies that will contribute to sustainability of the project. The modeling approach, assumptions and results were discussed with project beneficiaries and relevant updates were made based on their feedback.

- As the model built in the LEAP software is scenario based, there were three scenarios developed in scope of the RFA: 1) BAU scenario, where no new policy effect is taken into account, 2) forecasted energy sales with customer-owned generation, and 3) forecasted energy sales including customer-owned generation and energy efficiency impacts.

The outcome of the model will be used in the decision making process and will therefore contribute to the energy planning process and provide more accurate estimations for investors in the energy sector. Increased capacity will allow CSOs and other parties to further refine the model and create new ones. In case recommendations regarding the missing data collection are taken into account, the capacity of the CSOs with access to the comprehensive data will increase their ability to produce other models for forecasting and energy planning.
3. METHODOLOGY

3.1 DATA ASSESSMENT

The first and one of the most crucial issues is to assess data availability to be used in forecasting electricity demand. Essential data is collected and managed by different stakeholders in the energy sector, international organizations and CSOs. Hence, data that is used in the project were collected from National Regulatory Authority - Electricity System Commercial Operator (ESCO), transmission and distribution system operators, the National Statistics Office of Georgia (GeoStat) and international organizations. Furthermore, energy end-use data in the household sector collected by Association of Young Professionals in Energy of Georgia (AYPEG) and energy end-use data in commercial and industrial sectors collected by a World Experience for Georgia (WEG) survey were also analyzed. A detailed data assessment is provided in Appendix A of the report. The main conclusion from the assessment was that the available data does not have a long series limiting use of dynamic models. Furthermore, there is no real-time measurement data available to assess the contribution of different activities (e.g. lighting, space heating) to peak demand. Such gaps in data limit the accuracy of end-use models, which are the most commonly used ones. Recommendations for filling the data gaps are provided in chapter 5, “Recommendations.”

3.2 MODEL ASSESSMENT

After gathering information on available data, the next important step was to choose the model for forecasting electricity demand. While the most common internationally used models were analyzed and assessed, a survey was conducted to understand what approaches are currently used in Georgia for electricity demand forecasting purposes. A stakeholder survey covered those organizations that use or are supposed to use electricity demand forecasting for energy system planning. These organizations are the Ministry of Energy of Georgia (now a department under the Ministry of Economy and Sustainable Development (MoESD), JSC Georgian State Electrosystem (GSE), ESCO and Georgian electricity distribution companies: JSC Energo-Pro Georgia and JSC Telasi. Furthermore, research and analytical organizations use energy planning models that incorporate the demand forecasting part. The survey showed that long-term energy forecasts are an integral part of energy planning models in Georgia, however they are not sufficiently developed for producing forecasted electricity peak load and load shapes per customer classes. Survey results enabled to identify several limitations and challenges regarding electricity demand forecasting:

- Lack of sophisticated energy data delays comprehensive electricity demand forecast process;
- Lack of capacity to work with comprehensive models in Georgia;
- Most of existing electricity demand forecasts do not consider seasonality;
- Long-term electricity demand forecasting does not incorporate increasing tendency of peak load;
- Currently existing electricity demand forecast methods do not consider future development trends of economic sectors in the country.

The results of stakeholders’ survey, including the filled out questionnaire by each interviewee, is provided in Appendix B.

Using different models to forecast electricity consumption trends accurately is an important issue for electricity production and distribution systems. According to the forecasting time-period in the literature, there are three most common categories of electricity consumption. Long-term forecasting (5-20 years) is applied for resource management and investments development and decision-making. Mid-term forecasting (a month to five years)
is used for planning the electricity production resources and tariffs, and short-term forecasting (an hour to a week) is mostly used for scheduling and analyses of the distribution system. As electricity demand changes in different time-periods and depends on socio-economic, demographic, climate, cultural and other variables, accurate demand forecast requires a comprehensive approach. Provided below is the description of various methods of electricity demand forecasting based on the international experience.

Electricity sales are a function of demand, which in turn can be forecasted for the short, medium or long term. It is important to forecast not only electricity sales but also peak demand during the day, i.e. the peak load of the system.

The models used for forecasting electricity demand can be classified into three major groups:

- End-Use models;
- Input-Output models;
- Econometric models.

As concluded from the data assessment section, there is no data with a long time series, which would enable use of the econometric approach. Hence, it is impossible to employ any of econometric models. In addition, econometric models are not often used to predict the indicators required by the project. Data limitation is also problematic for input-output and its descended computable general equilibrium (CGE) models. While existing data enables building a static model, which enables to differentiate short, medium and long-run results, there is no possibility to use a dynamic model, which will provide a precise forecast by years. In addition, such models are not best suited for the purpose of the project. The review of all type of models is provided in Appendix C of this report.

End-use models remain most suitable for the purposes of the project. End-use models are most often used to predict the indicators of interest. All of them differ by data intensity. Data availability and aim of the forecast are the main factors to take into account while deciding which model to use. As the model must be able to provide the forecast of indicators of our interest, there are two options regarding data availability. Firstly, to choose the model, which fits the existing data, or secondly, choose and build model based on existing and/or estimated data in hope to replace the assumed indicators with real ones once more accurate measurement is available. The project team decided to build a comprehensive end-use type model in LEAP software and use estimates for the missing data based on number of realistic assumptions/estimations. In addition, LEAP has several advantages: LEAP is free of charge to use, very user friendly and requires less intensive data. As one of the outputs of the project is to increase the capacity of Georgian CSOs in modeling, any future update of the model will be possible within a short period of time.

LEAP is a modeling environment that allows building specific applications suited to particular problems. It is an integrated modeling tool based on scenarios that can be used to determine the optimal level of long-term energy system development, energy consumption and production, both on the state and on the economic sectoral level. It is important to emphasize that LEAP is an accounting framework tool and requires user to develop modelling approach and scenarios based on the enquired question. Therefore, it relies much on expert judgment in describing energy system model and evaluates impact of different policy options. LEAP is a flexible modelling environment that allows building specific applications suited to particular problems at various geographical levels (cities, state, country, region or global). LEAP is successfully used to develop energy policies and strategies in advanced and developing countries. Hundreds of organizations use LEAP worldwide in more than 150 countries, especially in the developing world. LEAP is an integrated modeling tool based on scenarios that can be used to determine the optimal level of long-term energy, energy consumption, and production and energy resources, both in the state level and in the economic sectors. LEAP can provide long-term forecasting environment of the energy sector, integrated management of resources and calculate the country's energy balance. As an integrated energy planning model, LEAP covers both the demand and supply sides of the energy system.

### 3.3 MODELLING AND CALIBRATION OF THE BASE YEAR
The electricity demand forecasting model was constructed using LEAP modelling software to meet the project goals. Specifically, the modeling tool has enabled forecasting of annual and monthly electricity demands as well as monthly peak loads. The architecture of the end-use electricity model for Georgia was largely influenced by available data. Table 1 below provides the type of data and time series, relevant for the LEAP electricity demand modelling, collected by the project team.

A bottom-up approach enables observation of peak demand variations hour by hour, capturing possible peak shaving or peak shifting. Moreover, this approach is to evaluate various energy efficiency policies applied to different end-uses and in this manner to construct energy efficiency scenario.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Type of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESCO</td>
<td>Monthly Electricity Balances (2006 –current) disaggregated by distribution system operators (DSOs), direct customers and Autonomous Republic of Abkhazia level</td>
</tr>
<tr>
<td>GSE</td>
<td>Hourly Peak Load (2014-2016)</td>
</tr>
<tr>
<td>DSOs</td>
<td>Monthly electricity sales disaggregated by household and non-household levels (including differentiation of consumption on different voltage level)</td>
</tr>
<tr>
<td></td>
<td>Household energy end-use survey 2017</td>
</tr>
<tr>
<td>AYPEG</td>
<td>Household Energy End-Use Survey, 2014</td>
</tr>
<tr>
<td>WEG</td>
<td>Commercial Sector Energy End-Use Survey, 2015</td>
</tr>
</tbody>
</table>

Table 1. Sources of electricity consumption and end-use data collected by the project team

GeoStat provides the most disaggregated data for modelling purposes on electricity end-use annually. The electricity sector is described separately as part of total energy balance. Among production, import-export and transformation information, energy balances provide final consumption of electricity per sector. Table 2 describes end-use variables that are available for the years of 2013-2015.

According to the information provided on Table 2, industry, residential and commercial and public sectors are the largest consumer groups in Georgia. While industry data is detailed showing contribution of each industrial subsector to the final consumption, residential and commercial sector data is provided in an aggregated level. Therefore, it is important to split up residential and commercial consumption in different end-uses since these two sectors have different load profiles and are “suspects” of determining peak load in a given hour.

<table>
<thead>
<tr>
<th>Electricity end-use/years</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Consumption (GWh)</td>
<td>9,074.7</td>
<td>9,785.5</td>
<td>9,906.4</td>
</tr>
<tr>
<td>Industry</td>
<td>2,327.3</td>
<td>2,816.9</td>
<td>2,751.3</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>1,449.8</td>
<td>1,446.4</td>
<td>1,250.3</td>
</tr>
<tr>
<td>Chemical (including petrochemical)</td>
<td>301.2</td>
<td>198.3</td>
<td>317.3</td>
</tr>
<tr>
<td>Non-ferrous metals</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Non-metallic minerals</td>
<td>244.1</td>
<td>221.9</td>
<td>279.8</td>
</tr>
<tr>
<td>Transport equipment</td>
<td>10.4</td>
<td>6.6</td>
<td>5.3</td>
</tr>
<tr>
<td>Machinery</td>
<td>4.6</td>
<td>11.1</td>
<td>12.4</td>
</tr>
<tr>
<td>Mining and quarrying</td>
<td>-</td>
<td>91.8</td>
<td>117.2</td>
</tr>
<tr>
<td>Food, beverages and tobacco</td>
<td>177.7</td>
<td>194.5</td>
<td>196.6</td>
</tr>
</tbody>
</table>
Paper, pulp and printing | 10.9 | 13.3 | 15.3
Wood and wood products | 4.3 | 4.1 | 5.4
Construction | 87.4 | 371.5 | 128.7
Textiles and leather | 6.0 | 7.5 | 13.3
Not elsewhere specified (Industry) | 30.9 | 250.1 | 410.0
Transport | 282.0 | 266.7 | 293.9
Rail | 282.0 | 266.7 | 293.9
Other | 6 465.4 | 6 701.8 | 6 861.2
Commercial and public services | 2 572.20 | 2 567.5 | 2 544.9
Residential | 2 253.30 | 2 465.2 | 2 462.4
Agriculture/forestry/fishing | 34.6 | 30.5 | 56.7
Not elsewhere specified (Other) | 1,605.3 | 1,638.6 | 1,797.2

**Table 2. Decomposition of electricity end-use by sectors (GWh), GeoStat energy balances**

Based on energy end-use surveys (listed in Table 1), the project team has identified major end-use types for the household and commercial-public sectors. In the household sector, the following end-uses are evaluated separately: water-heating, space-heating, space-cooling, refrigeration, lighting, cooking and other. The latter end-use unifies all the other electric appliances such as TVs, computers, dishwashers, etc. The commercial-public sector was divided into the following end-uses: cooling, space-heating, water-heating, cooking, refrigeration, lighting and other uses. Overall, the electricity demand in 34 end-use categories is modelled, assigning respective hourly load shapes and forecasting for the next 15 years. The model’s base year is 2015 as the most recent year that includes the GeoStat energy balance.

The end-uses surveys described in Table 1 provide percentage penetration levels of different appliances, however there is no information available of electricity usage per activity in kWh. Therefore, typical load profiles from available literature were used, guess assumptions were made and thus a proxy demand profiles for each end-use were developed.

Because system load data is only available on an aggregated level (total system load recorded by GSE), annual sub-sector electricity consumptions from GeoStat data was used and assigned derived hourly load shapes to construct the total system load. Figure 1 below illustrates the modeling process for disaggregation of annual demand into sub-sectors (for example, dividing household electricity demand into activities such as cooking, water heating, etc.) and by time of use.
A peak day of each month was defined for the year of 2015 as a day when monthly hourly peak demand occurred. For the selected peak day, 24 “time-slices” were created to derive peak day hourly load data. The rest of the energy in the month is unified in a single time-slice called “off-peak month.” So, for example in January, there are 24 time-slices for peak day and “off-peak January” that is monthly demand in January reduced by peak day consumption. Thus, 12X24+12=300 time slices were received that cover annual energy demand (8760-hour load).

![Figure 2. Illustration of base year calibration for peak load time-slices](image)

Calibration work was devoted to minimize the difference between actual total system hourly loads and summed up hourly load shapes (derived from surveys and assumptions for each end-use peak day hourly load profile). Figure 2 shows calibration of total system load data for peak day hourly loads for each month. The blue line represents actual system load profiles for 2015 while the red line is estimated electricity hourly demand aggregated based on proxy load profiles.

Average estimation error for the calibration year is 4% and the standard deviation 3%. However, as peak loads for each month are more important for research purposes, more effort was devoted to reduce estimation errors for peak hours and therefore estimation errors for them are lower.

### 3.4 DEVELOPMENT OF SCENARIOS

To forecast scenario-based electricity demand, five different scenarios were developed. The baseline scenarios (including medium, high and low GDP growth scenarios) predict future demand with existing environment and without any specific policy measures. On the contrary, other two scenarios take into account development of customer-owned generation and increase in energy efficiency.
3.4.1 BASELINE SCENARIO

The BAU or baseline scenario in LEAP is a consistent description of how a system might evolve in the future in the absence of explicit new policies. The baseline scenario (BAU) is not just a simple extrapolation of current trends but it also considers likely evolution of customer groups’ behavior for electricity demand and existing policies. The BAU scenario also includes macroeconomic and demographic trends, any structural shifts in the economy (i.e. away from agriculture to services, changes brought about by resource constraints) evolution of technologies or practices, etc. For this scenario, trends observed in current/historical data are expected to continue and policies that have been introduced, but not implemented, are assumed to proceed.

