Partnership for Growth, Ghana

TOU Tariff Analysis and Program Development

Final Report

March 2015

This document was prepared for the United States Agency for International Development (USAID) by ICF International under Cooperative Agreement No. AID-OAA-L-11-00003-00.

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Executive Summary

ICF International (ICF) is pleased to submit this report to the United States Agency for International Development (USAID) entitled Partnership for Growth, Ghana, a project under ICF's current Leader with Associates Cooperative Agreement with USAID, Energy Efficiency for Clean Development Program (EECDP), No. AID-OAA-L-11-00003-00. This project is to provide technical assistance to address load management by developing a Time of Use (TOU) tariff analysis and program design targeted at the industrial sector.

The electricity and power crisis in Ghana, in which chronic capacity and energy shortages regularly force customer load shedding, impacts all sectors of the population. The industrial sector, in particular, is hit hard by the lack of reliable power supply, and forced load shedding. The recent tariff increase to about US $0.20/kWh by the ECG, about twice the U.S. average retail price, in addition to fueling customer dissatisfaction with ECG, may have significant adverse impacts on the competitiveness of Ghanaian industries. To address these issues, ICF's recommendation is to implement a TOU tariff program. As industrial customers already have the necessary infrastructure in the form of smart meters installed at their facilities, and industrial customer electricity demand, which holds the greatest potential for load modification, accounts for a high share of the total electricity usage, the program is initially targeted to the industrial customers.

Various scenarios were analyzed resulting in *economic* potential demand reduction ranging from 73MW to 167MW. Due to the already high electricity prices, the scenario that results in the least aggressive pricing is recommended to ensure widespread acceptability. The recommended tariff, as shown in Figure 1, is estimated to result in 56MW *achievable* potential which is around 5% of the industrial load or 2% of the system load by 2019.

Figure 1 – Recommended Time of Use Rate Structure

	LV	MV	HV	HV - Mines	Time Period[i]	Hours per Day	Total Hours per Year	% Total Annual Hours
Current Energy Charge (Ghp/kWh)	51.71	40.02	36.80	58.41	All Hours	24	8760	N/A
Proposed Off-Peak Energy Charge (Ghp/kWh)	43.95	34.02	31.28	49.65	11 PM to 6 PM	5	1825	21%
Proposed On-Peak Energy Charge (Ghp/kWh)	87.90	87.90	87.90	87.90	6 PM to 11 PM	19	6935	79%

It is recommended the program be launched as a voluntary pilot for a period of 3-6 months. The program should be revised based on the outcome of the pilot, and 'opt-in' program should be launched for a period of 12-18 months. This will give sufficient time for the program to mature, which will enable the utilities to launch a mandatory (with necessary exemptions) TOU tariff program.

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1 Introduction

1.1 Time of Use Tariff

ICF International (ICF) is pleased to submit this report to the United States Agency for International Development (USAID) entitled Partnership for Growth, Ghana a project under ICF's current Leader with Associates (LWA) Cooperative Agreement with USAID, Energy Efficiency for Clean Development Program (EECDP), No. AID-OAA-L-11-00003-00.

The objective of the project is to provide technical assistance to address load management issues by developing a Time of Use (TOU) tariff analysis and program design targeted at the industrial sector. Given Ghana's power sector challenges, especially the power grid capacity and energy shortages that constrain economic growth and reduce grid reliability, shifting industrial peak loads to off-peak hours through TOU rates can be one of the country's most cost-effective near-term steps in balancing its power sector and economic growth policies.

Economic fundamentals suggest that in any market, prices should convey to consumers the cost of the resources that are used to make a product, and convey to investors the returns they can expect to get by making the product. As electric power is also a product, this principle is equally applicable to in the case of electricity rates. When consumers, especially industrial companies that pay close attention to costs and prices, do not see the full cost of electricity in their power bills, they tend to over-consume. This in turn forces the power sector to invest excessive capital and fuel resources. This effect is especially critical during peak periods when the capacity and energy costs of producing electricity tend to be much higher than during off-peak periods, largely because electricity cannot be economically stored in large quantities.

Utilities in many countries have managed such peak load challenges through a set of technology and pricing solutions known as demand response (DR). DR programs tend to fall into one of two categories: (1) load curtailment programs that provide direct controls or other mechanisms, plus incentives, for reducing peak load during peak periods, and (2) dynamic pricing programs that use price differentials between time periods as incentives for customers to reduce peak loads. Both types of DR programs fall within the larger sphere of electricity utility efforts to help customers manage their electricity loads and power bills, known as Demand Side Management (DSM). DSM includes a variety of load shape objectives, from energy efficiency to reduced usage across the load curve, to beneficial electrification that uses off-peak power for clean energy solutions such as electric vehicle charging.

Dynamic pricing, a form of demand response in which electricity prices vary by time of use, can help ensure that equilibrium between electricity generation and demand is maintained. The goal of dynamic pricing is to alter the demand curve in order to help demand and supply balance, by aligning price and cost of power more accurately at the time of use.

Load curtailment programs tend to comprise either direct load control, or interruptible load tariffs. Direct load control programs traditionally involve incentive payments and physical control devices for common loads such as air conditioners and water heaters. Interruptible load tariffs are another common curtailment approach in which customers receive incentive payments for agreeing to full or partial curtailment of electricity service, typically limited to a certain number of events per year, and requiring advance notice from the utility. In some wholesale electricity markets, market-based DR programs have evolved to where system operators post prices, typically a day ahead, for load reductions that customers participating in the DR program make voluntarily. Participating customers are paid based on measured reductions.

Dynamic pricing differs from curtailment programs in that it depends purely on price signals—no other incentives are offered, and the utility does not control customer loads or directly measure load reductions. It is designed to lower system costs for utilities and bring down customer bills by raising prices during peak (and typically highest-cost) hours of electricity production, and lowering them during off-peak (and typically lower-cost) hours. Dynamic pricing's load shape objective is to reduce peak loads and/or shift load from peak to off-peak periods. A dynamic pricing tariff requires relatively low administrative expenses and no hardware costs if smart meters are already in place, as is the case with the large customers of the Electric Company of Ghana (ECG).

Dynamic pricing is a common tool used in many countries with varying results. There are several dynamic pricing options:

- **Real-time pricing (RTP):** Price for electricity fluctuates hourly depending on the wholesale price of electricity on a day-ahead or hour-ahead basis.
- **Time of Use (TOU)**: TOU pricing comprises different unit prices for usage during different blocks of time and should reflect the average cost of generating and delivering electricity during that period of time. TOU programs are compared to and sometimes coupled with other dynamic pricing options in order to provide flexibility for customers to modify consumption in a beneficial manner.
- **Critical Peak Pricing (CPP)**: A CPP rate basic structure is a type of TOU pricing scheme. However, the normal peak price can be replaced with a much higher price and triggered by certain events, such as reduced system reliability or high supply prices.

TOU tariffs are the most common dynamic pricing program in use today, and are commonplace in developed economies around the world. These tariffs incentivize customers to lower peak loads in order to reduce their electricity bills. The objective for the electric utility is to reduce peak loads and/or shift load from peak to off-peak periods.

