A Business Case for Electric Power Distributors Using Simulation :Investigating the Combined Use of the Strategies of Feed-In-Tariffs, Distributed Generation, Time of Use Rates, and Efficiency

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Abstract

Numerous references found in the academic and trade literature discuss the availability and applicability of certain technologies and policies to allow the U.S. electrical grid to address the future challenges of continued growth and aging infrastructure. However, the existing utility companies seem reluctant to adopt these new measures. This thesis will describe some of these strategies and develop a model using Stella system dynamics software that will explore the potential financial impact to the utilities from using these strategies in combination. The four strategies to be investigated are feed in tariffs, time of use rates, distributed generation, and demand-side energy efficiency .

There are other strategies that could be considered such as Renewable Portfolio Standards, Net Metering, Critical Peak Pricing, and Renewable Energy Tax Credits. These other strategies are either similar in implementation to the four discussed in this paper or have been shown to not have lasting affect on the utility industry's bottom line. For this reason, the four listed above have been chosen.

From the research and the test case data used in this paper, the following findings were observed:

- Distributed Generation will most likely not be implemented without some true incentive to the owner and without a policy such as Feed-In Tariffs.
- Energy Efficiency practices can significantly reduce electrical consumption. Specific technologies have very attractive payback or return on investment and others are not practical when only taking into account ROI measurements.
- Peak Shifting or Peak shaving can have significant effect on the utility's profit but has no effect on the consumer's electricity bill.
- Time of Use rates have very different effects on the utility. Depending upon the cost structure of their generation and the nature of its customer load, the TOU rate can significantly reduce the profit of the utility even without Peak Shifting.
- The biggest positive impact for society as a whole would be a policy that lowers electrical consumption, decreases the release of greenhouse gases, and allows the utility to remain a viable business. The combination of strategies that offers this impact would be the use of Peak Shifting with no TOU rates,

demand-side Energy Efficiency, and the implementation of a FIT for photovoltaic generation.

Answering the Questions

1. How might combinations of the strategies of Time of Use pricing, Feed-In-Tariffs, Distributed Generation, and Energy Efficiency affect HEC costs, customer electric bills, and overall electrical consumption in the HEC residential class customer base?

From the scenarios shown above in ***Table 1***, it is apparent that the different strategies affect the metrics (profit, electrical consumption, etc.) by the same quantities if activated during any run of the model. There is very little interaction between the strategies. Only when a combination of strategies that reduced HEC CP charges (the peak demand charge from Dominion) and lowered the amount of electricity sold, did a cumulative effect appear.

	Strategies	Utility Gross Profit	Utility Annual Energy Costs	Utility Annual Energy Sales (customer bill)	DG Energy Costs	Annual Strategy Costs	Total Electricity Consumption	DG kWh Produced	Annual Savings from EE	Annual Cost of EE
1	None	$5,816,371	$14,038,597	$19,854,968	0	0	209,351,690	0	$0	$0
2	Peak shifting	$6,316,053	$13,541,287	$19,857,340	0	$357,181	209,351,690	0	$0	$0
3	TOU-no shifting	$823,201	$14,038,597	$14,861,798	0	0	209,351,690	0	0	0
4	TOU w/ peak shifting	$1,155,961	$13,541,287	$14,697,248	0	$357,181	209,351,690	0	0	0
5	FIT(1)	$5,047,824	$14,807,145	$19,854,968	$1,152,219	$918,000	209,351,690	4,800,914	0	0
6	EE (2)	$5,425,826	$13,219,370	$18,645,195	0	0	196,595,787	0	$1,209,897	$1,816,263
7	EE (3)	$5,693,972	$13,781,846	$19,475,818	0	0	205,353,910	0	$379,189	$117,584
8	Peak Shifting & EE	$6,193,653	$13,284,536	$19,478,189	0	$357,181	205,353,910	0	$379,189	$117,584
9	Peak Shifting,	$1,128,911	$13,284,536	$14,413,447	0	$357,181	205,353,910	0	$283,821	$117,584
10	EE, FIT	$4,925,424	$14,550,394	$19,475,818	$1,152,219	$918,000	205,353,910	4,800,914	$379.189	$117,584
11	ALL	$360,364	$14,053,084	$14,413,447	$1,152,219	$1,275,18	205,353,910	4,800,914	$283,821	$117,584

Table 1- Results from Model Runs

Notes

1. *This FIT implementation uses only PV and includes no FIT recovery mechanism for the utility.*
2. *All three EE implementations were used.*
3. *Only LED lighting was implemented.*