Demographic and economic changes are main drivers of electricity demand. The residential demand on electricity is dependent on the number of households and end-use electricity consumption for different types of activities, such as heating, cooling, cooking etc. Penetration levels of different appliances is also one of the main determinants of electricity demand in the household sector. For industry, demand on electricity depends mainly on the production rates and energy consumed per unit of production.

To model long-run electricity demand for Georgia, the following assumptions regarding demographic and economic fluctuations were made in the model:

Assumptions on Demographic Indicators:

- The population of Georgia will decrease to 3,571,000 people by 2030. Population growth/decline rate is based on the figures obtained from the World Bank (WB) database, which contains demographic estimates and projections for 1960-2050 years.

- According to GeoStat, in 2015, the average household size was 3.34 persons per household and this figure will decline by 0.5% annually within the following 15 years. The assumption is based on the data of the population census 2014 obtained from GeoStat databases. Compared to the year of 2002, average household size was declining by 0.5% annually. In the model, it is assumed that the household size will decline by the same rate for the next 15 years. This is a reasonable assumption, since empirical evidence also suggests that household size declines with economic development, not only worldwide but also in Georgia.

- The number of households is defined as the population number divided by the household size. Reduced household size offsets slight decline of population and therefore the number of households is expected to increase in the future. Table 3 below provides a brief summary of the projected number of households in Georgia.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Years</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household size (person)</td>
<td>3.34</td>
<td>3.26</td>
<td>3.17</td>
<td>3.10</td>
<td></td>
</tr>
<tr>
<td>Population (Thousands)</td>
<td>3,713.7</td>
<td>3,695</td>
<td>3,641</td>
<td>3,571</td>
<td></td>
</tr>
<tr>
<td>Number of Households (Thousands)</td>
<td>1,112.62</td>
<td>1,135.11</td>
<td>1,146.91</td>
<td>1,153.41</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Projected demographic indicators during 2015 - 2030.

Assumptions on Household Electricity Demand:

In the baseline scenario, household electricity demand is based on number of households and activity level of households, implying only a certain percentage of households are engaged in specific activities and a share of households using electricity for the specific activity. The model incorporates activity levels for each end-use category in the household sector. This implies a percentage of total number of households for a specific year.
that applies activities described as “tree” branches in the model. Table 4 provides information related to application of activities in households in percentage terms.

For the base year, figures from AYPEG’s households national end-use survey were used, while for the year of 2016, data from GeoStat’s national survey on households energy consumption were used. For the subsequent years, penetration levels of different appliances from EU statistics were used to determine utilization of new appliances.

Table 4. Activity level of Household sector (% of households)

<table>
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</table>

At the same time, with the activity levels of households for each branch, it is also important to break down which type of energy resources are used for each branch in the household sector. While for the project only information for electricity was important, Table 5 below summarizes saturation levels or % of households using electricity for the branch activities.

Table 5. Share (%) of Households using electricity for the Branch Activities

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<td>5.73</td>
<td>5.50</td>
<td>5.40</td>
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<td>3.65</td>
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<tr>
<td>Lighting: Efficient</td>
<td>18.60</td>
<td>20.30</td>
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<td>26.00</td>
<td>28.00</td>
<td>30.00</td>
<td>31.00</td>
<td>32.00</td>
<td>33.00</td>
<td>34.00</td>
<td>35.00</td>
<td>38.75</td>
<td>42.50</td>
<td>46.25</td>
<td>50.00</td>
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<tr>
<td>Lighting: Existing</td>
<td>81.40</td>
<td>79.70</td>
<td>78.00</td>
<td>76.00</td>
<td>74.00</td>
<td>72.00</td>
<td>70.00</td>
<td>69.00</td>
<td>68.00</td>
<td>67.00</td>
<td>66.00</td>
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<td>61.25</td>
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<td>Cooking</td>
<td>3.55</td>
<td>6.93</td>
<td>10.30</td>
<td>10.73</td>
<td>11.15</td>
<td>11.58</td>
<td>12.00</td>
<td>12.60</td>
<td>13.20</td>
<td>13.80</td>
<td>14.40</td>
<td>15.00</td>
<td>17.50</td>
<td>20.00</td>
<td>22.50</td>
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</table>

In addition, AYPEG’s household end-use survey provides estimations on yearly electricity consumption per activity. To summarize, the information provided in tables 3-5 and estimated annual electricity consumption per activity multiplied by the number of households provides total electricity used per activity, hence electricity demand = number of “units” x energy per unit. For example, 98% of households do cooking but only 3.55% use electricity for this purpose. Additionally, households spend on average 553 KWh electricity for cooking annually. Knowing that the number of households in 2015 was 1.1 million (Mln), the result will be:

Final demand on electricity for cooking=1.1*98%*3.55%*553= 21 Mln. kWh.

General Assumptions on Economic Sectors

In the model, real GDP growth rate affects electricity demand for the commercial, agricultural and industrial sectors. Electricity demand growth is directly linked with GDP growth rate for the commercial sector. A slightly different approach is used for projecting industrial energy demand, which is described below under “Assumptions on Industry”:

- The data on the real GDP growth rate was obtained from International Monetary Fund’s (IMF’s) World Economic Outlook database, which provides projection of GDP growth until 2022. It is assumed that after 2022, Georgia’s economy will grow by 5.4% on average. This assumption is also made due to historical data on Georgia’s average economic growth rate which has been in the range of 5-6% during the last 10 years. Moreover, the Low Emission Development Strategy (LEDS) and National Energy Efficiency Action Plan (NEEAP) rest on the similar assumption, that long-term economic growth in Georgia will be 5.4-5.6% on average.

- GDP value added per sector was obtained from GeoStat and forecasted for the next 15 years based on the total GDP growth rate described above. It is assumed that the economic structure of Georgia
will be the same over time and the share of each economic sector in total GDP will remain constant. From this assumption follows that each sector will grow at the same rate.

Assumption on Industry:

According to World Energy Council, energy intensity in industry has been improved annually by 1% during 2000-2014\(^2\). This means that industrial energy use per value added was reducing annually by 1% on average for the world. Most of it can be explained by technological diffusion, as newer technologies are more efficient compared to older ones. It is envisaged that energy intensity for Georgia will be reduced by 1% in the industrial sector.

Assumption on Electricity Consumption by the Autonomous Republic of Abkhazia:

Electricity consumption by the Autonomous Republic of Abkhazia has been increasing significantly during recent years. Enguri and Vardnili hydro-power plants (HPPs) are supplying electricity to the Autonomous Republic of Abkhazia, therefore increased consumption has also increased the share of generated electricity by the above-mentioned HPPs that was supplied to Abkhazia. The table below provides data on electricity generation by Enguri and Vardnili plants, as well as consumption of Abkhazia during 2010-2016.

It is assumed that the electricity consumption of Abkhazia will continue to grow until reaching 50% of average annual generation by Enguri and Vardnili HPPs for the year of 2018. An average 2075 Mln kWh is assumed to be consumed after 2018.

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<tbody>
<tr>
<td>Electricity Supply to Abkhazia (Consumption)</td>
<td>1377.1</td>
<td>1613.37</td>
<td>1533.657</td>
<td>1605.28</td>
<td>1638.1</td>
<td>1797.2</td>
<td>1926.9</td>
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<tr>
<td>Consumption Growth</td>
<td>-</td>
<td>15%</td>
<td>-5%</td>
<td>4%</td>
<td>2%</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>Electricity Generation: Enguri HPP</td>
<td>4300.9</td>
<td>3257.591</td>
<td>3173.271</td>
<td>3605.134</td>
<td>3331.9</td>
<td>3313.9</td>
<td>3548.7</td>
</tr>
<tr>
<td>Electricity Generation: Vardnili HPP</td>
<td>731.6</td>
<td>588.265</td>
<td>586</td>
<td>667.2</td>
<td>624.1</td>
<td>592</td>
<td>662.3</td>
</tr>
<tr>
<td>Total Enguri and Vardnili</td>
<td>5032.5</td>
<td>3845.856</td>
<td>3759.271</td>
<td>4272.334</td>
<td>3956</td>
<td>3905.9</td>
<td>4211</td>
</tr>
<tr>
<td>Share of Abkhazia Consumption vs Generation of Enguri and Vardnili</td>
<td>27%</td>
<td>42%</td>
<td>41%</td>
<td>38%</td>
<td>41%</td>
<td>46%</td>
<td>46%</td>
</tr>
</tbody>
</table>

Table 6. Electricity supply to Abkhazia and power generation from Vardnili and Enguri HPPs (2010-2016)

Assumptions on Electricity Consumption by Crypto Currency (Bitcoin) Miners:

Recently, electricity consumption by Bitcoin miners began in Georgia and has been increasing very rapidly. Several Bitcoin mining facilities were constructed in the country and according to the information obtained from DSOs there are other applications for connecting new mining facilities to network. Additionally, DSO’s have applications for extending the existing mining plants, therefore electricity consumption for Bitcoin mining as a separate branch is included. As servers and computers for mining are switched on constantly, the electricity usage throughout the day or season is flat. Based on information obtained from DSOs connected mining capacity in 2016 was 75 MW. In 2017 it has increased and comprised 109.5 MW. Additionally, based on applications for connecting new capacities for crypto currency mining, DSOs anticipate an additional 80 MW to go live in 2019. After 2019, it is assumed that the total capacity of 189.5 MW will be on the grid through 2030 with a flat load profile. The uncertain future of Bitcoin’s price and Bitcoin in general makes it problematic to forecast electricity usage. According to analysts, “under Bitcoin’s current design, this depends entirely on what

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\(^2\) The corresponding Information is available on World Energy Council website: [https://wec-indicators.enerdata.net/electric-process-steel-industry.html#/industry-energy-intensity-world-level-trends.html](https://wec-indicators.enerdata.net/electric-process-steel-industry.html#/industry-energy-intensity-world-level-trends.html)
happens to the price of Bitcoin. If Bitcoin's price doubles, we can expect the Bitcoin network's energy consumption to roughly double as well. If Bitcoin's price falls significantly, on the other hand, miners will find their operations unprofitable and will start to switch off their least efficient equipment, causing energy use to decline\(^3\).

**Assumptions on Transport:**

In the model, electricity use by the transport sector is divided in two parts: rail and road. The latter describes electricity consumption by electric vehicles. According to the data obtained from the Ministry of Internal Affairs of Georgia (MoIA), in 2017 (January–November) 650 electric cars were imported in Georgia. Before 2017, there were only 91 registered electric cars in the country. It is assumed that the same trend will continue until 2030 and the number of electric cars will reach around 9,191. Annual electricity consumption by electric cars was evaluated based on average driving demand (km per year) known from surveys and average use of electricity by an electric car (kWh per km). There is poor data available on the transport sector regarding to the time-series of freight shipment and passenger travel. Therefore, the assumption is based on available historical electricity consumption growth rate in the sector. According to the GeoStat's annual energy balances, compound annual growth rate of the electricity consumption by transport sector was 2.16% during the 2013-2016 period. It is assumed that electricity demand by rail will increase with the same average growth rate per year, i.e. 2.16% annually until 2030.

**Assumptions on Losses:**

For the year of 2016, the actual loss for electricity distribution and transmission is inserted. For the subsequent years, it is assumed that electricity system losses in the power network reach the same percentage (% total demand) as the current EU level. This implies that the losses in absolute terms will increase but will gradually decrease in percentage terms of total demand (From 6.7% in 2015 to 6% in 2030\(^4\)).

To summarize, electricity demand projections in LEAP Georgia model are based on socio-economic variables and their development trends. Number of households, penetration level of various end-use appliances, real GDP, industrial energy intensity changes are the main variables that drive electricity demand in the baseline scenario. Table 7 below summarizes demand sectors and activities that influence electricity demand growth in Georgia.

<table>
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<tr>
<th>Sector</th>
<th>Activity Change</th>
<th>Energy Intensity Change</th>
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<tbody>
<tr>
<td>Residential</td>
<td>Number of households / penetration levels of appliances</td>
<td>None/constant</td>
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<tr>
<td>Commercial and Services</td>
<td>Growth with total GDP</td>
<td>None/constant</td>
</tr>
<tr>
<td>Industry</td>
<td>Growth with total GDP</td>
<td>Declining</td>
</tr>
<tr>
<td>Agriculture, Forestry, Fishing</td>
<td>Growth with total GDP</td>
<td>None/constant</td>
</tr>
<tr>
<td>Transport</td>
<td>Consumption grows at fixed percentage per year</td>
<td></td>
</tr>
<tr>
<td>Non-specified (Abkhazia)</td>
<td>Consumption grows at fixed percentage per year, up to the assumed cap.</td>
<td></td>
</tr>
<tr>
<td>Bitcoin</td>
<td>Based on DSO’s capacity applications till 2019</td>
<td></td>
</tr>
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</table>

**Table 7. Electricity consumption by sectors and their growth factors**

Baseline scenario incorporates two sub-scenarios. High and low GDP growth scenarios assume ±10% GDP growth/decrease considered in the base year. All the other parameters and assumptions are kept the same.