TOU tariffs vary their pricing structure by time of day, to reflect the changing costs associated with electricity production. Prices are typically set higher during on-peak hours, most often in the afternoon/early evening (Ghana's system peak typically occurs in the 6pm-10pm period), and lower in off-peak hours, most often in nighttime and weekend hours. Electricity demand and power supply costs are typically lower during off-peak periods; during the electricity system peak, more expensive generation sources are brought on line, and system losses increase, which drive up system costs during those hours. Some TOU tariffs also include a mid-peak pricing period, typically in early to late evening hours, during which load and system costs fall in between peak and off-peak levels. TOU tariff prices are designed to align with these cost variations, and to shift customer loads into off-peak or mid-peak hours, with the result of lower peak demand, less forced load shedding, and lower total system costs.

As described in the section below, we believe that TOU tariffs can be a beneficial DSM program choice for ECG, and can produce significant impacts in the near term with measureable benefits for Ghana's power sector and its economic development goals.

1.2 TOU Tariff Applicability to ECG

The electricity and power crisis in Ghana, in which chronic capacity and energy shortages regularly force customer load shedding, impacts all sectors of the population. The industrial sector, in particular, is hit hard by the lack of reliable power supply, and forced load shedding and other reliability problems that have significant effects on productivity and costs. Industrial facilities are typically in need of modernization, including energy-efficiency technologies and production methods. Lack of awareness, technical expertise, and financing chronically inhibit efficient operating practices and investments.

The Ghanaian power sector is also in the difficult position of working without modernized grid systems, sustainable business models and, very importantly, public trust and buy-in. The recent tariff increase to about US $0.20/kWh by the ECG, about twice the U.S. average retail price, in addition to fueling customer dissatisfaction with ECG, may have significant adverse impacts on the competitiveness of Ghanaian industries. Even with recent tariff increases, the cost of service (COS) of electricity is not fully recovered due to high cost of electricity production during peak hours. This issue is explained in more detail in Section 2.4.

In this context, higher energy tariffs are not likely to be well received, but rather are likely to be seen as a setback for this still-struggling economy. The fact that tariff subsidies from state oil revenues have not materialized in the six years since Ghana began major oil production operations in 2007 contributes to the sensitivity of the situation. However, tariff increases are also essential for the power sector to become more economically viable, enabling utilities to address their high costs of generation, transmission, and distribution.

To address these issues, ICF's recommendation is to implement a TOU tariff structure that will initially target industrial customers. Even though industrial customers have a relatively constant electricity consumption load profile, they account for the Ghanaian utilities' greatest share of peak load[1] and electricity sales and, therefore, provide the best immediate target for efforts to reduce system peak load and energy use. Implementation of a rapid-deployment TOU tariff project will benefit both industrial customers and ECG by providing new options for industrial customers to manage their own energy costs and a specific mechanism for ECG to reduce its total system costs. Based on ICF's experience, industrial customers often have substantial flexibility in operational scheduling and load management, and are thus most likely to be able to respond to an alternative tariff structure. We anticipate that participating customers will appreciate the associated relief in their electricity costs, and will provide supportive testimony to wider use of TOU tariffs and other DSM programs. At the same time, we expect that ECG will be able to show measured reductions in system peak demand and some improvement in net revenue collection, and will be able to use the TOU project to justify wider application of TOU and other DSM strategies.

[1] Approximately 1000 customers on Special Load Tariffs account for some 30% of power sales

Our assessment, based on a review of ECG data and discussions with stakeholders, is that a TOU tariff approach will realize the greatest relief from forced load shedding, at the lowest cost and in the shortest timeframe. Other DSM options, including direct load control, wholesale demand response programs, and energy efficiency programs, should be considered for the medium term, but a TOU tariff is recommended as the initial DSM offering.

1.3 Approach

The following activities were conducted to develop the TOU Tariff structure:

- **Activity 1: Document Review.** The objective of this activity was to gain an understanding of the power sector in Ghana, including ECG's operations, business and cost structure, customer base, load, and technical challenges, as well as the related political, economic, and historical contexts relevant to the power sector. Tasks were conducted to establish key underlying assumptions and conditions for the analysis. Documents reviewed included a 2011 cost of service study by Mercados, tariff proposals from ECG, NEDCo, VRA, and GRIDco, and the 2013 energy statistics report from the Energy Commission of Ghana.
- **Activity 2: Conduct Metering Data Analysis.** ECG collects 15-minute interval electric meter data, demand factor, power factor, and other data on approximately 1,700 industrial customers with advanced meters installed. ICF conducted detailed analyses on a sample of these customers with the objective of identifying load management options.
- **Activity 3: Determine Utility Costing Periods and Develop TOU Tariff Strategies**. ICF analyzed utility data in order to identify the appropriate off-, mid-, and on-peak time periods, and the system cost and tariff pricing calculations applicable to each costing period to recommend a TOU tariff structure incorporating prices.
- **Activity 4: Create Marketing Plan and Support Pilot Rollout.** The final activity was to develop a program a program plan to promote participation, administer implementation processes, and manage ongoing program needs. ICF has created the program plan as a part of this report and will continue to work with the ECG marketing staff to support the roll out of the program.

1.4 Report Overview and Organization

The remainder of this report is organized as follows:

- **Section 2** summarizes baseline (existing) energy use by customer segment and for the ECG system
- **Section 3** describes the analysis that was conducted to determine the TOU time periods
- **Section 4** describes the analysis that was conducted to determine the TOU rate structure
- **Section 5** describes the proposed TOU program design
- **Section 6** gives an estimate of the expected customer response from the TOU program
- **Section 7** summarizes the recommended next steps

2 Baseline Energy Use

Understanding how energy is currently used within a utility's service territory is the first step to developing an effective TOU Tariff. Data and information collected during activities 1 and 2 were used by ICF to estimate baseline energy use in Ghana. In the subsections below, we give an overview of the electricity sector and the stakeholders. We summarize the baseline energy use starting at the service territory level, by tariff class, and then at the end-use level, by sector. Finally, an explanation of the revenue shortfall is given which in part is the motivation for our recommendation to implement the TOU Tariff.

2.1 Ghana Electricity Market Overview

There are various stakeholders of the electricity sector in Ghana. Understanding of the role of each is important to ensure acceptance of the TOU tariff. The various stakeholders with responsibilities are presented below:

Volta River Authority (VRA): The VRA was established in 1961 as the sole entity in Ghana responsible for generating power, primarily through hydro-electricity in the Volta River. It was also responsible for transmission and distribution. In 1997, two bodies were established to provide oversight on Ghana's electricity industry:

- The Energy Commission is responsible for granting licenses to generators, transmitters and distributors of electrical power. The commission enforces technical regulation through the Electricity Transmission Rules (2008) and the Electricity Regulations Act (2008).
- The Public Utilities Regulatory Commission (PURC) is responsible for approving rates, protecting consumer rights, promoting competition within the industry, and monitoring performance of public utility service.