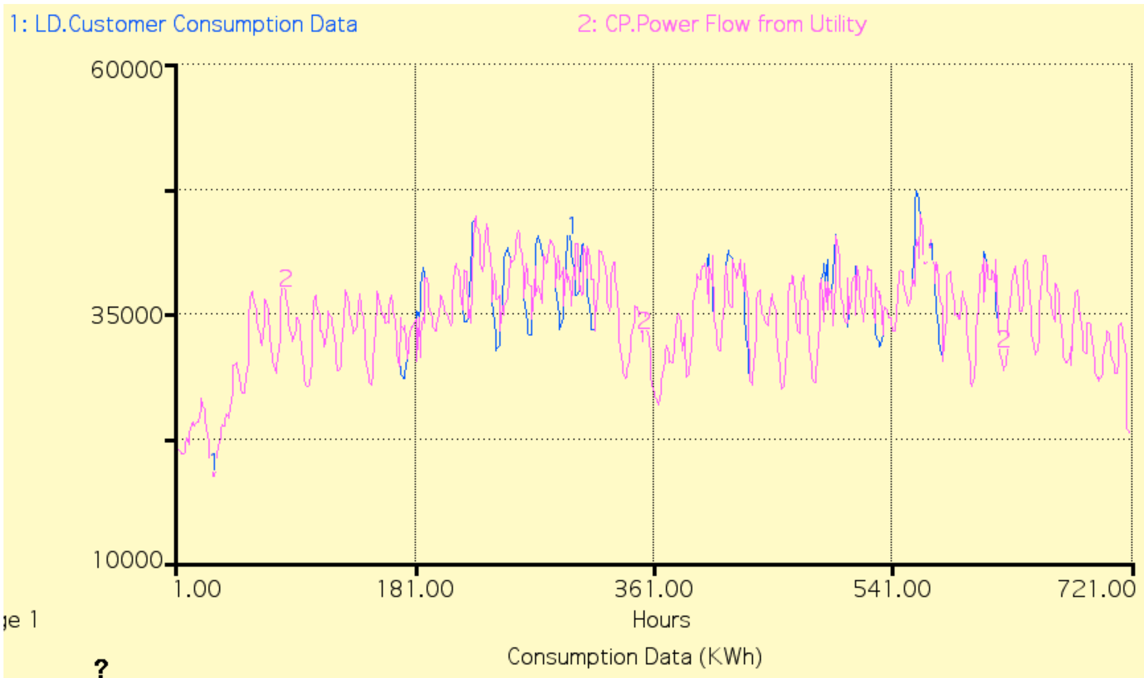

Figure 19- Consumption Data for Run number 2 which only includes the Peak Shifting for HEC (1 month)

The graph in ***Figure 19*** shows where the load is shifted at its peaks and troughs during Run #2. The blue that shows through at the top of a curve is where customer consumption remains the same but that the amount of energy sold by HEC is reduced. This difference comes from energy being withdrawn from storage that HEC bought from its supplier during an off-peak or trough in demand. Where the blue shows through at a trough is where HEC is buying more KW than the customers are using because this extra power is going into some form of storage. Notice the largest peak at about time 560 is reduced by this strategy. The net effect is the significant reduction in HEC's CP demand charge for this month.