\(^{3}\)https://arstechnica.com/tech-policy/2017/12/bitcoins-insane-energy-consumption-explained/

\(^{4}\)https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS?name_desc=false
3.4.2 IMPACT OF ENERGY EFFICIENCY POLICY ON DEMAND

The energy efficiency scenario is based on the assumption that during the forecasting period of electricity demand in Georgia, energy intensities of household appliances will decrease and technological process in the commercial and industrial sector will improve due to technology advancements. Assumptions on energy intensities are based on experience of European countries where energy efficiency policies have already been introduced. Table 9 below summarizes assumptions on energy intensities in household sector:

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<td>20.90</td>
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<td>25.50</td>
<td>27.00</td>
<td>28.50</td>
<td>30.00</td>
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<tr>
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<td>9.72</td>
<td>8.06</td>
<td>6.40</td>
<td>6.18</td>
<td>5.95</td>
<td>5.73</td>
<td>5.50</td>
<td>5.40</td>
<td>5.30</td>
<td>5.20</td>
<td>5.10</td>
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<tr>
<td>Lighting: Efficient</td>
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<td>69.25</td>
<td>73.50</td>
<td>77.75</td>
<td>82.00</td>
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<td>Lighting: Existing</td>
<td>81.40</td>
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<td>39.00</td>
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<td>30.75</td>
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<td>Cooking</td>
<td>3.55</td>
<td>6.93</td>
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Table 10. Share (%) of households using electricity for the branch activities

<table>
<thead>
<tr>
<th>Branches</th>
<th>Base year</th>
<th>EE (2019-2026)</th>
<th>EE (2026-2030)</th>
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<tr>
<td>Cooling</td>
<td>376.03</td>
<td>-2%</td>
<td>-1%</td>
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<td>Lighting: Existing</td>
<td>204.91</td>
<td>-2.5%</td>
<td>-2.5%</td>
</tr>
<tr>
<td>Lighting: Efficient</td>
<td>129.43</td>
<td>-1%</td>
<td>-1%</td>
</tr>
<tr>
<td>Space heating</td>
<td>58.51</td>
<td>-3%</td>
<td>-1%</td>
</tr>
<tr>
<td>Water Heating</td>
<td>156.85</td>
<td>-2%</td>
<td>-1%</td>
</tr>
<tr>
<td>Other</td>
<td>1012.2</td>
<td>-2%</td>
<td>-1%</td>
</tr>
<tr>
<td>Cooking</td>
<td>212.43</td>
<td>-2%</td>
<td>-1%</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>630.12</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
</tbody>
</table>

Table 11. Energy intensity assumptions on commercial sector (kWh)
### Table 12. Energy intensity assumptions on industrial sector (kWh)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Base year (2017-2030)</th>
<th>EE (2019-2026)</th>
<th>EE (2026-2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron and Steel</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Chemical</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Non Metallic Minerals</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Machinery</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Mining and Quarrying</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Food Beverages and Tobacco</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Paper Pulp and Printing</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Wood and Wood Products</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Construction</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Textiles and Leather</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Other</td>
<td>-1%</td>
<td>-3%</td>
<td>-1.5%</td>
</tr>
</tbody>
</table>

### 3.4.3 IMPACT OF CUSTOMER-OWNED GENERATION (NET-METERING POLICY) ON DEMAND

Net metering policy is defined by the Law on Electricity and Natural Gas of Georgia and Georgian National Energy and Water Supply Regulatory Commission (GNERC) regulation on electricity supply and consumption. One of the pillars of the net metering policy is micro power plants that imply all renewable energy sources under 100 KW of installed capacity at retail consumers’ premises. Such consumers have a reverse meter that turns in both directions and counts energy flows from and to the grid. Generation of micro power plants is meant to cover consumer’s internal consumption first, while excessive energy, due to the low consumption or energy surplus, is exchanged with the grid. Net metering policy is deemed as one of the supporting mechanisms for micro renewable energy installation development. Currently, net metering policy sets an overall subscription limit at 2% of the distribution company’s annual peak demand due to operational reasons. Therefore, apart from economic factors, there are technical limitations for developing micro installations.

The net metering policy scenario implies two motivators for accelerated development: 1) intense support of development of micro power plants at the retail consumer level (mostly for households and multi-residential buildings, schools and etc.) and 2) binding obligations set by building code to meet renewable energy obligations during new constructions and major renovation. Such motivators are based on several international commitments of Georgia, among them accession conditions to the Energy Community that, among others, sets a renewable energy target by 2020-2030 for each contracting party. Development of micro renewable energy sources is a good way to reach renewable energy obligations and also implies an energy saving effect as a major part of generated energy covers internal consumption of a consumer and in this way decreases energy demand at the grid connection point.

The net metering policy scenario is based on the following assumptions:

1. In order to calculate maximum subscription capacity, DSO peak loads were calculated up to 2030 (see table 13);
2. GNERC changes overall subscription limit from 2% up to 5% till 2030 (see table 14);
3. Subscription capacity utilization is average 15% per year until it reaches 100%;
4. Demand coverage factor - 70% of generated electricity by micro power plants covers self-consumption (decreases demand) and 30% is injected into the grid;
5. One KWp micro power plant generates 1600 KWh on average (derived from average capacity factor of existing solar photovoltaic technologies) based on the sixth and seventh assumptions and PVGIS online software calculations;
6. Technology mix – 80% solar PV and 20% Micro HPPs;
7. Micro HPP capacity usage factor for summer day is 50% and for winter day 30% (Yearly 40%). Solar Panel capacity factor for summer day is 20% (reaching 100% capacity at noon) and for winter 10% (reaching 70% capacity at noon) that corresponds to the early 15% capacity factor;
8. Micro HPP daily curve is assumed to be constant while solar PV strictly corresponds to available sun irradiation.

Peak load forecast of DSOs (Energo-pro Georgia and Telasi) is based on past factual peak load data and five year development plan forecasts up to 2022 that are approved by GNERC. Prolongation of the forecast from 2022 till 2030 was based on past annual growth rate.

<table>
<thead>
<tr>
<th>Peak Load</th>
<th>Actual</th>
<th>Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>735</td>
<td>735</td>
</tr>
<tr>
<td>2015</td>
<td>774</td>
<td>774</td>
</tr>
<tr>
<td>2016</td>
<td>820</td>
<td>820</td>
</tr>
<tr>
<td>2017</td>
<td>870</td>
<td>870</td>
</tr>
<tr>
<td>2018</td>
<td>918</td>
<td>918</td>
</tr>
<tr>
<td>2019</td>
<td>943</td>
<td>943</td>
</tr>
<tr>
<td>2020</td>
<td>966</td>
<td>966</td>
</tr>
<tr>
<td>2021</td>
<td>974</td>
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</tr>
<tr>
<td>2022</td>
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<tr>
<td>2023</td>
<td>1047</td>
<td>1047</td>
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<tr>
<td>2024</td>
<td>1063</td>
<td>1063</td>
</tr>
<tr>
<td>2025</td>
<td>1082</td>
<td>1082</td>
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<tr>
<td>2026</td>
<td>1103</td>
<td>1103</td>
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<tr>
<td>2027</td>
<td>1129</td>
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<tr>
<td>2028</td>
<td>1156</td>
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<td>1185</td>
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<tr>
<td>2030</td>
<td>1212</td>
<td>1212</td>
</tr>
</tbody>
</table>

Table 13. DSOs peak load forecast 2018-2030 (MW)

Subscription limit change until 2030 is envisaged in the scenario according to the assumption below. Subscription limit increment is justified under increased capabilities of DSOs to handle intermittent generation from renewable energy sources and by the increased demand on net metering policy.

<table>
<thead>
<tr>
<th></th>
<th>2018-2021</th>
<th>2022-2024</th>
<th>2025-2027</th>
<th>2028-2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limit</td>
<td>2%</td>
<td>3%</td>
<td>4%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Table 14. Subscription limit evolution

Based on peak load forecasts for distribution network and assumptions on subscription limits (in percentage), forecasted maximum yearly subscription capacities (in MWs) were obtained (Table 15).

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPG</td>
<td>18.4</td>
<td>18.9</td>
<td>19.3</td>
<td>19.5</td>
<td>29.3</td>
<td>31.4</td>
<td>31.9</td>
<td>43.3</td>
<td>44.1</td>
<td>45.1</td>
<td>57.8</td>
<td>59.3</td>
<td>60.6</td>
</tr>
<tr>
<td>Telasi</td>
<td>11.5</td>
<td>12.3</td>
<td>13.0</td>
<td>13.8</td>
<td>21.7</td>
<td>22.8</td>
<td>23.9</td>
<td>33.3</td>
<td>34.8</td>
<td>36.3</td>
<td>47.2</td>
<td>49.0</td>
<td>50.8</td>
</tr>
<tr>
<td>Total</td>
<td>29.9</td>
<td>31.2</td>
<td>32.3</td>
<td>33.2</td>
<td>51.0</td>
<td>54.2</td>
<td>55.8</td>
<td>76.6</td>
<td>78.9</td>
<td>81.4</td>
<td>105.0</td>
<td>108.3</td>
<td>111.4</td>
</tr>
</tbody>
</table>

Table 15. Maximum overall connection capacities of micro generators (MW)

The figures provided on Table 15 show allowed connection capacities that can be utilized by renewable micro power plants. However, it is assumed that allowed connection capacities will be utilized gradually, starting from 5% in 2018 and reaching 100% in 2025 -2030 (Table 16).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>15%</td>
<td>30%</td>
<td>45%</td>
<td>60%</td>
<td>75%</td>
<td>90%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Table 16. Utilization level of subscription of overall capacities (%)
The following renewable energy sources mix are assumed: 20% will be generated by micro HPPs and 80% from solar. For simplification purposes, wind and biomass are excluded from the assumptions as for retail consumers that might be negligible that does not influence daily load shapes from micro generator production. It is assumed that hydro generation overall capacity usage actor is 40% while solar PV capacity usage factor is assumed maximum 15%. Special web based software\(^5\) was used that works on PV GIS data base for modeling solar PV annual, monthly and typical daily production in Georgia. The simulation results in terms of annual, monthly and daily production, as well as horizontal outline of 21 June and 21 December days, of 1 KWp building integrated silicon PV panel is shown in Figure 3.

Forecasted utilized connection capacities were derived from Tables 15-16. The table below shows utilized yearly capacities of distributed micro-generation from renewable energy sources.

<table>
<thead>
<tr>
<th>Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPG</td>
<td>0.9</td>
<td>2.8</td>
<td>5.8</td>
<td>8.8</td>
<td>17.6</td>
<td>23.6</td>
<td>28.7</td>
<td>43.3</td>
<td>45.1</td>
<td>57.8</td>
<td>59.3</td>
<td>60.6</td>
<td></td>
</tr>
<tr>
<td>Telasi</td>
<td>0.6</td>
<td>1.9</td>
<td>3.9</td>
<td>6.2</td>
<td>13.0</td>
<td>17.1</td>
<td>21.5</td>
<td>33.3</td>
<td>34.8</td>
<td>36.3</td>
<td>47.2</td>
<td>49.0</td>
<td>50.8</td>
</tr>
<tr>
<td>Total</td>
<td>1.5</td>
<td>4.7</td>
<td>9.7</td>
<td>15.0</td>
<td>30.6</td>
<td>40.7</td>
<td>50.2</td>
<td>76.6</td>
<td>81.4</td>
<td>105.0</td>
<td>108.3</td>
<td>111.4</td>
<td></td>
</tr>
</tbody>
</table>

\(^5\)http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php (See screenshot of software and calculations on figure 3)
PVGIS estimates of solar electricity generation

Location: 41°47' North, 44°44'59" East, Elevation: 466 m a.s.l.
Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 14.4% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 2.7%
Other losses (cables, inverter etc.): 10.0%
Combined PV system losses: 25.1%

<table>
<thead>
<tr>
<th>Month</th>
<th>Ed</th>
<th>Em</th>
<th>Hd</th>
<th>Hm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>2.62</td>
<td>81.1</td>
<td>3.25</td>
<td>101</td>
</tr>
<tr>
<td>Feb</td>
<td>2.94</td>
<td>82.3</td>
<td>3.68</td>
<td>103</td>
</tr>
<tr>
<td>Mar</td>
<td>3.54</td>
<td>110</td>
<td>4.61</td>
<td>143</td>
</tr>
<tr>
<td>Apr</td>
<td>3.73</td>
<td>112</td>
<td>5.69</td>
<td>162</td>
</tr>
<tr>
<td>May</td>
<td>4.36</td>
<td>135</td>
<td>5.99</td>
<td>186</td>
</tr>
<tr>
<td>Jun</td>
<td>4.66</td>
<td>140</td>
<td>6.53</td>
<td>196</td>
</tr>
<tr>
<td>Jul</td>
<td>4.66</td>
<td>145</td>
<td>6.03</td>
<td>205</td>
</tr>
<tr>
<td>Aug</td>
<td>4.43</td>
<td>137</td>
<td>6.29</td>
<td>195</td>
</tr>
<tr>
<td>Sep</td>
<td>4.16</td>
<td>124</td>
<td>5.63</td>
<td>169</td>
</tr>
<tr>
<td>Oct</td>
<td>3.36</td>
<td>105</td>
<td>4.44</td>
<td>136</td>
</tr>
<tr>
<td>Nov</td>
<td>2.73</td>
<td>82.0</td>
<td>3.47</td>
<td>104</td>
</tr>
<tr>
<td>Dec</td>
<td>2.44</td>
<td>75.6</td>
<td>2.94</td>
<td>91.2</td>
</tr>
<tr>
<td>Year</td>
<td>3.64</td>
<td>111</td>
<td>4.88</td>
<td>149</td>
</tr>
<tr>
<td>Total for year</td>
<td>1330</td>
<td>1780</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ed: Average daily electricity production from the given system (kWh)
Em: Average monthly electricity production from the given system (kWh)
Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m²)
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m²)

Figure 3. PVGIS web platform interface
Two daily load curves have been elaborated for two typical days: 21st of June that corresponds to the summer season and 21th of December that corresponds to the winter season (See Figures 5 and 6). The curves were derived based on the graphs retrieved from the PVGIS model and based on the following assumptions:

- Technology mix is 80% solar PV and 20% micro HPP
- Micro HPP capacity usage factor is 50% in summer, 30% in winter (40% annual)

**Figure 4. Information retrieved from the PVGIS model**
- Solar PV capacity usage factor is 20% in summer (reaching 100% at noon), 10% in winter (15% annual)
- Micro HPP daily curve is assumed to be constant, while solar PV daily curve corresponds to available irradiation

![Figure 5. Microgeneration daily capacity usage factor for 21 June](image-url)
Figure 6. Microgeneration daily capacity usage factor for 21 December

Total system demand decrease factor due to the customer-owned generation in %’s for the typical winter and summer days are retrieved by multiplying micro generators’ daily capacity usage maximum values with the demand coverage factor (70% - assumption 4).