Ghana's government pursued power sector reforms in 2005. As a result the transmission function was separated from the VRA. A large portion of existing power generation assets in Ghana, with the total installed capacity of approximately 2900 MW, are still owned and operated by the VRA.

GRIDCo is the sole transmission operator in Ghana. There are three distribution companies in Ghana: **Electricity Company of Ghana** (ECG), **Northern Electricity Distribution Company** (NEDCo), and the **Enclave Power Company** – which is a smaller distribution company focused on the Tema Free Zone.

NEDCO served 380,000 customers in 2011. Residential customers constituted 82.05% (311,997) of the total customers, non-residential customers constituted 17.94% (68,010), while the Special Load Tariff (SLT) customers constituted only 0.01% (40).

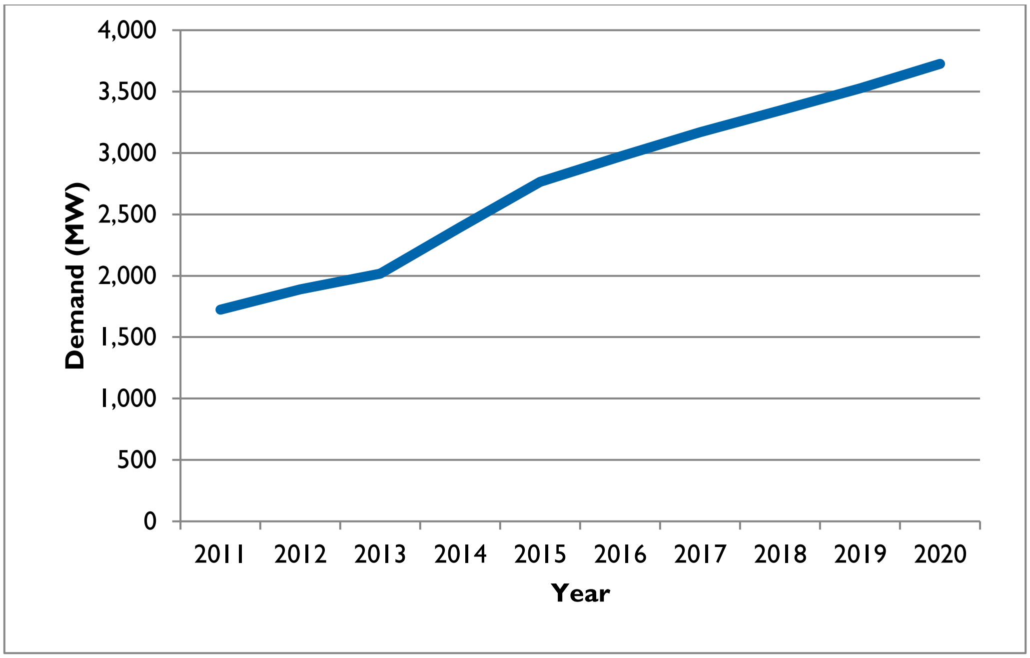
As of December 2012, ECG serves 2.5 Million customers. Out of this population, 71% or 1.78 million are active customers that are mainly Non Special Load Tariff (NSLT) customers. There are around 1,605 SLT customers.

The Government of Ghana is promoting Independent Power Producers (IPPS) to construct and operate new power plants. With the exception of the Bui hydro-electric power plant and two thermal power plants, all the new power plant licenses have been granted to IPPs with a total under construction capacity of 865 MW and a planned capacity of 1025 MW.

2.2 Total Electricity Use

The total peak demand on the system is around 2,000 MW in 2013. Figure 2 shows the electricity load forecast for the system, which is expected to grow by 75% to over 3,500 MW through 2020. Management of this additional load through added system capacity alone will be very challenging. Therefore, demand side management, energy efficiency, and demand response will likely have to play a significant role in meeting the forecasted load.

Figure 2 – Electricity Load Forecast through 2020



Source: GRIDCo

2.3 Electricity Use by Tariff Class

Electricity consumption in Ghana can be characterized in four categories. The industrial sector accounts for nearly half of electricity consumption. Therefore a TOU program focused on shifting on-peak load from this market segment can be beneficial in meeting system peak load reduction. The percentage of consumption for each of those sectors is shown in Figure 3.

Figure 3 – Customers and Sale by Tariff Class (2013)

Tariff Class	Customers in Tariff Class	% Total Cust.	Total Sales (GWh)	% Sales	Total Demand (MW)
Residential	2,160,000	99 %	3,228	35%	1008
Non-Residential			1,525	16%	
Industrial	1,645	< .01%	4,224	45%	1008
Street Lighting	N/A	N/A	377	4%	N/A
Total	2,161,645		9354	100%	2,016

Source: Energy Commission and Cost of service study

2.4 Electricity sector Revenue Shortfall

Ghana's electricity sector reform has been afflicted with various challenges. In particular, the revenue generated through the sales of electricity does not cover the cost of service (COS) to generate and deliver electricity. Based on a COS study conducted in December 2012, the COS is comprised of the following:

- **Generation cost**
  - Short run marginal costs in the form of fuel and variable operations and maintenance
  - Capacity costs in the form of capital and fixed operating costs
  - Ancillary services in the form of spinning reserves, non-spinning reserves, voltage control and reactive power regulation.
- **Transmission cost**
- **Distribution cost**
  - New major assets capital expenditure such as medium voltage (MV) and low voltage (LV) transformers and feeders
  - New complimentary assets capital expenditure such as MV to MV substations and other minor equipment
  - End of life replacement infrastructure and equipment
  - Operational costs in the form of staff compensation, operations management, commercial cycle (billing), and call centers.

The COS estimated in the study alongside ECG revenue requirements put forward by ECG is summarized in Figure 4.

Figure 4 – Cost of Service (COS) in 2014

Year	Generation COS (million US$)	Transmission COS (million US$)	Distribution COS (million US$)	ECG Revenue Requirements, COS study (million US$)	ECG Revenue Requirements, ECG (million GHc [million US$][2])
2014	764	96.4	433	442	3,389.3 [1,118.5]

The difference, shown in Figure 4, in the revenue requirement estimated in the COS study and those put forward by ECG suggests that the electricity market is subject to considerable volatility and uncertainty. The reasons behind ECG's predicted revenue shortfall are multifaceted. At a macroscopic level, customers pay in Ghanaian Cedi but ECG is contractually obligated to compensate IPPs in US dollars, exposing ECG to losses caused by currency exchange fluctuations. Additionally, the cost of equipment and material, primarily imported from international markets, has been steadily increasing from 2012 due to a weakening Cedi. ECG's poor financial performance, in turn, has spurred an increase in the cost of capital that hinders the company's ability to cope with system maintenance and expansion as required by the Government of Ghana's rural electrification efforts.

More recently, the introduction of bulk generation customers – energy intensive consumers that receive discounted rates from GRIDCo – do not compensate ECG for system use. ECG has proposed a "wheeling" charge that will compensate ECG for the cost of service to deliver electricity for this class of customers. These issues all contribute to the current situation, in which existing tariffs are not cost-reflective due to the additional costs, the high cost of producing electricity during peak hours, and the necessary investment in equipment, explained above, are the reasons for revenue shortfall. This situation is ripe for TOU tariffs as a first step in rationalizing energy prices, encouraging load management, and beginning to address the endemic issues in the power sector.