By applying the 4th assumption to the above figures and multiplying to the 5th table values, daily demand relieve effect in MW can be calculated in case of development of this scenario. Demand relieve effect on figure 3.3.5 is shown for the illustration purposes for typical days in summer (21th of June) and in winter (21th of December) for the year 2030. The same load shape is applied to all summer and winter days.
4. FINDINGS

This report is designed to illustrate results that were expected from the project i.e. monthly energy sales and peak demand. Therefore, it includes graphs and data on annual demand and peaks sales for the baseline and energy efficiency scenarios. The impact of customer-owned generation on total demand is negligible and it is provided only for the given peak day resolution such as August 2030. Additionally, comparison of all scenarios in terms of final annual energy demand is presented in the last subchapter.

4.1 BASELINE SCENARIO

The figure below presents annual electricity demand by sub-sectors. The modeling results suggest that the share of commercial and industrial sectors in total electricity demand will increase.

![Figure 7. Projected electricity demand by sectors, baseline scenario, TWh, 2015-2030](image)

Because of the increased share of industrial and commercial electricity consumption by 2030, it is expected that peak hour will be shifted from evening to daytime. Figure 8 illustrates forecasted electricity peak load demand in August 2030.
The peak day in December 2030 has a slightly different shape compared to the peak August day. However, results suggest that the December and August Peak load levels will be almost the same by 2030.
Even though the growth rate of the summer peak demand is much higher than the winter peak, the model predicts that the peaking month will remain as December for Georgia. However, Georgia will become a double peak country. Tables 18a and 18b provide monthly peak loads and monthly sales forecasts for Georgia.

Table 18a. Forecasted total system peak load by month, 2015-2030, MW

<table>
<thead>
<tr>
<th>Years</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>96799</td>
<td>935660</td>
<td>915138</td>
<td>89732</td>
<td>84569</td>
<td>805987</td>
<td>879679</td>
<td>888353</td>
<td>803672</td>
<td>794235</td>
<td>894964</td>
<td>986700</td>
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<tr>
<td>2016</td>
<td>1055484</td>
<td>1022353</td>
<td>1002933</td>
<td>985943</td>
<td>932874</td>
<td>892092</td>
<td>971311</td>
<td>980604</td>
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<td>1042632</td>
<td>1026864</td>
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<td>933050</td>
<td>1018026</td>
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<td>985582</td>
<td>969337</td>
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<td>1174279</td>
</tr>
<tr>
<td>2018</td>
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<td>1176385</td>
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<td>1103929</td>
<td>1066982</td>
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<td>1069862</td>
<td>1047973</td>
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<td>1153622</td>
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<td>1096917</td>
<td>1073487</td>
<td>1178112</td>
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Table 18b. Forecasted monthly energy sales, 2015-2030, MWh

4.2 ENERGY EFFICIENCY SCENARIO

If the annual targets provided in the draft National Energy Efficiency Action Plan will be achieved, Georgia can decrease its electricity consumption significantly for the year of 2030 as compared to the baseline scenario. Figure 10 illustrates difference between baseline and energy efficiency scenarios, thus showing potential of electricity savings. Up to 2.3 TWh (12.17%) can be saved for the year of 2030. Additionally, the modeling results suggest that significant reductions can be achieved through energy efficiency policies during the peak days. However due to the limitations of data on specific energy efficiency programs we conclude that resulted estimated reduction potential is optimistic.
Figure 10. Difference between energy efficiency and the baseline scenario for annual electricity demand, TWh, 2030

Figure 11 a. Difference between energy efficiency and the baseline scenario for December Peak loads, TWh, 2030
Figure 11b. Difference between energy efficiency and the baseline scenario for August Peak loads, TWh, 2030

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4.3 IMPACT OF CUSTOMER-OWNED GENERATION (NET-METERING POLICY) ON DEMAND

The scenario described in section 2.2 provides that annual generation of micro-generators will reach 178,291,593 Kwh by 2030. The results are provided in Table 20.

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**Table 19.b.** Forecasted monthly energy sales, 2015-2030, MWh

Applying fourth assumption (Demand coverage factor - 70% of generated electricity by micro power plants covers self-consumption (decreases demand) and 30% is injected into the grid) to the table 20 results, annual energy consumption decrease effect resulting from micro-generators is obtained (see table 21).

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**Table 20.** Annual generated electricity by micro-generators
Finally, demand decrease effect is shown in Figures 12 and 13.

**Table 21. Annual energy consumption decrease effect**

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**Figure 12. Microgeneration total demand capacity decrease factor in % for typical winter and summer days**

**Figure 13. Demand decrease effect in MW**
Of course, the peak demand reduction effect is not significant when comparing to the total system load (figure 23). However microgeneration provides local solutions to distribution grids and also their peak generation coincides to the system peak demand.

Figure 14. The impact of customer-owned generation on total demand, August 2030, MW

4.4 LOW AND HIGH GDP GROWTH SCENARIOS

The purpose of developing high and low GDP growth scenarios was to observe sensitivity of electricity demand to changes in economic growth. According to the modeling approach and assumptions, GDP growth directly effects commercial and agricultural electricity demand in Georgia. As for industrial sector, GDP growth also increases electricity demand but with slightly less rate due assumed technological improvements (increased efficiency reduces energy intensity per value added GDP). The Figure 15 provides comparison of annual electricity demand projections under all scenarios. Based on modeling results, lower GDP growth (10% lower growth rate compared to baseline scenario) reduces electricity demand by 0.7 TWh compared to baseline electricity demand, for the year of 2030. On the other hand, higher GDP growth (10% higher growth rate compared to baseline scenario) increases demand by 0.8 TWh for the year of 2030. Compared to BAU scenario, energy efficiency policies can reduce electricity demand by 2.3 TWh in 2030. The impact of customer-owned generation on electricity demand reduction compared to BAU scenario is 0.1 TWh for the year of 2030.
Figure 15. Comparison of all scenarios, projected annual electricity demand
5. RECOMMENDATIONS

Based on stakeholder consultation meeting and surveys on the existing demand forecasting models in Georgia it was revealed that the TSO and DSOs are not conducting comprehensive demand forecasting. Therefore, improving electricity demand forecasting capacities of the stakeholders and implementation of comprehensive demand forecasting tools is necessary for proper planning of Georgian electricity sector development.

Presented LEAP-Georgia electricity demand forecasting model is a tool that enables to forecast monthly energy sales and total system peak loads using bottom-up method. Even though there is practically no data on hourly demand by end-uses, our approach was to construct the model identifying all important customer groups that influence peak demand for seasonal, daily and hourly horizon. As peak load forecast is largely determined by hourly load shapes of various electricity end-uses it is important to have good estimation of real system disaggregated load. Currently we have used demand proxies of various end-uses based on scientific literature and publicly available sources. Further work has to be accomplished to reduce the number of assumptions and demand proxies to increase accuracy of depiction of real picture and correspondingly improve the forecast.

We identify two different ways to obtain disaggregated hourly load data:

1. Demand profiles for small customers:
   - Data loggers for typical household appliances
   - Data loggers for small and medium business

2. Demand profiles of large customers:
   - Definition of threshold for large customer
   - Impose obligation for hourly metering

Firstly, representative sample of typical households and small and medium businesses have to be identified for installation of data loggers. The output of data loggers shall present different load shapes for each appliance by daily and monthly resolutions. Secondly, currently only part of large customers are metered hourly and they are not grouped according to their activity type (i.e. industrial, agricultural etc). However, it is necessary that all large customers (there has to be established threshold for defining “large customer”) are metered hourly and DSOs and TSO shall be obliged to keep hourly load data separately by customer groups and provide it to the entity in charge of demand forecasting.

As the LEAP Georgia electricity forecasting model uses economic indicators as exogenous variables to predict power demand growth, it is important to forecast sectorial economic growth in Georgia. This enables the model to capture sectoral shifts in the economy and their effect on long-term electricity demand growth.
APPENDIX A:

Based on the existing data assessment, a list of available data for electricity demand forecast was created taking into account following data characteristics:

- **Energy source**: indicates types of energy sources that use space heating, cooking, water heating and other activities in the household and commercial sector;
- **Statistics (data description)**: provides information on data;
- **Source**: indicates source of where data is collected;
- **Unit of measurement**: indicates unit of measurement of the data where applicable;
- **Regional break-down level**: indicates data availability on a national, regional or urban/rural level; “NAT” implies that data is available on a national level; “REG” implies that data is available on a regional level and “U/R” implies that data is available on a urban/rural level;
- **Sectoral break-down level**: indicates data availability on a sectoral level where “No BD” implies that there is no sectoral break-down of the data, “RES/COM” implies that data is available on a residential and commercial \(^6\) level and data on commercial sector is aggregated and is not broken-down. “RES/COM w BD” implies that data is available on a residential and commercial level and data on commercial sector is also broken-down;
- **Frequency**: indicates data collection and availability frequency such as yearly, quarterly, monthly, weekly, daily and hourly;
- **Time series**: indicates in which years data is available;
- **Accessibility**: indicates which users can access the statistics. “High” implies that data can be accessed via a publicly available electronic database managed by the national statistical office; “Medium” implies that data can be accessed via a publicly available electronic database managed by an organization other than the statistical office and “Low” indicates that data can be accessed via some other means;
- **Coverage**: indicates the completeness of the time series. “Complete” implies that there are no gaps in the time series of the data; “Some gaps” implies that there is less than half of data points missing in the time series and “Significant gaps” implies that more than half of data points missing in the time series;
- **Accuracy**: indicates whether readily accessible information regarding the degree to which the information correctly describes the phenomena it was designed to measure is available to users.