ECG has also undertaken an expansive effort to install smart metering technology that, in addition to providing hourly demand data, will reduce the costs associated with billing errors, reading costs, and service connection/disconnection. ECG's special load tariff (SLT) and Bulk Generation Customers (BGC) customers, characterized by high consumption and system load, have already been converted to smart meters. While ECG's non-special load tariff (NSLT) rate class, primarily comprised of residential and commercial customers, are planned for future conversion to smart meters. This development is fortuitous in that the deployment of smart metering is key to enabling TOU tariffs among other DSM program options.

[2] Conversion rate of $1 Ghanian Cedi to 0.33 US dollar

3 Analysis to Determine Peak Time Periods

Specifying on-peak and off-peak time periods, and setting the accompanying prices assigned to each time period, are the key elements of a TOU program. This section describes the approach that was taken to determine the on-peak and off-peak time periods for the TOU program. Section 4 describes the approach that was taken to determine the appropriate rates to charge during each time period.

The analysis conducted to determine the on-peak and off-peak time periods included a review of the system load for the entire ECG system, as explained in Section 3.1. In addition to the system load review, a selective set of industrial customer load was reviewed, as explained in Section 3.2.

3.1 System Load Review

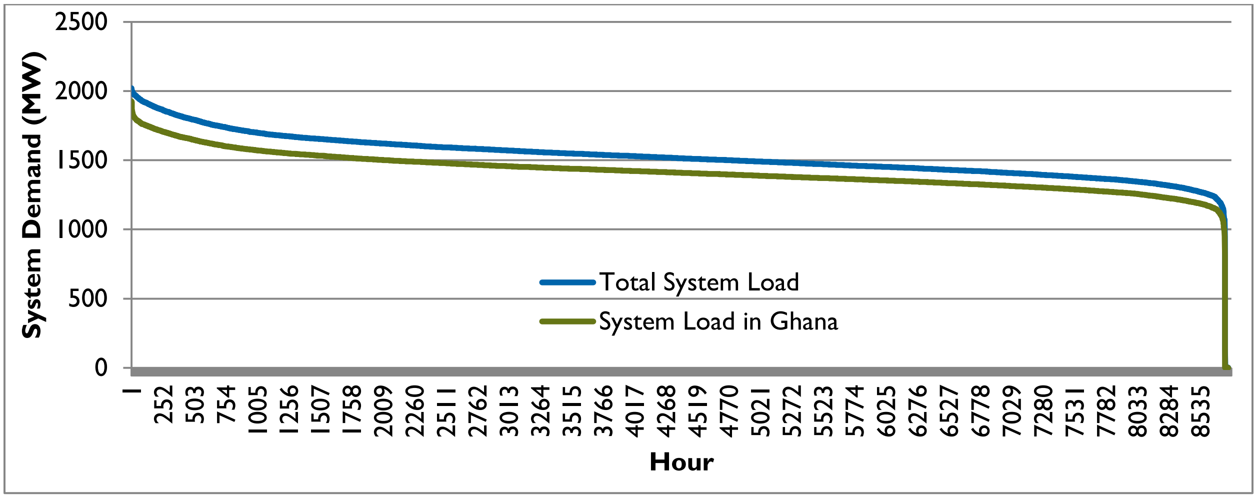
System load was analyzed using the load duration curve of the system for the year 2013. Sorting system hourly demand for a given year from highest demand to lowest, and then plotting that data series on the Y-axis against annual hours on the X-axis gives the load duration curve, as shown in Figure 5 – . The figure shows two data series: the *Total System Load*, which includes load from VALCO as well as Communauté Electrique du Bénin (CEB); and *System Load in Ghana*, which excludes the electricity load of CEB.

Plotting a load duration curve is useful in analyzing possible TOU program structure: the shape of the curve illustrates variance in annual demand; inflection points on the curve can be used to help determine different TOU periods. The load duration curve for system load in Ghana shown in Figure 5, also shown in tabular form in Figure 6, has a relatively shallow slope across the majority of hours and begins to steeply taper at around 1600 MW. In fact, 73 percent of the 2013 system load year is under 1600 MW. Approximately 16% of hours in 2013 exceeded 1500 MW. System loads greater than 1500 MW primarily occur from 6 pm to 11 pm.

The hourly load profile suggests that system peak is primarily driven by lighting and household consumption. Due to Ghana’s proximity to the equator, this pattern is constant for all seasons, as lighting is used in similar daily patterns year-round.

While a significant number of TOU programs across the world use a three-tier structure, including a mid-peak period, due to the relatively shallow slope of the system load duration curve our analysis quickly suggested a two-tier structure where only the on-peak and off-periods are defined. A two-tier structure is beneficial from an administrative perspective and its relative simplicity can be easier to explain and “sell” to customers.

Figure 5 – System Load Duration Curve (Graphic)



Source: ECG

Figure 6 – System Load Duration Curve (Tabular)

System Demand Bin	% 2013 Hours	% Cumulative Hours
0<MW<=1000	0%	0%
1000<=MW<1100	0%	0%
1100<=MW<1200	0%	1%
1200<=MW<1300	3%	4%
1300<=MW<1400	14%	18%
1400<=MW<1500	27%	45%
1500<=MW<1600	28%	73%
1600<=MW<1700	16%	89%
1700<=MW<1800	6%	95%
1800<=MW<1900	4%	98%
>1900	2%	100%

As shown in Figure 7, and in tabular form in Figure 8, 72 % of system load between 1500-1700 MW and around 100 % of the load over 1700 MW occurred between 6PM and 11PM (18:00-23:00), which is defined as the *on-peak time-block*. Conversely, the *off-peak time-block* was defined as 12AM-5PM (24:00-17:00).

Figure 7 – Distribution of Peak Hours in 2013 for System Load in Ghana (Graphic)

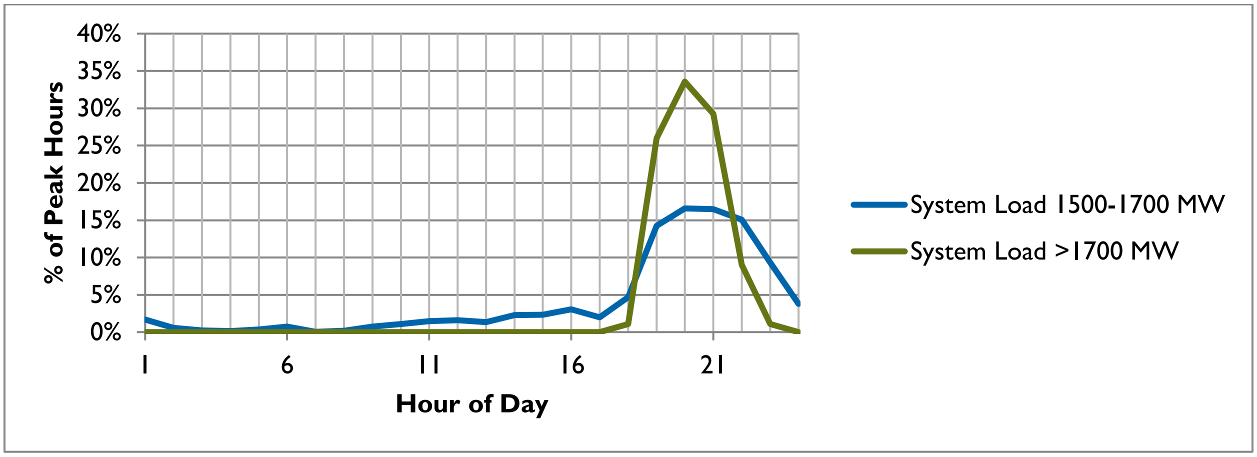
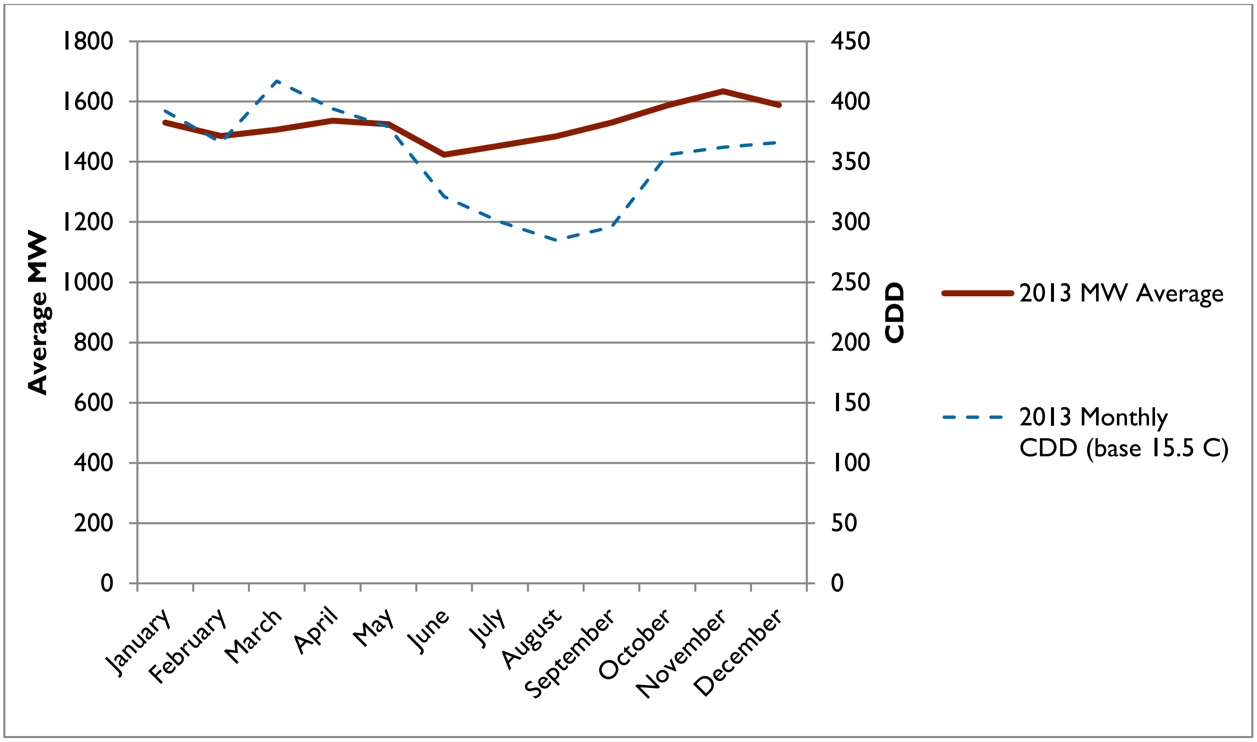


Figure 8 – Distribution of Peak Hours in 2013 for System Load in Ghana (Tabular)

Time	System Load 1500-1700 MW	System Load >1700 MW
12-1 am	2%	0%
1-2 am	1%	0%
2-3 am	0%	0%
3-4 am	0%	0%
4-5 am	0%	0%
5-6 am	1%	0%
6-7 am	0%	0%
7-8 am	0%	0%
8-9 am	1%	0%
9-10 am	1%	0%
10-11 am	1%	0%
11 am -12 pm	2%	0%
12-1 pm	1%	0%
1-2 pm	2%	0%
2-3 pm	2%	0%
3-4 pm	3%	0%
4-5 pm	2%	0%
5-6 pm	5%	1%
6-7 pm	14%	26%
7-8 pm	17%	34%
8-9 pm	17%	29%
9-10 pm	15%	9%
10-11 pm	9%	1%
11 pm -12 am	4%	0%

Some TOU tariffs have seasonal components. In ECG's case there is no correlation between cooling degree days (CDD) and system demand, indicating low variance in seasonal demand as shown in Figure 9. Therefore, it is not necessary to vary ECG's TOU tariff by season. Since this simpler rate design will be easier to explain to customers, it will also be easier for facility owners and managers to plan their operations accordingly.

Figure 9 – System Demand Compared to Cooling Degree Days (CDD)



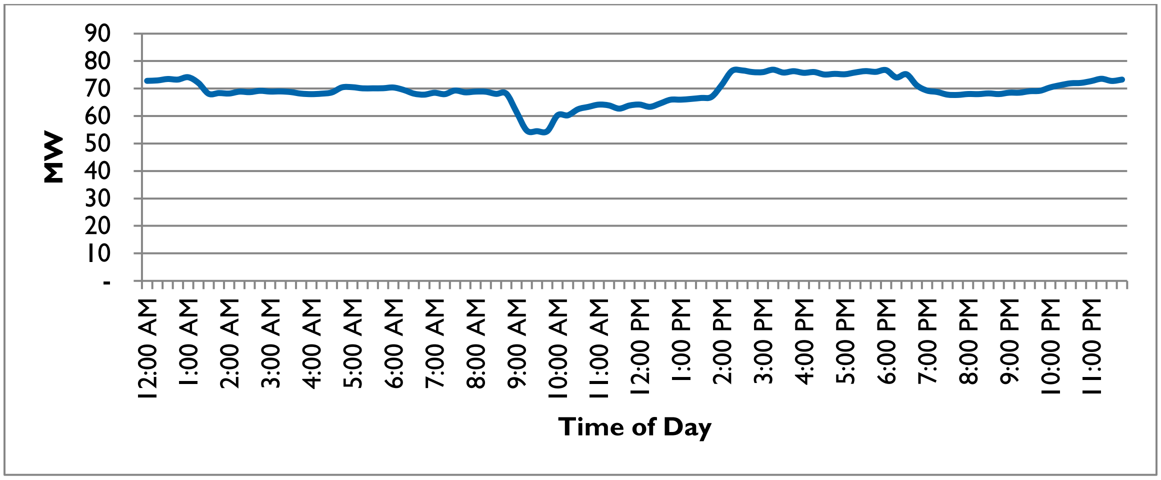
3.2 Sample Industrial Customer Load Review

A review of a sample[3] of 36 ECG high voltage customers suggests that industrial customers do not necessarily follow the same hourly profile as the overall system load. Most industrial customers in the sample demonstrated relatively constant energy demand throughout the day. However, a few of the largest customers show increased demand during system peak hours of 6pm to 11pm.