---

\(^6\) Commercial sector means non-household consumption
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<td>4</td>
<td>N/A</td>
<td>Types of water heating appliances used</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td>Complete</td>
<td>Yes</td>
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<td>5</td>
<td>electricity, natural gas, wood, LPG</td>
<td>Source of energy used for water heating appliances (by types)</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td>Complete</td>
<td>Yes</td>
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<td>6</td>
<td>N/A</td>
<td>Types of cooking appliances used</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td>Complete</td>
<td>Yes</td>
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<td>7</td>
<td>electricity, natural gas, wood, LPG</td>
<td>Source of energy used for cooking appliances (by types)</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td>Complete</td>
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<td>8</td>
<td>N/A</td>
<td>Use of air conditioning system</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td>Complete</td>
<td>Yes</td>
<td>Dummy variable (yes/no)</td>
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<td>N/A</td>
<td>Air conditioned area of dwelling</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>Sq.meter REG No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td>Complete</td>
<td>Yes</td>
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<td>N/A</td>
<td>Share of air conditioned area of dwelling</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>% REG No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td>Complete</td>
<td>Yes</td>
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<td>N/A</td>
<td>Quantity of electric appliances owned by household</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>Quantity</td>
<td>REG</td>
<td>No BD</td>
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<td>Quantity of different type of light bulb</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>Quantity</td>
<td>REG</td>
<td>No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
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<td>Solar panels in use</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG</td>
<td>No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
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<td>N/A</td>
<td>Area of Solar panels surface</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>Sq.meter</td>
<td>REG</td>
<td>No BD</td>
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<td>Solar collectors in use</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG</td>
<td>No BD</td>
<td>Yearly</td>
<td>2016</td>
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<td>Area of Solar collectors surface</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
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<td>Quantity of different type of vehicles owned by household</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>Quantity</td>
<td>REG</td>
<td>No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td>Complete</td>
<td>Yes</td>
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<td>18</td>
<td>wood, coal, LPG</td>
<td>Quantity of energy acquainted (purchased or in-kind) by household and used for space heating, water heating or cooking in period 01.05.2016 - 01.05.2017 (by sources of energy)</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>kg/liter/m^3</td>
<td>REG</td>
<td>No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
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<td>19</td>
<td>N/A</td>
<td>Price of energy purchased by household and used for space heating, water heating or cooking in period 01.05.2016 - 01.05.2017 (by sources of energy)</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>GEL</td>
<td>REG</td>
<td>No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td>Complete</td>
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<td>electricity, natural gas, wood, coal, LPG</td>
<td>Total consumption of different energy sources (including electricity) for space heating, water heating, cooking and other activity, if any</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG</td>
<td>No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
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<td>Total consumption for all activities</td>
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<td>Use of different energy sources (including electricity) for space heating,</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG</td>
<td>No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
<td></td>
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<td>water heating, cooking and other activity, if any</td>
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<td>22</td>
<td>Use of different energy source by households in commercial activities</td>
<td>GeoStat (Energy Consumption in Households. Survey)</td>
<td>REG</td>
<td>No BD</td>
<td>Yearly</td>
<td>2016</td>
<td>High</td>
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<td>23</td>
<td>Final energy consumption by energy sources</td>
<td>GeoStat (Energy Balance of Georgia)</td>
<td>GWH, TJ</td>
<td>NAT</td>
<td>RES/COM w BD</td>
<td>Yearly 2013-2015</td>
<td>High</td>
<td>Some gaps</td>
<td>yes</td>
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<td>24</td>
<td>Period of occupation during a year (summer/winter/year/weekend/holidays)</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
<td>Low</td>
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<tr>
<td>25</td>
<td>Ownership of Dwellings (own, rent, mortgaged, etc.)</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
<td>Low</td>
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<td>26</td>
<td>Number of people living in the house</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>Quantity</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
<td>Low</td>
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<td>27</td>
<td>Number of people staying at home whole day</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>Quantity</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
<td>Low</td>
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<td>28</td>
<td>Stay-at-home adults</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>Quantity</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
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<td>Yes</td>
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<td>29</td>
<td>Type of living residence (house, apartment, etc.)</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
<td>Low</td>
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<td>Apartment construction time</td>
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<td>Years</td>
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<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
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<td>Approximate size of living space of dwelling</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>Sq.meter</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
<td>Low</td>
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<td>31</td>
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<td>Approximate size of non-living space of dwelling</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>Sq.meter</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
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<td>32</td>
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<td>Access to electricity Grid Network (yes/no)</td>
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<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
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<td>33</td>
<td>N/A</td>
<td>Average monthly electricity bill (summer/winter)</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>GEL</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
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<td>Average monthly natural gas bill (summer/winter)</td>
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<td>GEL</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
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<td>N/A</td>
<td>Usage of LPG by months</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>kg</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
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<td>Complete</td>
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<td>36</td>
<td>N/A</td>
<td>Average monthly usage of LPG</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>kg</td>
<td>U/R</td>
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<td>Average price of 1 kg LPG</td>
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<td>U/R</td>
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<td>38</td>
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<td>Usage of coal by months</td>
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<td>kg</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
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<td>Average monthly usage of coal</td>
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<td>kg</td>
<td>U/R</td>
<td>No BD</td>
<td>Yearly</td>
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<td>Average price of 1 kg coal</td>
<td>AYPEG (Household Energy End-use Survey)</td>
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<td>U/R</td>
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<td>42</td>
<td>wood</td>
<td>Usage of wood for heating/cooking/water heating by months</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>m3</td>
<td>U/R</td>
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<td>Average wood consumption during last 12 months</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>m3</td>
<td>U/R</td>
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<td>Expenses on wood consumption</td>
<td>AYPEG (Household Energy End-use Survey)</td>
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<td>N/A</td>
<td>Space heating appliances that was used during past 12 months</td>
<td>AYPEG (Household Energy End-use Survey)</td>
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<td>No BD</td>
<td>Yearly</td>
<td>2014</td>
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<td>electricity</td>
<td>Share of electricity used for space heating</td>
<td>AYPEG (Household Energy End-use Survey)</td>
<td>%</td>
<td>U/R</td>
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<td>Yearly</td>
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<td>Share of natural gas used for space heating</td>
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<td>Quantity of different types of light bulbs</td>
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<td>N/A</td>
<td>Quarterly</td>
<td>2003-2017 (1 quarter)</td>
<td>High</td>
<td>Complete</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>98</td>
<td>Consumer Price Index (Annual/Monthly)</td>
<td>Geostat</td>
<td>Index</td>
<td>REG</td>
<td>Monthly</td>
<td>2004-2017 (June)</td>
<td>High</td>
<td>Complete</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>n/a</td>
<td>Population total</td>
<td>World Bank Database</td>
<td>Persons</td>
<td>NAT</td>
<td>No BD</td>
<td>Yearly</td>
<td>1990-2016</td>
<td>High</td>
<td>Some gaps</td>
<td>yes</td>
<td>No gaps after 2007</td>
</tr>
<tr>
<td>----</td>
<td>-----</td>
<td>------------------</td>
<td>---------------------</td>
<td>--------</td>
<td>-----</td>
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<td>----------</td>
<td>-----</td>
<td>------------------</td>
</tr>
<tr>
<td>100</td>
<td>n/a</td>
<td>Population growth rate</td>
<td>World Bank Database</td>
<td>%</td>
<td>NAT</td>
<td>No BD</td>
<td>Yearly</td>
<td>1990-2016</td>
<td>High</td>
<td>Some gaps</td>
<td>yes</td>
<td>No gaps after 2007</td>
</tr>
<tr>
<td>101</td>
<td>n/a</td>
<td>Total Household final consumption/expenditure (Current Price)</td>
<td>World Bank Database</td>
<td>GEL/USD</td>
<td>NAT</td>
<td>No BD</td>
<td>Yearly</td>
<td>1994-2016</td>
<td>High</td>
<td>Complete</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>n/a</td>
<td>Household final consumption expenditure, etc. (% of GDP)</td>
<td>World Bank Database</td>
<td>Percent Change</td>
<td>NAT</td>
<td>No BD</td>
<td>Yearly</td>
<td>2012-2016</td>
<td>High</td>
<td>Complete</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>103</td>
<td>n/a</td>
<td>Household final consumption expenditure, etc. (%) of GDP</td>
<td>World Bank Database</td>
<td>%</td>
<td>NAT</td>
<td>No BD</td>
<td>Yearly</td>
<td>1994-2016</td>
<td>High</td>
<td>Complete</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>n/a</td>
<td>Population total</td>
<td>Geostat</td>
<td>Persons</td>
<td>REG</td>
<td>Yearly</td>
<td>2007-2017</td>
<td>High</td>
<td>Complete</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>n/a</td>
<td>Distribution of average monthly expenditure per household</td>
<td>Geostat</td>
<td>GEL</td>
<td>REG</td>
<td>Yearly</td>
<td>2006-2016</td>
<td>High</td>
<td>Complete</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>n/a</td>
<td>Distribution of average monthly expenditure of total population</td>
<td>Geostat</td>
<td>GEL</td>
<td>REG</td>
<td>Yearly</td>
<td>2006-2016</td>
<td>High</td>
<td>Complete</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>n/a</td>
<td>Distribution of average monthly expenditure per capita</td>
<td>Geostat</td>
<td>GEL</td>
<td>REG</td>
<td>Yearly</td>
<td>2006-2016</td>
<td>High</td>
<td>Complete</td>
<td>yes</td>
<td></td>
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<tr>
<td>107</td>
<td>electricity</td>
<td>Electricity consumption</td>
<td>distribution licenses</td>
<td>kWh</td>
<td>REG</td>
<td>RES/COM</td>
<td>Monthly</td>
<td>2014-2016</td>
<td>Med</td>
<td>Some gaps</td>
<td>yes</td>
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<tr>
<td>108</td>
<td>electricity</td>
<td>Peak loads</td>
<td>distribution licenses</td>
<td>MW</td>
<td>REG</td>
<td>No BD</td>
<td>Monthly</td>
<td>2014-2016</td>
<td>Low</td>
<td>Significant gaps</td>
<td>Yes</td>
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<tr>
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<td>electricity</td>
<td>Electricity consumption</td>
<td>TSO (GSE)</td>
<td>kWh</td>
<td>NAT</td>
<td>No BD</td>
<td>Hourly</td>
<td>2014-2016</td>
<td>Low</td>
<td>Some gaps</td>
<td>yes</td>
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<td>No</td>
<td>Description</td>
<td>Source</td>
<td>Unit</td>
<td>Data Availability</td>
<td>Level</td>
<td>Completeness</td>
<td>Notes</td>
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<tr>
<td>110</td>
<td>Electricity consumption of qualified customers</td>
<td>TSO (GSE)</td>
<td>kW</td>
<td>Monthly</td>
<td>2014-2016</td>
<td>Low</td>
<td>Some gaps</td>
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<tr>
<td>111</td>
<td>Company characteristics</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>kWh</td>
<td>Monthly</td>
<td>Dec 2014-Dec 2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
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<td></td>
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<tr>
<td>112</td>
<td>Price of electricity consumed</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>GEL</td>
<td>Monthly</td>
<td>Dec 2014-Dec 2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>113</td>
<td>Appliances used for space heating and their usage level</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>114</td>
<td>Appliances used for water heating and their usage level</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
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<td>115</td>
<td>Appliances used for air conditioning and their usage level</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
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<tr>
<td>116</td>
<td>Use of refrigeration Equipments and their usage level</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
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<tr>
<td>117</td>
<td>Appliances used for cooking and their usage level</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
<td></td>
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<tr>
<td>118</td>
<td>Capacity of different light bulbs and their usage level</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
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<td>#</td>
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<td>Description</td>
<td>Source</td>
<td>Measure</td>
<td>Frequency</td>
<td>Year</td>
<td>Completeness</td>
<td>Accuracy</td>
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<tr>
<td>121</td>
<td>n/a</td>
<td>Number of different electric appliances and their usage level</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
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<tr>
<td>122</td>
<td>electricity</td>
<td>Electricity consumption voltage level</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>KV</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
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<tr>
<td>123</td>
<td>n/a</td>
<td>Serving distribution company</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
<td></td>
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<tr>
<td>124</td>
<td>n/a</td>
<td>Major uses of electricity (Processes)</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>125</td>
<td>n/a</td>
<td>Cost of electricity consumed</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>GEL</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2014-2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>126</td>
<td>electricity</td>
<td>Amount of electricity consumed</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>kwh</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2014-2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>n/a</td>
<td>Characteristics of electric motors (Except of elevators) and their usage level</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>128</td>
<td>n/a</td>
<td>Use of high temperature technologies (only characteristics)</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>129</td>
<td>n/a</td>
<td>Use of low temperature technologies (only characteristics)</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>n/a</td>
<td>Use of elevators and their consumption</td>
<td>WEG (Energy and Water Consumption Survey in Organizations)</td>
<td>NAT</td>
<td>COM BD</td>
<td>Yearly</td>
<td>2015</td>
<td>Low</td>
<td>Complete</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX B:

4.1. Questionnaire filled out by the Ministry of Energy of Georgia

Questionnaire for Existing Electricity/Energy Demand Forecasting models in Georgia

<table>
<thead>
<tr>
<th>1. Name, occupation and contact details of respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. Name and Surname</td>
</tr>
<tr>
<td>1.2. Name of Organization</td>
</tr>
<tr>
<td>1.3. Position</td>
</tr>
<tr>
<td>1.4. Tel</td>
</tr>
<tr>
<td>1.5. E-mail</td>
</tr>
</tbody>
</table>

2. Do you use or have you ever used electricity/energy demand forecasting model(s) for your organization's operations? (Insert "X" where appropriate)

<table>
<thead>
<tr>
<th>2.1. yes</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2. No</td>
<td>Go to the next question</td>
</tr>
<tr>
<td>2.3. No</td>
<td>Stop filling the questionnaire</td>
</tr>
</tbody>
</table>

3. What electricity/energy demand forecasting model/s do you use in your organization? (Please provide name and brief description of the model, modeling method and main purpose of using model)

3.1. Model 1

“MARKAL-Georgia” - The MARKAL (MARKet Allocation) based integrated energy planning model for Georgian energy sector.

Key features of model:
- Encompasses the entire energy system from resource extraction through to end-use demands;
- Employs least-cost optimization;
- Identifies the most cost-effective pattern of resource use and technology deployment over time;
- Provides a framework for the evaluation of mid-to-long-term policies and programs that can impact the evolution of the energy system;
- Quantifies the costs and technology choices, and the associated emissions, that result from imposition of the policies and programs;
- Fosters stakeholder buy-in and consensus building.

The principal demand drivers for the Business-as-Usual scenario (comparison scenario) are the Gross Domestic Product (GDP) and population growth assumptions.

The MARKAL-Georgia model is used for examine the role of energy efficiency and renewable energy in meeting anticipated Energy Community commitments and European Union accession directives.

3.2. Model 2

The Excel based Electricity Balance planning model.

The model is used for develop and analyze various possible scenarios of the development of the country's electrical power industry. Considering the trend of consumption of previous years and the Gross Domestic Product (GDP) growth assumptions, the model determines the electricity consumption forecasts and estimated shortage. To cover the estimated shortage, it determines the advisability of construction of potential power plants (hydro, thermal, renewable) and also their impact on import-export and average weighted electricity price. It is also used for determine the need for additional trans boundary infrastructure.

3.3. Model 3

4. When was the electricity/energy demand forecasting model/s last time updated? (Fill out where appropriate)

4.1. Model 1

In 2016 (The model base year was updated and recalibrated to the 2014 national energy balance).

4.2. Model 2

In 2017

4.3. Model 3

5. What is the forecasting time horizon in the model? (Insert “X” where appropriate)

5.1 Model 1

<table>
<thead>
<tr>
<th>Short-term (up to 1 year)</th>
<th>Medium-term (between 1-5 years)</th>
<th>Long-term (more than 5 years)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

5.2 Model 2

<table>
<thead>
<tr>
<th>Short-term (up to 1 year)</th>
<th>Medium-term (between 1-5 years)</th>
</tr>
</thead>
</table>
### 5.2 Model 2

<table>
<thead>
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<th>Model Type</th>
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</thead>
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<tr>
<td>Short-term (up to 1 year)</td>
<td></td>
</tr>
<tr>
<td>Medium-term (between 1-5 years)</td>
<td></td>
</tr>
<tr>
<td>Long-term (more than 5 years)</td>
<td></td>
</tr>
</tbody>
</table>

6. Is the model user-friendly (easy to operate)? (score 1-5, where 1 indicates the simplest while 5 is the highest level of complexity)

6.1. 4
6.2. 2
6.3. 

7. Please specify level of required qualification to work on the model (score 1-5, where 1 indicates the basic qualification while 5 is the highest level of qualification)

7.1. 5
7.2. 3
7.3. 

8. Please specify main limitations of the model

8.1. The results of the model are given 2-year interval up to 2040
8.2. It is used only for electric power sector.
8.3. 

9. Please specify how data intensive is the model (Score 1-5, where 1 means that model can operate with limited data and 5 indicated that model requires very detailed data).

9.1. 5
9.2. 3
9.3. 

10. What are the main challenges that you faced/face using model? (please specify)

10.1. Model requires too many data and highest level of qualification.
10.2. Sometimes inadequate data
10.3. 

11. Please specify other important issue (if any)

11.1. 
11.2. 
11.3. 

Thanks for your time.