Figure 10 gives the daily average of two months (December 2012-January 2013) of electricity demand for the sample of 36 customers, which suggests that even though peak for these industrial customers does not occur during the system peak hours of 6pm to 11pm, a significant portion of electricity demand occurs during these hours. If some of the end-uses that comprise the demand during this period can be shifted to off-peak hours, it will relieve the system congestion.

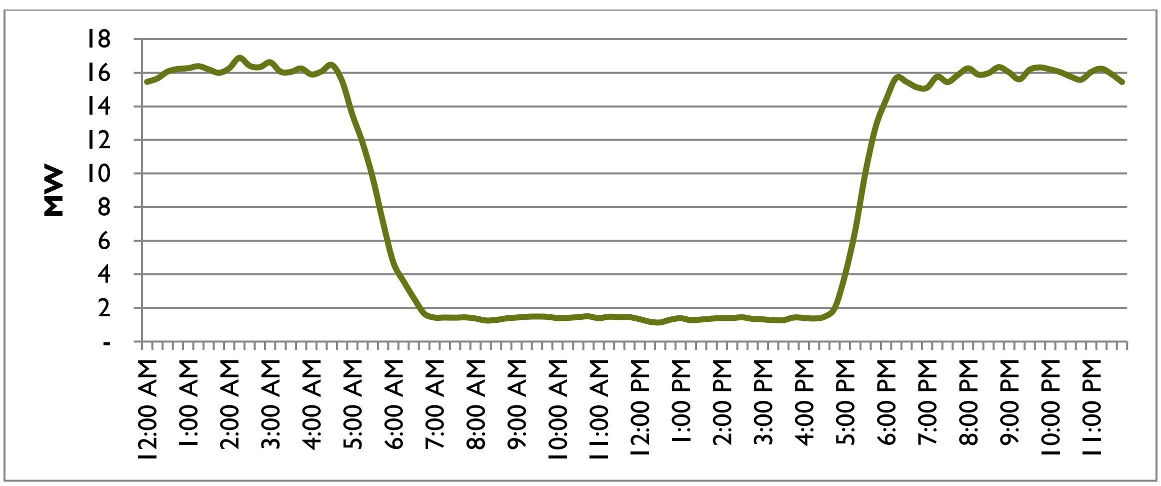
[3] Note that the sample was not statistically selected and, therefore, may not be representative of the sector.

Figure 10 – Daily Average Electricity Demand of 36 Industrial Customers



The analysis of the sample of industrial customers led to an interesting observation with regards to operational flexibility of the customers. A high volume steel manufacturing facility, as seen from the electric load profile in Figure 11, chose to operate 6 pm to 6 am to lower the risk of damage from high daytime temperature to their equipment. While this operation schedule is not ideal from the system peak management perspective, this observation is meant to highlight the flexibility within the sub-sector to move operations if favorable conditions exist.

Figure 11 – Electric Load Profile of a High Volume Steel Manufacturing Facility



4 Analysis to Determine Prices for a TOU Tariff

The number of pricing periods as well as the on-peak and off-peak prices are the key elements of a TOU program. As explained in Section 3, the on-peak and off-peak time periods were determined through load analysis. However, the rate structure design is an iterative process. The typical approach is to conduct a pilot study to determine the response of customers to the TOU rates; this is referred to in economics terminology as measuring *price elasticity*. The observed price elasticity is then used to estimate the impact on peak demand and total consumption, which is then used in the final program design. However, as described in Sections 1 and 2, there is an immediate need for the TOU program. Therefore, we have taken a somewhat more aggressive approach to design the program. We created a spreadsheet model to test the price elasticity impacts of several TOU rate structures. We used literature review to estimate the inputs to the model, which include price elasticity, and ratio of on-peak to off-peak prices. We also added realistic constraints to the model on the revenue impact and rate structure that would be both financially and politically acceptable.

As with all USAID projects, we encourage the development of local expertise. We will provide the model that was used for the analysis to the utilities and work to build local capacity among utility staff. This will enable them to revisit the approach once the program has been implemented and adjust the model using actual program experience.

The price elasticity values and ratio of on-peak to off-peak prices were gathered from rate design literature, as explained in Section 4.1. These values were used to create a model as explained in Section 4.2.

4.1 Literature Review

ICF conducted an extensive literature review of TOU programs around the world to provide a range for estimating the ratio of on-peak to off-peak prices, and the associated price elasticity.

A summary of selected TOU tariff information from our literature search is shown in

Figure 12. As the actual rates being used in these countries are a function of the respective utility's cost of service, the ratio of the on-peak to off-peak rates is more meaningful for the purpose of this analysis. For the 16 TOU tariffs that were reviewed, the ratio of the rates is shown in

Figure 12. While the majority of the programs use three pricing periods (on-peak, off-peak, and mid-peak) as explained in Section 3.2, a two-tier period works better for Ghana.

Figure 12 – Selected TOU Tariff Research

Country	Ratio of on-peak to off-Peak rates	Pricing Periods
Algeria	8.2	3
Iran	5.4	3
Israel	21.13	3
Egypt	4.12	2
Jordan	9.2	2
Lebanon	21.2	3
Morocco	13.8	3
Syria	6.5	3
Tunisia	10.1	4
China (Jiangsu)	3.8	3
Korea	3.58	3
South Africa[4]	7.3	3
Taiwan	2.67	3
Thailand	2	2
Turkey	2.59	3
Vietnam	3.12	3

There are two types of customer electricity use responses, or price elasticity, to TOU rates – own-price elasticity and substitution elasticity. Own-price elasticity can be used to estimate change in total electricity consumption relative to a change in electricity price. This relationship is mathematically defined as:

$$E_D = \frac{\frac{Q'}{Q} - 1}{\frac{P'}{P} - 1}$$

Where,

Q is the total energy consumption in the absence of a TOU program,

Q’ is the total energy consumption with a TOU program,

P is the weighted average price of consumption in the absence of a TOU program,

[4] South Africa’s ESKOM operates a few optional TOU programs for medium and large customers. The tariff is available to urban customers larger than 25 kVa and smaller than 5 MVa. The rate includes price periods with differentiated energy charges and a maximum demand charge. Mandatory and voluntary load reduction for key industrial customers was approximately 7% while municipal customers observed 9.5% load reduction

P' is the weighted average price of consumption with a TOU program.

The own-price elasticity of electricity, like many other goods, is negative since consumption decreases as the price increases.

TOU program customer response is also evaluated using substitution elasticity, which in the context of this analysis is the change in demand from one period relative to the price change in another period. Substitution elasticity is mathematically defined as:

$$E_S = \frac{\frac{Q'_p}{Q'_o} \Big/ \frac{Q_p}{Q_o} - 1}{\frac{P'_p}{P'_o} \Big/ \frac{P_p}{P_o} - 1}$$

Where

Q'_p is the energy consumption during on-peak periods after a TOU program is implemented,

Q'_o is the energy consumption during off-peak periods after a TOU program is implemented

P'_p is the price of energy during on-peak periods after a TOU program is implemented,

P'_o is the price of energy during off-peak periods after a TOU program is implemented,

Q_p is the energy consumption during on-peak periods before a TOU program is implemented,

Q_o is the energy consumption during off-peak periods before a TOU program is implemented

P_p is the price of energy during on-peak periods after a before a TOU program is implemented,

P_o is the price of energy during off-peak periods before a TOU program is implemented.

Unlike own-price elasticity, substitution elasticity is usually positive.

Electricity price elasticity[5] has been studied in various jurisdictions and customer segments. Unfortunately, none of these studies directly apply to Ghana, but similar to the TOU program design, a survey of multiple elasticity studies can provide a range of reasonable values that will enable an analysis of estimated customer response.

Figure 13[6] presents a summary of electricity elasticity studies for different demand response programs.

[5] While studies suggest that industries with different electricity intensities have different price elasticity we took an average of sectoral price elasticity for this study, as the sub-sector level price elasticity is not relevant to the sector level TOU program design.

Figure 13 – Snapshot of Industrial Electricity Price Elasticity Studies

Market	Date of Study	Own-price Elasticity	Substitution Elasticity
Ontario Canada	1997	-0.07 to -0.09	0.7 to 0.11
CA, NY, and Midwest	1984	-0.014 to -0.02	
California US	1983	-0.03	
Ontario Canada	1986	N/A	
Texas US	1984	-1.1	0.21
California US	1983	-0.15 to -.27	
California US	1984	-0.02 to -0.09	
California US	1991	-0.04 to -0.09	
Ontario Canada	1983	0 to -0.24	N/A
US	1978	-0.41	
US	1978	-0.78	
US	1978	-1.01	

4.2 Analysis

The analysis was conducted using a spreadsheet model that uses mathematical expressions to define own-price and substitution elasticity. The model uses 15-minute interval smart meter data for ECG to evaluate the impact from several scenarios. It also includes constraints on revenue impact and rate structure.

Based on the literature review, three conservative values of 2, 4, and 8 were chosen as the ratio of on-peak to off-peak rates to use for the analysis. The scenarios were designed to test the impact on the shift in consumption patterns (substitution elasticity) and the resulting revenue impact from a total decrease in electricity consumption (own-price elasticity). A constraint was put in place in the model such that the revenue impact would not change by more than 5% in either direction.

The impact on the total electricity consumption was calculated using three different own-price elasticity values, which were based on the literature review. For each of the own-price elasticity values, the shift in consumption pattern was calculated using three different values of substitution elasticity, which were also based on the literature review. The values used for the elasticity are given in

[6] TOU tariffs impact electricity use patterns in both short and long run. Examples of changes made in the short run (<2 years) include reducing production during peak, or reducing the use of non-essential equipment such as lighting or air conditioning. In the long run, customers can implement more fundamental changes such as installing more efficient equipment or adding production capacity that will enable the facility to operate during off-peak hours instead of on-peak hours. Since in best practice utility resource planning and DSM are viewed in the long-run, this analysis was conducted using long run estimates of price elasticity to estimate the impacts or the proposed TOU rate.

Figure 14.

Figure 14 –Price Elasticity Inputs for Various Scenario

		Substitution Elasticity		
		0.02	0.15	0.27
Own Price Elasticity	-0.41	**Calculation for Each Combination:** On-Peak Consumption Change Off-Peak Consumption Change Revenue Impact		
	-0.78			
	-1.01			

In total there were nine calculations that were performed for each scenario, or one for each combination of substitution and own price elasticity. Each calculation included the impact on on-peak consumption, off-peak consumption, and system revenue from energy charges. For each of the three scenarios, the average of the nine calculations, which is representative of the range of elasticity values found in literature, is shown in Figure 15.

The analysis was conducted using 15-minute interval smart meter data in the month of December 2012 through January 2013 for select high voltage customers of ECG. As there is limited variation in seasonal demand, we believe that the three months of data is representative of the full year.

Figure 15 – Scenario Results

	Scenario 1 (Recommended)	Scenario 2	Scenario 3
Ratio of On-Peak to Off-peak	2	4	8
TOU Off-peak discount	15%	35%	55%
Estimated On-Peak Consumption Change	-8%	-13%	-18%
Estimated Off-Peak Consumption Change	-1%	-2%	-6%
Estimated Revenue Impact	0%	-2%	-4%
Potential System Peak Load Reduction (MW)	73	121	167

The most aggressive scenario has an on-peak to off-peak rate ratio of 8, which is close to the average of the international programs that were reviewed and summarized in

Figure 12.

Consideration was given to avoid burdening industrial customers with a limitation to shift their loads in the initial phase of the program. Therefore, there is no current need for an aggressive pricing model. Finally, in choosing the modest price ratio, consideration was given to other factors such as potential political backlash, risk of the industrial customers switching to on-site generation due to fatigue from power rationing programs, and potential reduction of industrial output for Ghana. However, the scenarios should be revisited once the program has matured to consider the costs and benefits of a more aggressive pricing model.

The result of the analysis is that Ghana's electricity system stakeholders can expect an average system peak load reduction of 8% with a peak price ratio of 2 and off-peak rate discounted by 115% as the current flat rate and on-peak rate increase of 50% for four hours of the day. This scenario is revenue neutral for the utilities.

While these estimates are created using extensive literature review and ICF experience, it is not meant to completely replace the natural process of learning through a pilot implementation. It is unlikely that the proposed TOU tariff during off-peak would cause ECG any difficulty in meeting its revenue requirement for the industrial tariff class. As stated previously, once the system is implemented, ECG can use data on revenues to make adjustments to rates such that the system is revenue-neutral (or, if appropriate, revenue-positive).

5 Proposed TOU Tariff

The proposed TOU tariff is recommended for the industrial customer class, because smart meters have already been installed at the industrial facilities, and industrial customer electricity demand, which holds the greatest potential for load modification, accounts for a high share of electricity usage. ECG's industrial customer base comprises less than 0.01% of total system customers, but uses 45% of system electricity. Further, industrial operating schedules are not currently affected by the time-varying cost of electricity production, given that the energy charge under the current tariff is a flat price per kWh for all hours of the day throughout the year. This misalignment of prices and costs has contributed to system outages, revenue loss by ECG, lost production/revenue by companies, cross subsidies across customer classes, and other inefficiencies. While an industrial TOU tariff alone cannot fix all of these problems, better alignment of energy charges with energy costs will help improve the economic efficiency of the ECG system, may help reduce the number of system outages, and can better support Ghana’s economic growth goals.

ICF developed the TOU program recommendations based upon data gathered and analyses performed under activities 1 through 3 including research of international TOU tariffs, as well as ICF experience with program design and implementation in other countries. The recommended TOU tariff program is based on well-understood designs with proven performance in numerous developed and developing countries. Their experience is adapted here to address market barriers and other issues specific to Ghana.

5.1 Proposed Tariff

ICF recommends a two-tier TOU tariff for industrial customers as shown in Figure 16[7].