---

4.2. Questionnaire filled out by Energo-Pro Georgia

**Questionnaire for Existing Electricity/Energy Demand Forecasting models in Georgia**

1. Name, occupation and contact details of respondent

1.5. Name and Surname
Irakli Kokhodze

1.6. Name of Organization
JSC “Energo-pro Georgia”

1.7. Position
Head of Reporting and Tariff Policy Division

1.8. Tel
+995 557 35 03 04

1.6 E-mail
Irakli.kokhodze@energo-pro.ge

2. Do you use or have you ever used electricity/energy demand forecasting model(s) for your organization’s operations? (Insert “X” where appropriate)

2.1. yes X
Go to the next question
3. What electricity/energy demand forecasting model/s do you use in your organization? (Please provide name and brief description of the model, modeling method and main purpose of using model)

3.1. Excel - It's simply used soft, it's easy to change/modify, it have a large amount of variables, it is possible to change methods in an easy way – linear, polynomial, logarithmic etc.

4. What is the forecasting time horizon in the model? (Insert "X" where appropriate)

4.1. Short-term (up to 1 year)  
4.1.2 Medium-term (between 1-5 years) X  
4.1.3 Long-term (more than 5 years) 
4.2.1 Short-term (up to 1 year)  
4.2.2 Medium-term (between 1-5 years)  
4.2.3 Long-term (more than 5 years) 
4.3.1 Short-term (up to 1 year)  
4.3.2 Medium-term (between 1-5 years)  
4.3.3 Long-term (more than 5 years)

5. Is the model user-friendly (easy to operate)? (score 1-5, where 1 indicates the simplest while 5 is the highest level of complexity)

5.1. 2  
5.2. 
5.3. 

6. Please specify level of qualification to work on the model (score 1-5, where 1 indicates the basic qualification while 5 is the highest level of qualification)

6.1. 3  
6.2. 
6.3. 

7. Please specify main limitations of the model

7.1. N/A  
7.2.  
7.3. 

8. Please specify how data intensive is the model (Score 1-5, where 1 means that model can operate with limited data and 5 indicated that model requires very detailed data).

8.1. 2 – Reliability of the forecast much more depends upon the extent of specifying  
8.2.  
8.3. 

9. What are the main challenges that you faced/face using model? (please specify)

9.1. The key challenge is selection of the information and forecasting of new consumers  
9.2.  
9.3. 

10. Please specify other important issue (if any)

10.1.  
10.2.  
10.3. 

Thanks for your time.

4.3. Questionnaire filled out by Electricity System Commercial Operator (ESCO)
**Questionnaire for Existing Electricity/Energy Demand Forecasting models in Georgia**

1. **Name, occupation and contact details of respondent**
   - 1.9. Name and Surname: Malkhaz Broladze
   - 1.10. Name of Organization: LTD “Electricity System Commercial Operator” (ESCO)
   - 1.11. Position: Head of Analysis, Monitoring and Forecasting Department
   - 1.12. Tel: +995 591114107
   - 1.7 E-mail: mbroladze@esco.ge

2. **Do you use or have you ever used electricity/energy demand forecasting model(s) for your organization’s operations? (Insert “X” where appropriate)**
   - 2.1. yes
   - 2.2. No X

3. **What electricity/energy demand forecasting model/s do you use in your organization? (Please provide name and brief description of the model, modeling method and main purpose of using model)**
   - 3.1. Excel - It’s simply used soft, it’s easy to change/modify, it have a large amount of variables, It is possible to Change methods in an easy way – linear, polynomial, logarithmic etc.

4. **What is the forecasting time horizon in the model? (Insert “X” where appropriate)**
   - 4.1.1 Short-term (up to 1 year)
   - 4.1.2 Medium-term (between 1-5 years)
   - 4.1.3 Long-term (more than 5 years)
   - 4.2.1 Short-term (up to 1 year)
   - 4.2.2 Medium-term (between 1-5 years)
   - 4.2.3 Long-term (more than 5 years)
   - 4.3.1 Short-term (up to 1 year)
   - 4.3.2 Medium-term (between 1-5 years)
   - 4.3.3 Long-term (more than 5 years)

5. **Is the model user-friendly (easy to operate)? (score 1-5, where 1 indicates the simplest while 5 is the highest level of complexity)**
   - 5.1.
   - 5.2.
   - 5.3.

6. **Please specify level of qualification to work on the model (score 1-5, where 1 indicates the basic qualification while 5 is the highest level of qualification)**
   - 6.1.
   - 6.2.
   - 6.3.

7. **Please specify main limitations of the model**
   - 7.1.
   - 7.2.
   - 7.3.

8. **Please specify how data intensive is the model (Score 1-5, where 1 means that model can operate with limited data and 5 indicated that model requires very detailed data).**
   - 8.1.
   - 8.2.
   - 8.3.

9. **What are the main challenges that you faced/face using model? (please specify)**
9.1. The key challenge is selection of the information and forecasting of new consumers
9.2.
9.3.

10. Please specify other important issue (if any)
10.1.
10.2.
10.3.

Thanks for your time.

4.4. Questionnaire filled out by Georgian State Electrosystem

**Questionnaire for Existing Electricity/Energy Demand Forecasting models in Georgia**

1. Name, occupation and contact details of respondent

<table>
<thead>
<tr>
<th>1.1. Name and Surname</th>
<th>Mikheil Tavberidze</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2. Name of Organization</td>
<td>Georgian State Electrosystem</td>
</tr>
<tr>
<td>1.3. Position</td>
<td>Head of Operational Planning and contracts registration Service</td>
</tr>
<tr>
<td>1.4. Tel</td>
<td>+995 577 240250</td>
</tr>
<tr>
<td>1.8 E-mail</td>
<td><a href="mailto:Mikheil.tavberidze@gse.com.ge">Mikheil.tavberidze@gse.com.ge</a></td>
</tr>
</tbody>
</table>

2. Do you use or have you ever used electricity/energy demand forecasting model(s) for your organization's operations? (Insert “X” where appropriate)

<table>
<thead>
<tr>
<th>2.1. yes</th>
<th>Go to the next question</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2. No</td>
<td>X Stop filling the questionnaire</td>
</tr>
</tbody>
</table>

3. What electricity/energy demand forecasting model/s do you use in your organization? (Please provide name and brief description of the model, modeling method and main purpose of using model)

| 3.1. |
| 3.2. |
| 3.3. |

4. What is the forecasting time horizon in the model? (Insert “X” where appropriate)

| 4.1.1 Short-term (up to 1 year) |
| 4.1.2 Medium-term (between 1-5 years) |
| 4.1.3 Long-term (more than 5 years) |
| 4.2.1 Short-term (up to 1 year) |
| 4.2.2 Medium-term (between 1-5 years) |
| 4.2.3 Long-term (more than 5 years) |
| 4.3.1 Short-term (up to 1 year) |
| 4.3.2 Medium-term (between 1-5 years) |
| 4.3.3 Long-term (more than 5 years) |

5. Is the model user-friendly (easy to operate)? (score 1-5, where 1 indicates the simplest while 5 is the highest level of complexity)

| 5.1. |
| 5.2. |
| 5.3. |

6. Please specify level of qualification to work on the model (score 1-5, where 1 indicates the basic qualification while 5 is the highest level of qualification)

| 6.1. |
| 6.2. |
| 6.3. |
6.1.
6.2.
6.3.

<table>
<thead>
<tr>
<th>7. Please specify main limitations of the model</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1.</td>
</tr>
<tr>
<td>7.2.</td>
</tr>
<tr>
<td>7.3.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8. Please specify how data intensive is the model (Score 1-5, where 1 means that model can operate with limited data and 5 indicated that model requires very detailed data).</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1.</td>
</tr>
<tr>
<td>8.2.</td>
</tr>
<tr>
<td>8.3.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9. What are the main challenges that you faced/face using model? (please specify)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1.</td>
</tr>
<tr>
<td>9.2.</td>
</tr>
<tr>
<td>9.3.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10. Please specify other important issue (if any)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1.</td>
</tr>
<tr>
<td>10.2.</td>
</tr>
<tr>
<td>10.3.</td>
</tr>
</tbody>
</table>

Thanks for your time.

4.5. Questionnaire filled out by Remissia

**Questionnaire for Existing Electricity/Energy Demand Forecasting models in Georgia**

<table>
<thead>
<tr>
<th>1. Name, occupation and contact details of respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.13. Name and Surname</td>
</tr>
<tr>
<td>1.14. Name of Organization</td>
</tr>
<tr>
<td>1.15. Position</td>
</tr>
<tr>
<td>1.16. Tel</td>
</tr>
<tr>
<td>1.19. E-mail</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Do you use or have you ever used electricity/energy demand forecasting model(s) for your organization’s operations? (Insert “X” where appropriate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1. yes</td>
</tr>
<tr>
<td>2.2. No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. What electricity/energy demand forecasting model/s do you use in your organization? (Please provide name and brief description of the model, modeling method and main purpose of using model)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1. Model 1</td>
</tr>
<tr>
<td>3.2. Model 2</td>
</tr>
<tr>
<td>3.3. Model 3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. When was the electricity/energy demand forecasting model/s last time updated? (Fill out where appropriate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1. Model 1</td>
</tr>
<tr>
<td>4.2. Model 2</td>
</tr>
<tr>
<td>4.3. Model 3</td>
</tr>
</tbody>
</table>
5. What is the forecasting time horizon in the model? (Insert "X" where appropriate)

<table>
<thead>
<tr>
<th>5.1 Model 1</th>
<th>Short-term (up to 1 year)</th>
<th>Medium-term (between 1-5 years)</th>
<th>Long-term (more than 5 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2 Model 2</td>
<td>Short-term (up to 1 year)</td>
<td>Medium-term (between 1-5 years)</td>
<td>X</td>
</tr>
<tr>
<td>5.2 Model 2</td>
<td>Short-term (up to 1 year)</td>
<td>Medium-term (between 1-5 years)</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Long-term (more than 5 years)</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

5.2 Model 2

6. Is the model user-friendly (easy to operate)? (score 1-5, where 1 indicates the simplest while 5 is the highest level of complexity)

| 6.1. | 5 |
| 6.2. | 2 |
| 6.3. | 5 |

7. Please specify level of required qualification to work on the model (score 1-5, where 1 indicates the basic qualification while 5 is the highest level of qualification)

| 7.1. | 5 |
| 7.2. | 4 |
| 7.3. | 5 |

8. Please specify main limitations of the model

| 8.1. | capacity of specialist working on it, some specific features not available |
| 8.2. | capacity of specialist working on it, demand side optimization not available |
| 8.3. | capacity of specialist working on it, |

9. Please specify how data intensive is the model (Score 1-5, where 1 means that model can operate with limited data and 5 indicated that model requires very detailed data).

| 9.1. | for current MARKAL-Georgia it is about 4, while MARKAL model can be constructed with whatever data is available data requirements depend on the purpose of using the model rather than model itself. |
| 9.2. | for current LEAP-Tbilisi this is about 3, while LEAP model can be constructed with whatever data is available, data requirements depend on the purpose of using the model rather than model itself. |
| 9.3. | TIMES model can be constructed with whatever data is available, data requirements depend on the purpose of using the model rather than model itself. |

10. What are the main challenges that you faced/face using model? (please specify)

| 10.1. | explaining to users how to use it (conceptually, not technically) |
| 10.2. | same as above |
| 10.3. | same as above |

11. Please specify other important issue (if any)

| 11.1. | Too much time is spent in comparing different models. It is possible to create good and bad models with whatever model framework |
| 11.2. | |
| 11.3. | |

4.6. Questionnaire filled out by JSC TELASI

Questionnaire for Existing Electricity/Energy Demand Forecasting models in Georgia
1. Name, occupation and contact details of respondent

<table>
<thead>
<tr>
<th>1.1 Name and Surname</th>
<th>Levan Chubinidze</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 Name of Organization</td>
<td>Telasi</td>
</tr>
<tr>
<td>1.3 Position</td>
<td>Head of Business Centers’ Coordination and Planning Service</td>
</tr>
<tr>
<td>1.4 Tel</td>
<td>595990733</td>
</tr>
<tr>
<td>1.5 E-mail</td>
<td><a href="mailto:levan.chubinidze@telasi.ge">levan.chubinidze@telasi.ge</a></td>
</tr>
</tbody>
</table>

2. Do you use or have you ever used electricity/energy demand forecasting model(s) for your organization’s operations? (Insert “X” where appropriate)

| 2.1. yes | X | Go to the next question |
| 2.2. No | | Stop filling the questionnaire |

3. What electricity/energy demand forecasting model/s do you use in your organization? (Please provide name and brief description of the model, modeling method and main purpose of using model)

| 3.1 Model 1 | Excel based model which considers two main factors: increase of number of customers and new connections. Model uses simple statistical method for forecasting however accuracy of the model is limited. |
| 3.2 Model 2 | |
| 3.3 Model 3 | |

4. When was the electricity/energy demand forecasting model/s last time updated? (Fill out where appropriate)

| 4.1 Model 1 | N/A |
| 4.2 Model 2 | |
| 4.3 Model 3 | |

5. What is the forecasting time horizon in the model? (Insert “X” where appropriate)

| 5.1 Model 1 | Short-term (up to 1 year) | Medium-term (between 1-5 years) | X |
| 5.2 Model 2 | Short-term (up to 1 year) | Medium-term (between 1-5 years) |
| 5.2 Model 2 | Short-term (up to 1 year) | Medium-term (between 1-5 years) | Long-term (more than 5 years) |

6. Is the model user-friendly (easy to operate)? (score 1-5, where 1 indicates the simplest while 5 is the highest level of complexity)

| 6.1 | 4 |
| 6.2 | |
| 6.3 | |

7. Please specify level of required qualification to work on the model (score 1-5, where 1 indicates the basic qualification while 5 is the highest level of qualification)

| 7.1 | 3 |
| 7.2 | |
| 7.3 | |

8. Please specify main limitations of the model

| 8.1 | There is no limitation of the model. However for 5 year distribution network development we might need more sophisticated modeling tool. |
| 8.2 | |
| 8.3 | |

9. Please specify how data intensive is the model (Score 1-5, where 1 means that model can operate with limited data and 5 indicated that model requires very detailed data).

| 9.1 | 2 |
9.2. 
9.3. 