Figure 16 – Proposed Industrial Customer TOU Tariff Summary

	LV	MV	HV	HV - Mines	Time Period[i]	Hours per Day	Total Hours per Year	% Total Annual Hours
Current Energy Charge (Ghp/kWh)	51.71	40.02	36.80	58.41	All Hours	24	8760	N/A
Proposed Off-Peak Energy Charge (Ghp/kWh)	43.95	34.02	31.28	49.65	11 PM to 6 PM	5	1825	21%
Proposed On-Peak Energy Charge (Ghp/kWh)	87.90	87.90	87.90	87.90	6 PM to 11 PM	19	6935	79%

[i] The tariff periods were determined by analyzing the sub-set of hours during which ECG's system demand was 1500 MW or greater, as described in Section 3.1.

This tariff for industrial customers is designed to motivate facility owners and managers to shift electricity use during periods when there is the greatest demand on the grid to periods of lower demand by setting price signals for the cost of energy that better align with the costs of production at different times of day. The tariff is designed primarily to shift load away from periods of peak demand by setting a peak energy charge that is somewhat consistent with the cost of energy during such periods. The design sets the on-peak energy charge at a price point designed to motivate industrial customers to shift a modest amount of their load from on-peak to off-peak.

The proposed two-tier tariff was designed with simplicity in mind. Experience shows that overly complex TOU rates can be counterproductive to utility goals, mainly because they can be difficult for customers to understand and act upon. This tariff design takes into account the relatively shallow slope of ECG's load duration curve and the lack of variation in seasonal load. The main purpose is to encourage industrial customers to shift production from periods of highest system demand to periods of lower system demand. Consideration was given to the scenario where a large shift in load from on- to off-peak could simply result in changing the time period in which the system peak is likely to occur, without actually reducing system peak demand. We think this is not likely with the proposed rate structure since industrial customers have a relatively constant annual electricity consumption load profile.

The recommended tariff for *on-peak* energy charge is an increase over the existing flat tariff charge and the off-peak energy charge is a decrease over the existing flat tariff charge. This will help to shift the system load for peak hours to off-peak hours. The design of the tariff charge ensures minimal impact on the revenue of ECG. This is explained in more detail in Section **Error! Reference source not found.**.

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7 Although some TOU tariffs also include demand charges that vary by period, such charges add a layer of complexity that can be counterproductive. In addition, focusing on energy is most consistent with the overall goal of TOU tariffs, is to better align retail energy charges with long run marginal energy costs.

6 Estimated Impacts and Costs

Figure 17 summarizes projected program costs and savings over the forecast period. Based on a 2015 start-up, customers on the tariff could achieve total demand savings of 56 MW, or just over 2% of current ECG system peak load, by 2019. Program costs are higher in 2015 to account for start-up costs. There is some associated energy savings in MWh that were estimated for the recommended tariff structure, as shown in Figure 18.

Figure 17 – Industrial TOU Program Savings & Costs

Program Metric	2015	2016	2017	2018	2019
Incremental MWh Savings	0	145	168	231	262
Cumulative MWh Savings	0	145	168	231	262
Incremental MW Savings	0	31	36	50	56
Cumulative MW Savings	0	31	36	50	56
Annual Program Costs ($Millions, USD)	$0.45	$0.3	$0.3	$0.3	$0.3
Annual Program Costs (Millions GHc)	GHC 0	GHc 717	GHc 478	GHc 478	GHc 478

Figure 18 summarizes the results of TOU program cost-effectiveness analysis. This program includes no direct incentive costs; overall costs are relatively low, as these are largely administrative and marketing costs. Weighted against the large avoided capacity savings, this program is very cost-effective. Based on the Utility Cost Test[8] (UCT) result, we estimate that for every 1 GHc invested by ECG in the program, that ECG customers would save 4.7 GHc in the long run.

[8] UCT measures cost-effectiveness from the viewpoint of the sponsoring utility. It compares the avoided supply costs to the cost of the DSM program. UCT costs include DSM program costs, including incentive costs and non-incentive program delivery costs.

Figure 18 – Industrial TOU Program Cost-Effectiveness

Utility Cost Test (UCT) Ratio	4.7
Net UCT Benefits[9] ($Millions)	$36.6
Net UCT Benefits (Millions GHc)	GHS 110.9
Levelized cost per kWh ($)	$2.25
Levelized cost per kWh (GHc)	GHS 6.8
Levelized cost per kW ($)	$10
Levelized cost per kW (1000 GHc)	GHS 33.30

[9] Utility Cost Test benefits include the present value of the lifetime avoided kWh and kW costs due to measure installations

Figure 20 – Goals/Program Alternatives

Achievable MWh Savings Potential (Cumulative, 2019)	Achievable MW Savings Potential (Cumulative, 2019)	Market Transformation Potential	Equity	Political Feasibility	Program Complexity	Implementation Risk	Net Utility Benefits ($Millions)
262	56	Not applicable.	Equity within the industrial sector will be determined by the regulatory requirements of the tariff (e.g., whether it is opt-in or opt-out). Overall, the tariff increases system-wide equity by reducing cross-subsidies and outages caused in part by energy charges being misaligned with energy costs.	High. Required by policy. Some industrials may initially object due to inflexibility in system operation.	Low. Start-up could be complex. Ongoing implementation involves low complexity.	Low. Requires minimal infrastructure investment with potentially high system benefits.	$36.6

gives the Goals/Program Alternatives.

Figure 20 – Goals/Program Alternatives

Achievable MWh Savings Potential (Cumulative, 2019)	Achievable MW Savings Potential (Cumulative, 2019)	Market Transformation Potential	Equity	Political Feasibility	Program Complexity	Implementation Risk	Net Utility Benefits ($Millions)
262	56	Not applicable.	Equity within the industrial sector will be determined by the regulatory requirements of the tariff (e.g., whether it is opt-in or opt-out). Overall, the tariff increases system-wide equity by reducing cross-subsidies and outages caused in part by energy charges being misaligned with energy costs.	High. Required by policy. Some industrials may initially object due to inflexibility in system operation.	Low. Start-up could be complex. Ongoing implementation involves low complexity.	Low. Requires minimal infrastructure investment with potentially high system benefits.	$36.6

7 Recommended Next Steps

During the course of the study, ICF and ECG staff met with industrial groups to vet the concept of a TOU rate. Generally, ECG's customers, especially the large customers, understand the concept of TOU. Some of the large customers encouraged the introduction of a TOU rate to help them avoid the increase in production costs due to the anticipated electricity rate increases. However, In order to ensure successful implementation of the TOU tariff program, ECG should consider implementing the following steps:

1. Create marketing brochures to clearly communicate the program details. Implement a voluntary pilot with a small set of industrial customers.
2. Revise the program based on the findings of the pilot and launch 'opt-in' TOU program to build momentum. (3-6 months from program start date).
3. Conduct evaluation, measurement and verification (EM&V) activities. Revise the program requirements and launch a mandatory program with exemptions for certain industries e.g. continuous process petrochemicals. (12-18 months from program start date).