10. What are the main challenges that you faced/face using model? (please specify) 
10.1. Accuracy of forecasted results 
10.2. 
10.3. 

11. Please specify other important issue (if any) 
11.1. 
11.2. 
11.3. 

Thanks for your time.

4.7. Questionnaire filled out by World Experience for Georgia (WEG) 

Questionnaire for Existing Electricity/Energy Demand Forecasting models in Georgia

<table>
<thead>
<tr>
<th>1. Name, occupation and contact details of respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. Name and Surname</td>
</tr>
<tr>
<td>1.2. Name of Organization</td>
</tr>
<tr>
<td>1.3. Position</td>
</tr>
<tr>
<td>1.4. Tel</td>
</tr>
<tr>
<td>1.5 E-mail</td>
</tr>
</tbody>
</table>

2. Do you use or have you ever used electricity/energy demand forecasting model(s) for your organization’s operations? (Insert “X” where appropriate) 
2.1. yes X Go to the next question 
2.2. No Stop filling the questionnaire

3. What electricity/energy demand forecasting model/s do you use in your organization? (Please provide name and brief description of the model, modeling method and main purpose of using model) 

| 3.1. Model 1 | Basic electricity demand projection model (developed by WEG). The model was produced for internal use and analysis. The output of the model was used for basic electricity production planning model (also developed by WEG) as an input. The model suggests electricity demand projections by economic sectors: residential, agriculture, industry, commercial |
| 3.2. Model 2 | 
| 3.3. Model 3 | 

4. When was the electricity/energy demand forecasting model/s last time updated? (Fill out where appropriate) 

| 4.1. Model 1 | 2014 |
| 4.2. Model 2 | |
| 4.3. Model 3 | |

5. What is the forecasting time horizon in the model? (Insert “X” where appropriate) 

<table>
<thead>
<tr>
<th>5.1 Model 1</th>
<th>Short-term (up to 1 year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-term (between 1-5 years)</td>
<td></td>
</tr>
<tr>
<td>Long-term (more than 5 years)</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5.2 Model 2</th>
<th>Short-term (up to 1 year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-term (between 1-5 years)</td>
<td></td>
</tr>
<tr>
<td>Long-term (more than 5 years)</td>
<td></td>
</tr>
</tbody>
</table>

<p>| 5.2 Model 2 | Short-term (up to 1 year) |</p>
<table>
<thead>
<tr>
<th>Medium-term (between 1-5 years)</th>
<th>Long-term (more than 5 years)</th>
</tr>
</thead>
</table>

6. Is the model user-friendly (easy to operate)? (score 1-5, where 1 indicates the simplest while 5 is the highest level of complexity)
6.1.  2 The model is user friendly
6.2.
6.3.

7. Please specify level of required qualification to work on the model (score 1-5, where 1 indicates the basic qualification while 5 is the highest level of qualification)
7.1.  1-2 Model operator should have good knowledge of Microsoft Excel and understand basic principles of power sector
7.2.
7.3.

8. Please specify main limitations of the model
8.1. Lack of data disaggregation by specific sub sectors, however, the model can be improved once statistics on subsector level is available
8.2.
8.3.

9. Please specify how data intensive is the model (Score 1-5, where 1 means that model can operate with limited data and 5 indicated that model requires very detailed data).
9.1.  2
9.2.
9.3.

10. What are the main challenges that you faced/face using model? (please specify)
10.1. There were no significant challenges
10.2.
10.3.

11. Please specify other important issue (if any)
11.1.
11.2.
11.3.

Thanks for your time.
APPENDIX C:

1. END-USE MODELS

1.1. Model for Analysis of Electricity Demand (MAED)

MAED belongs to the family of electricity forecasting models which use a bottom-up (also known as end-use modeling) approach to predict future electricity demand. Energy system models such as MARKAL, MAED and LEAP belong to the same group of energy forecasting models. The bottom-up approach uses the factors influencing the energy demand of end-use consumers to project future patterns of electricity consumption. The existing studies showed that models based on the bottom-up approach show a high level of accuracy to produce mid-term and long-term forecasts of the electricity demand.

One of the advantages of the model is that it does not require large historical data to calculate prospect patterns of energy consumption. That is why when the past records of statistical databases contain large amount of missing data end-use modeling is preferred to be used for forecasting electricity demand. Despite this advantage the forecasting accuracy for MAED and other bottom-up approach models largely depend on the quality and quantity of the information collected from the end-use consumers through the surveys, energy audits and other technical studies.

MAED allows calculating future annual electricity consumption using a base year data considering different technological, socio-economic and demographic development scenarios. In order to produce a forecast it is enough to construct data for one base year, but if existing databases contain the records for previous years, it is preferable to be included in the model.

MAED links future energy demands to the production and consumption of goods and services from different sectors of economy and has capacity to capture the changes of energy consumption pattern caused by adoption of new technology and development of infrastructure, changes in consumption structure due to increased living standards, influence of population growth etc. The user defines the parameters of socio-economic, technological and demographic development scenarios exogenously.

MAED gives following results by processing the base year data:

- Useful/Final energy consumption by sector/fuel type;
- Electricity demand;
- Hourly electricity consumption;
- Load duration curve.

MAED has the capacity to capture the impact of policy changes through the scenario analyses and provide corresponding calculations of future energy demand patterns for various fuel types and economic sectors. In addition, the model allows breaking down energy demand for rural and urban areas, disaggregating predicted annual electricity demand into hourly electricity consumption and producing load curves. It must be mentioned that one of the limitation of the MAED is that model does not capture the impact of price change on energy consumption. Model gives great flexibility to user allowing constructing structure of the model based on the available data and choosing the desirable level of disaggregation of predicted energy demand.

Model gives end-use energy consumption forecast for four basic sectors:

- Industry (Agriculture, Construction, Manufacturing, Mining);
- Transportation;
- Service;
- Household.

Model allows breaking down the abovementioned sectors up to 10 subsectors. The final results are given in terms of useful energy form, allowing considering substitution between alternative energy forms and the impact of technological developments such as adoption of energy efficient technologies, market penetration of alternative energy sources, etc.
The forecasting procedure of the model includes the following steps:

- At the initial stage the final energy consumption is broken down into end-use consumption for different sectors and subsectors by various fuel type;
- Next step includes the determination of the economic, technological and social factors which influence the end-use energy consumption in different sectors;
- Construction of final energy consumption patterns for the base year using statistical data. If there exist the data for previous years it is preferable to be included in the model;
- Definition of the parameters for different socio-economic and technological development scenarios influencing future demand of energy;
- At the final stage model provides appropriate energy consumption forecasts for each development scenarios.

The second module of the model “MAED-2” breaks down predicted annual electricity consumption into hourly electricity demand considering the yearly growth rate of electricity consumption, seasonal patterns, type and the period of the day such as workday, holiday, morning, evening period etc. In order to decompose annual predicted consumption into hourly consumption of electricity, the “MAED-2” requires the data about the hourly electricity load for each day of the base year and information about distribution and transmission losses. “MAED-2” also considers seasonal patterns and the impact of the type of the day and the period of the day corresponding seasonal, daily and hourly load variation coefficients should be constructed.

MAED produces long-term forecast of electricity demand, the prediction period includes 20-30 years. Capturing the impact of economic and technological development, capacity to break down final energy consumption into sectoral and sub-sectoral level by different fuel types gives high flexibility to user set model structure and to define desired level of decomposition of predicted data. Although it must be noted that to receive accurate results model requires large and detailed input data from end-use consumers, demographic and economic variables. This variables might be GDP growth rate, GDP structure, share of each sector in total GDP, population growth rate, share of urban and rural population, energy intensity for different industries, mix of fuel types for each industry, the number of dwellings, type and space of apartments, the demand for heating and cooling measured by number of heating degree days and cooling degree days in the year, employment rates etc. This process is complicated and time-consuming and requires clear understanding of interdependency of various factors determining energy demand.

As a conclusion MAED model gives flexible and convenient package to produce annual and hourly electricity consumption forecast for long time horizon. One advantage of this model is that it allows decomposing consumption patterns for commercial, industrial and residential sectors and provides efficient tools to explain the effect of technical, economic and demographic factors on the pattern of future electricity demand. MAED using end-use modeling approach is efficient tool to run simulation to forecast electricity demand under different scenarios and explain the impact of energy policy changes on electricity consumption. Model has capacity to adapt and measure the impact of recent technological and economic changes on energy consumption, although the model does not capture the impact of price changes. The key limitation of this model is that it requires the availability of high quality and detailed survey data from end-use consumers, which is core factor to provide accurate prediction.

1.2. Long-Range Energy Alternatives Planning

LEAP is a flexible modelling environment that allows building specific applications suited to particular problems at various geographical levels (cities, state, country, region or global). The LEAP is successfully used to develop energy policies and strategies in advanced and developing countries. Hundreds of organizations use LEAP worldwide in more than 150 countries around the world, especially in the developing world. LEAP is an integrated modeling tool based on scenarios that can be used to determine the optimal level of long-term energy, energy consumption, and production and energy resources, both in the state level and in the economic sectors.

The main structure of the LEAP consists of the following modules:
• **Demand module:** It is divided into the following levels: households, industry, transport, agriculture and commercial sectors, each of which can be divided into sub-sectors, end-use and devices according to the complexity of research. Demographic, economic and energy information for the demand module is based on the development of scenarios and the segregated and aggregated levels of energy consumption in the forecast period by two factors: Activity level and energy intensity.

• **Transforming module:** This Module allows to create country's energy balance for the base year, which implies a complete picture of how and how many energy resources have been obtained in the country and what was the utilization factor. Such information includes electricity generated, energy efficiency of the country, imported and exported electricity and natural gas data, etc.

• **Resource module:** This Module analyzes existing energy resources in the country. Consequently, this module can analyze the level of future consumption of energy resources, including renewable energy sources and related costs.

• **Results module:** The module is designed to produce results generated by the optimization of the model for their analysis in a convenient way and conduct scenario analysis.

Consequently, LEAP can provide long-term forecasting environment of the energy sector, integrated management of resources and calculate the country's energy balance. The process of constructing structure, operation and optimization of the model is presented on Figure 1.

**Time frame:** LEAP is intended as a medium to long-term modeling tool. Most of its calculations occur on an annual time-step, and the time horizon can extend for an unlimited number of years. Studies typically include both a historical period known as the current accounts, in which the model is run to test its ability to replicate known statistical data, as well as multiple forward-looking scenarios. Typically, most studies use a forecast period of between 10 and 30 years. However, some results are calculated with a finer level of temporal detail. For example, for electric sector calculations the year can be split into different user-defined “time slices” to represent seasons, types of days or even representative times of the day. These slices can be used to examine how loads vary within the year, what are pick and off-pick load patterns, what factors constitute demand on electricity and how is covered through differently sources in different seasons.

**Energy balances:** LEAP has the ability to automatically generate results as standard format energy balance reports. These closely follow the standard format employed by the IEA and most national energy planning agencies. LEAP's energy balances can be displayed in table, chart and sankey diagram format and they can be customized to summarize information for detailed or simplified fuel categories, for different years or for different regions. Energy balance results can also be shown by sector or by subsector in any energy unit.
**Demand:** As an integrated energy planning model LEAP covers both the demand and supply sides of the energy system. However, due to the project purposes, brief outline the demand forecasting features of the LEAP model is provided here. The model follows the accounting framework approach to generate a consistent view of energy demand based on the physical description of the energy system. It also relies on the scenario approach to develop a consistent storyline of the possible paths of energy system evolution, thus for the demand forecasting analyses the implications of possible alternative factors and development scenarios on the demand. The demand analysis, following the end-use approach, is carried out as follows:

- The analysis is carried out at a disaggregated level, where the level of disaggregation can be decided by the users. The disaggregated structure of energy consumption is organized as a “hierarchical tree”, where the total or overall activity is presented at the top level and the lowest level reflects the fuels and devices used.

- Activity levels: In LEAP’s demand analysis, works by forecasting future energy consumption as the product of two factors: activity levels and energy intensities. Activity levels are simply a measure of the economic activity in a sector, and you can choose what data to use for this purpose. For example, in the household sector you may choose to use the number of households as the activity level, in the industry you might use tons of industrial production.

- Energy intensity data: If an aggregate analysis is prepared, most likely activity level data should be combined with national energy consumption statistics and energy balances to calculate historical energy intensity values by sector.

- Other useful sources of energy demand data include recent energy consumption surveys that analyze how energy is consumed by end-users or in different sub-sectors of economy, also reports from utilities and private companies on sales of electricity will be useful.

- If more detailed analysis is created, information on the stocks will be required, along with technical characteristics of major energy consuming devices.

As an example, how electricity demand forecast can be done in LEAP environment is explained below. In general, data is required describing the current and historical load patterns (and generation capacity in case demand-load forecasting), installed capacities (MW), efficiencies and actual load dispatch (MWh). Information
on the seasonal load shape is also essential for your electric system and the maximum availability and dispatch priority of each different type of power plant. Capacity expansion plans of various sub-sectors and end user types, if they exist, can be very useful for establishing forecasts of how the electric system is likely to evolve in the future. In addition to collecting data on load, data describing transmission and distribution losses must be collected as well including both technical and non-technical losses. It is convenient to analyze electric sector separately from the dedicated electric generation sector. Electric consumption analyze in separately in industrial, commercial and household sector, and finding correlation with the general indicators such as demography, economic factors and etc. is a key issue.

![Diagram of LEAP modeling process]

**Figure 2. Modeling Process in LEAP**

LEAP enables top-down macro-economic modeling simulation of the electricity sector and capacity expansion planning. In order to facilitate simulation of different electricity generation profiles, the model incorporates two main modules that form the basis of the hour-to-hour simulation, within the rules defined: Energy demand module and transformation modules as shown in the chart below. This allows the planner to capture the combined effects of separate changes at many levels, such as, for example, the growth in the total number of households, the rate of urbanization, the penetration of certain technology trends, analyzing market share of several factors that influence energy demand.

There are plenty of advantages of LEAP mostly that it is not a model created for a specific energy system, rather it can be used for the planning of energy systems with different structures and characteristics. LEAP is user friendly and flexible enough for users with a wide range of expertise. A key benefit of LEAP is its low initial data requirements. Many modeling tools rely on very particular and often quite complex solution algorithms such optimization, and so tend to have highly inflexible data requirements. Developing the data for such models is a time-consuming task and quite risky, requiring relatively high levels of expertise. By contrast, because it provides a choice of modeling methodologies and many aspects of LEAP are optional, it therefore has much lower initial data requirements and allows its users to get started building models based on relatively simple accounting principles. LEAP’s adaptable and transparent data structures are well suited to an iterative analytical approach: one in which the user starts by rapidly creating an initial analysis that is as simple as possible. In later iterations the user adds complexity only where data is available and where the added detail provides further useful insights into the questions being addressed in the analysis.
1.3. MARKAL model

Market Allocation (MARKAL) model is an integrated energy systems modeling framework to guide policy formulation and investment priorities. It is used to assess a wide range of energy, economic and environmental planning and policy issues. While it encompasses an entire energy system from resource extraction through to end-use demands as represented by a Reference Energy System (RES) network, it provides least-cost optimization for an energy system and identifies the most cost-effective pattern of resource use and technology deployment over time. Therefore, MARKAL can quantifies the costs and technology choices that result from imposition of the policies and strategies and identifies the benefits arising for various policies and programs (e.g., increase energy security and economic competitiveness, reduced emissions).
It should be noted that MARKAL model requires high quality and very detailed data. At the same time, it need to have experience and qualification to apply MARKAL. The process of modeling in MARKAL model (see figure 3) is the following: first of all data and assumptions are fed into data handling systems that provide input to the model generators. The model generators work in the GAMS environment and produce text output that is read by the results handling system. The results handling system produces numerical and graphical output for the user. Data input and results are generated in Excel format. However it need additional softwares: ANSWER, VEDA-FE and VEDA-BE.

- **VEDA-BE and FE** works with output in its elemental form and gives the user full flexibility in exploring the model solution. Elaborate tools are available for interactive and batch mode operation. It works well with both model generators.

- **ANSWER** has comprehensive but pre-defined output tables for MARKAL models. VEDA-BE is recommended for handling results from TIMES models running under ANSWER.

MARKAL can forecast energy system and its evolution over a period of usually 20 to 50 or 100 years at the global, multi-regional, national, state/province or community level taking into account input data. Any number of time slices, which is user-defined at three levels, can detail each annual load duration curve: seasonal (or monthly), week days – weekends, and hour of the day. The entire energy system can be modelled and it is represented as a network, depicting all possible flows of energy from resource extraction, through energy transformation and end-use devices, to demand for useful energy services – as many as desired, in the desired units. For example, demand for space heating or cooling can be specified by categories such as single or multifamily, urban or rural, existing or new. Finally, after calibration MARKAL finds the most optimal solution for the entire energy system in the country for each time period by selecting the set of options that minimizes total discounted system cost or the total discounted surplus over the entire planning horizon, within the limits of all imposed policy and physical constraints.
2. INPUT-OUTPUT MODELS

Input-output approach, and models based on it is widely used afterwards by different organizations, included government ones, to predict the future or estimate possible effect of the policy. Wassily Leontief developed input-output approach at the beginning of 20th century. Demand on energy is determined by performance of interrelated industries and Input-output models are trying to find direct and indirect links using multipliers. Models are capable to evaluate the effect on energy demand when specific sector output changes. However, classical input-output models are not able to estimate the effect of changes in prices on energy demand.

Unlike classical input-output models, Computable General Equilibrium (CGE) models, also descended from the input-output models, are able to integrate the price and the quantity system and focuses more on shortages labor, capital, or foreign exchange. On the figure below see the model of the economy depicting the relationship of different sectors/agents. Another limitation is that model does not consider technological change. All this shortcomings reduce accuracy.
Demand on energy depends on different factors such as demand from private and state sectors, demand of connected countries and etc. In its turn, demand on energy from households, for example, is influenced by various economic and social factors, like income, weather and etc. CGE models, like its ancestor input-output models can provide useful tools to measure the impact of direct and indirect factors on energy consumption pattern.

CGE models are Static or dynamic, stochastic or non-stochastic. Dynamic models are more commonly used and are more precise while there is a need for a data for more than one year. The main restriction for developing dynamic CGE models is data availability.

For the purpose of the project, the model to be developed needs break-down information of different indicators in various sectors of economy and various type of consumption (to capture load shape of the energy demand). In Georgia CGE model was developed in the International School of Economics at TSU (ISET). ISET has adopted special software, GAMS, developed for running CGE models. While the models developed by ISET do not focus on energy sector, it is a part of the model. The model developed by ISET aims on estimating investment effects on different sectors and general economic indicators, such as unemployment, GDP growth rate, export and etc.

As mentioned, CGE models are based on dataset called SAM which is derived from supply-use table and then updated with different information from different sources. In case of the CGE model developed by ISET, beside supply-use tables there is included an information estimated using integrated household surveys by Georgian National Statistics Office (GEOSTAT).

ISET representative in the interview mentioned that the data used in the model is the best they could gain but its accuracy level is not expected to be very high because different factors had to be estimated with survey data which does not provide high confidence level for each group the estimation is made for.

Taking into account the data availability and aim of the project, to forecast not only the demand of energy but load shape of the demand as well, makes input-output and even CGE models inappropriate. To build dynamic model no sufficient accurate data is available. While static model development is possible, it does not provide exact estimation, when the output will take place (only short-run, medium-run and long-run estimations will be possible). Such result is not in accordance with the project aims. Additionally, as literature review showed, CGE model were not used for estimated the load shape for the energy demand.

3. Electricity Demand forecasting models using regression models

In order to forecast future electricity/energy consumption several techniques have been developed over the last few decades, including traditional methods such as regression, econometrics, and time series, as well as soft computing techniques such as genetic algorithms, fuzzy logic, and Artificial Neural Networks (ANNs). Traditional Forecasting methods can be categorized to two major categories of causal and historical data based methods. The causal relation is considered between electricity consumption as output variable and social-economic and climate factors as input variables. Most frequently used causal methods are regression analysis and econometric models, and time series models are based on the historical data, which uses the previous values of a variables to forecast the future values.

**Econometric method:** This method combines economic theory with statistical methods to produce a system of equations for forecasting energy demand. The method estimates the relationship between electricity demand and demand influencing factors. To forecast electricity demand as a function of GDP, electricity price, technology, population and etc. econometric models are developed. Ramprasad Sengupta and Rao and Parikh in their studies concluded that such models are effective in forecasting electricity demand patterns in developing countries. Arsenault et al. have predicted the total energy demand as a function of previous year’s energy demand, price of energy, real income and heating day for the province of Quebec. Ordinary least square technique (OLS) is used and prediction is made sector-wise – residential, commercial, industrial and street lighting. Yearly data has been used for demand side projection. Mohamed Z. et al (2005) used economic and demographic variables for forecasting electricity consumption in New Zealand. Models are developed using multiple linear regression analysis with electricity consumption as a function of gross domestic product, non,
average price of electricity and population. In the context of climate change the future electricity demand is determined for Greece (Mirasgedis S at al, 2007). The electricity demand is determined using regression equation that considers population, GDP, energy intensity, monthly seasonality of electricity demand, monthly heating and cooling degree days. It is found that economic development has a strong effect on the future electricity demand. The electricity requirement in the future in Italy by Bianco et al. is forecasted using linear regression models and elasticities of GDP, price, GDP per capita for short run and long run and for domestic and non-domestic electricity consumption are determined. Pilli-Sihvola K.et al's investigates future electricity demand in Europe using log-linear econometric model and highlights how electricity demand responses on climate, electricity costs including carbon costs.

Conditional Demand Analyses (CDA) is most commonly used econometric technique to estimate end-use electricity demand forecasting model. For more precise prediction behavioral components, such as usage of electrical appliances, can be included in the model. As a result the model suggests that electricity consumption of household “i” is influenced by following factors:

- ownership of electric appliances
- electricity consumption of these appliances
- usage of electric appliances

The model is estimated by following equation:

\[ x_{ij} = y_j + \sum_{m=1}^{M} \rho_{jm}(C_{im} - \bar{C}_{jm}) + e_{ij} \]

\( x_{ij} \) _ Annual Electricity consumption for end-use j for household i

\( y_j \) _ electricity consumption for appliance j, given economic and demographic characteristics of that household  

\( C_{im} \) _ Demographic and economic variables (m=1…M), such as household’s income, electricity prices, Heating Degree Days (HDD), Cooling Degree Days (CDD),

\( \bar{C}_{jm} \) _ Mean Value of \( C_{im} \) variables for household owning appliance j

\( e_{ij} \) _error term

To increase accuracy of prediction the end-use model is combined with econometric models, by adding the economic and demographic factors, such as GDP growth rate, population growth, employment level, electricity prices. The addition of those parameters increases the accuracy of prediction for long time horizon.

The comparison of CDA estimation method of end-use electricity consumption with Neural Network and engineering based model, which are the models from Soft Computing Technique groups, showed that CDA estimation can achieve the similar level of accuracy in prediction as the abovementioned sophisticated models. Although, comparison showed that Neural Networks provide better estimators to evaluate the influence of socio-economic factors than CDA technique. In addition CDA can be useful to provide future electricity consumption forecast under different development scenarios.

Regression models usually establish a mathematical relationship between two or more variables and have been used to forecast energy demand. A successful regression analysis provides useful estimates of how previous changes in each of the independent variables have affected the dependent variable.

Dynamic relationship between electricity consumption and weather, price, and consumer income are examined by Harris and Lon-Mu, they were using 30 years data series from USA. Similarly, Egelioglu examines the influence of socio-economic variables on the annual electricity consumption using multiple regression analyses, the relationship between energy consumption, the number of customers, the price of electricity and the number of tourists is determined. A linear regression model was used to predict the electricity consumption for Turkey based on the population and per capita consumption growth rates (Yumurtaci Z. At al).

Regression Approach uses least square estimation technique to assess the effect of influential factor on electricity demand. Regression approach considers linear relationship between electricity consumption and
independent factors, such as electricity prices, economic growth, weather conditions etc. The equation takes the following form:

$$Y(t) = V_t a_t + e_t$$

$Y(t)$ - Total load of the system;

$V_t$ - vector of adapted variables (time, light intensity, wind speed, temperature etc.);

$a_t$ - Transported vector of regression coefficients;

$e(t)$ - error term;

The regressions basically is used to forecast electricity consumption for short time period, such as day ahead or hourly peak load forecasting, although some studies apply multiple regression method to provide long-term forecasts for electricity consumption.

**Time series models** are the simplest models which uses time series trend analysis for estimating future energy requirements. In time series models only explanatory variables are lagged values of the variable to be explained and predicted. The intuition underlying time-series processes is that the future behavior of variables is related to its past values, both actual and predicted, with some adjustment built-in to take care of how past realizations deviated from those expected. Simple time series analysis includes models such as the Weighted Moving Average and Basic Exponential Smoothing. More complex time series methods include factors for trends, seasonal patterns, and economic cycles. The models assume that each observed demand data point is comprised of some systematic component and some random component.

Stationary time series manner can be forecasted by ARMA (p,q), ARIMA, and SARIMA models. These models are a specific class of regression models. When time series data contains trends, seasonality, or both there is need to introduce autoregressive integrated moving average (ARIMA) models. In an ARIMA (p,d,q) model, d explains the number of performed differentiations to achieve a stationary process, with p autoregressive terms and q moving average terms. It is possible that in some cases the seasonality dominate the variations of the original time series. The multiplicative model SARIMA (P,D,Q) S - incorporates both seasonal and non-seasonal factors. Seasonal time series can be made stationary by differencing between one value and another with the lag of S or a multiple of S, which is called seasonal differencing.

ARIMA models are among the most useful short-term forecasting models, extensively used in energy demand forecasting. Sumer et al. have used three models namely ARIMA, seasonal ARIMA and regression model with seasonal latent variable in forecasting electricity demand by using data over the 1997:1–2005:12 periods. This study tries to examine the advantages of forecasting with ARIMA, SARIMA methods and with the model has seasonal latent variable to each other. The regression model with seasonal latent variable used in this study gives more successful results than ARIMA and SARIMA models because also this model can consider seasonal fluctuations and structural breaks.

**Genetic Algorithms (GA)** is the model from soft computing estimation technique. Using the artificial intelligence tools GA models can provide precise long-term prediction of electricity demand with probability of error. The problematic issues in computing such as non-linearity, imprecision and uncertainty is included in GA estimation model that gives big advantage compared to traditional estimation approach. Also GA is efficient tool to run simulation to predict electricity consumption under different development scenarios.

The algorithm of GA model is based on the evolutionary theory guided by the idea—“the best will survive”. The user defines the several input parameters, such as Population size, probability of crossover, probability of mutation, generation number, number of decision parameters for the problem. After specification of input parameters the Algorithm starts model selection process from initial observation and continues processing of initial data until the best model of fitness function ($F(x)$), with low forecasting error, is produced. The fitness function has the following form:

$$Max F(x) = \frac{1}{\sum_{i=1}^{m} s_i (E_{obs} - E_{est})}$$

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$E_{obs}$ - Observed electricity consumption

$E_{est}$ – Estimated electricity consumption

$s_i$ - Weighting factor

According to existing studies GA is one of the sophisticated techniques to provide precise long-term prediction for electricity consumption.