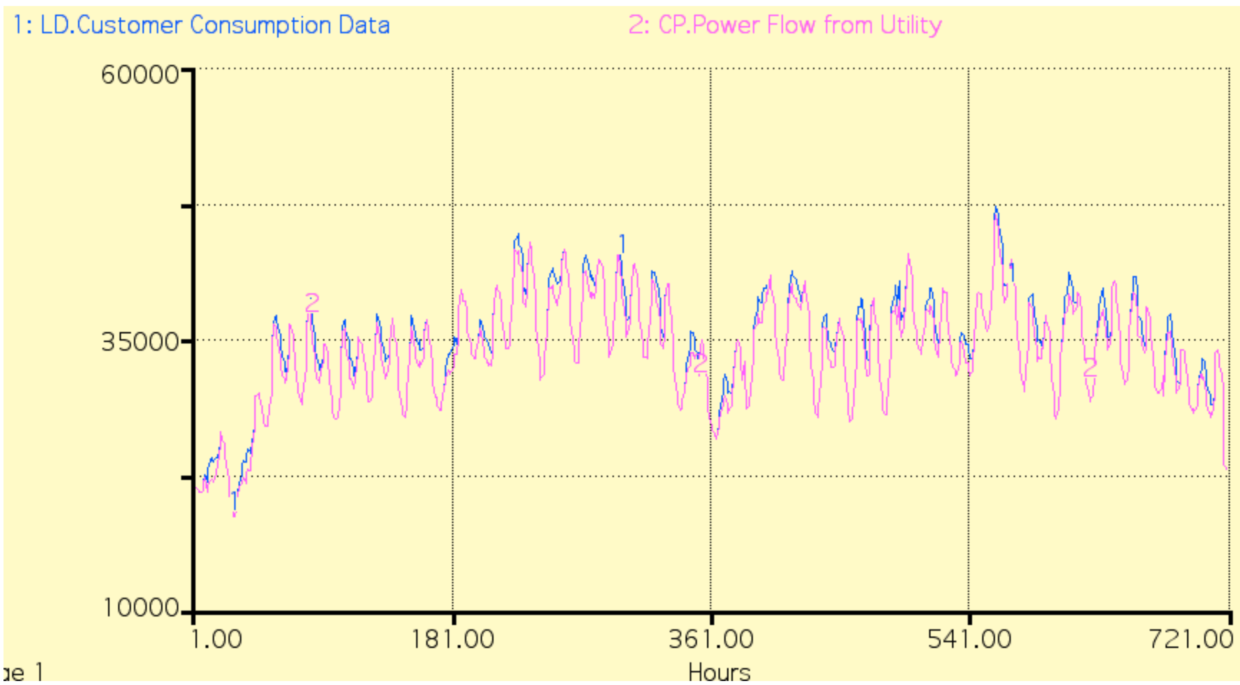

Figure 20- Consumption Data for Run number 5 which only includes FIT from photovoltaics (1 month)

The graph in ***Figure 20*** also shows where the load is shifted at its peaks but not at the troughs in Run #5. During this run the peak shifting is coming from the PV generation which tends to produce more power during HEC's peak hours. This graph is using data for January so the PV shift at 560 is slightly later than the same time period in ***Figure 19*** because the peak hour is 8:00am in the morning. The PV does not start producing at its peak until mid to late morning as indicated in the lower pink line on the graph at the peak at time 560 through 565. These hours coincide with 8:00am through 1:00pm on the 24[rd] day of the month. HEC's CP hour was 8:00am on that day when this data was recorded. Because there is no benefit at 8:00am, there is no benefit to HEC as there would be at a utility that might be able to run less peak generation.

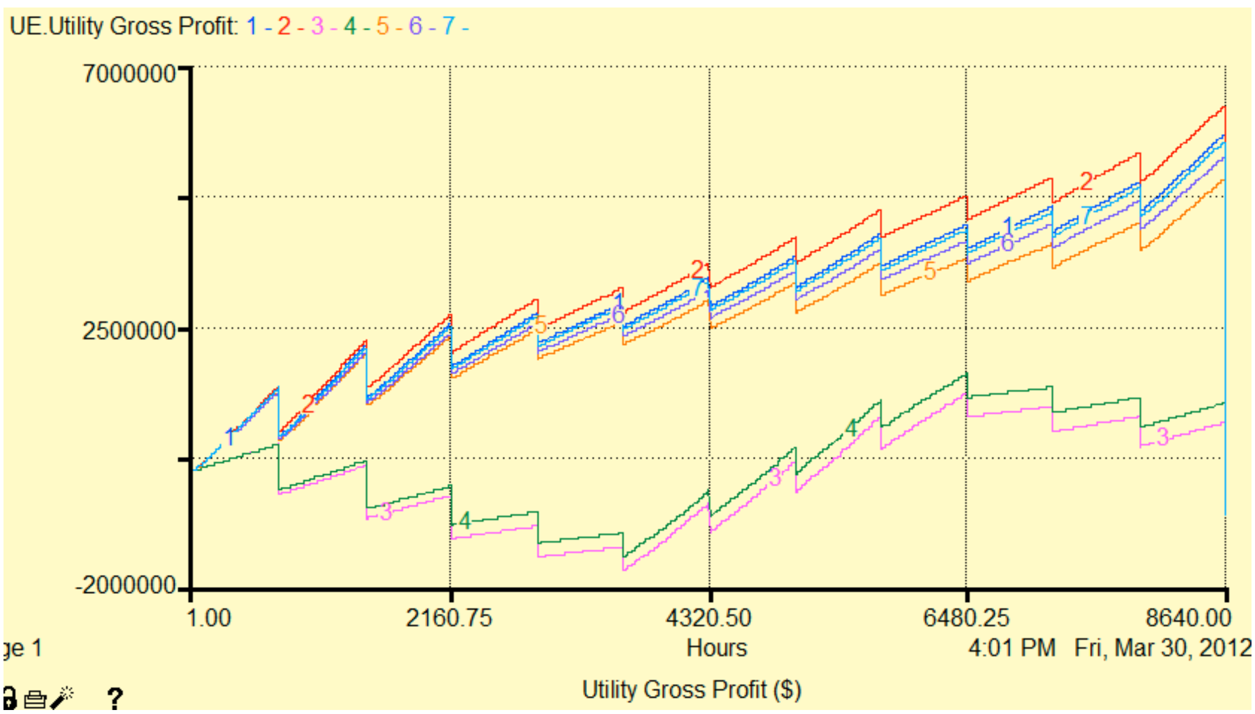

Figure 21- Annual Gross Profit for Run 1 through 7

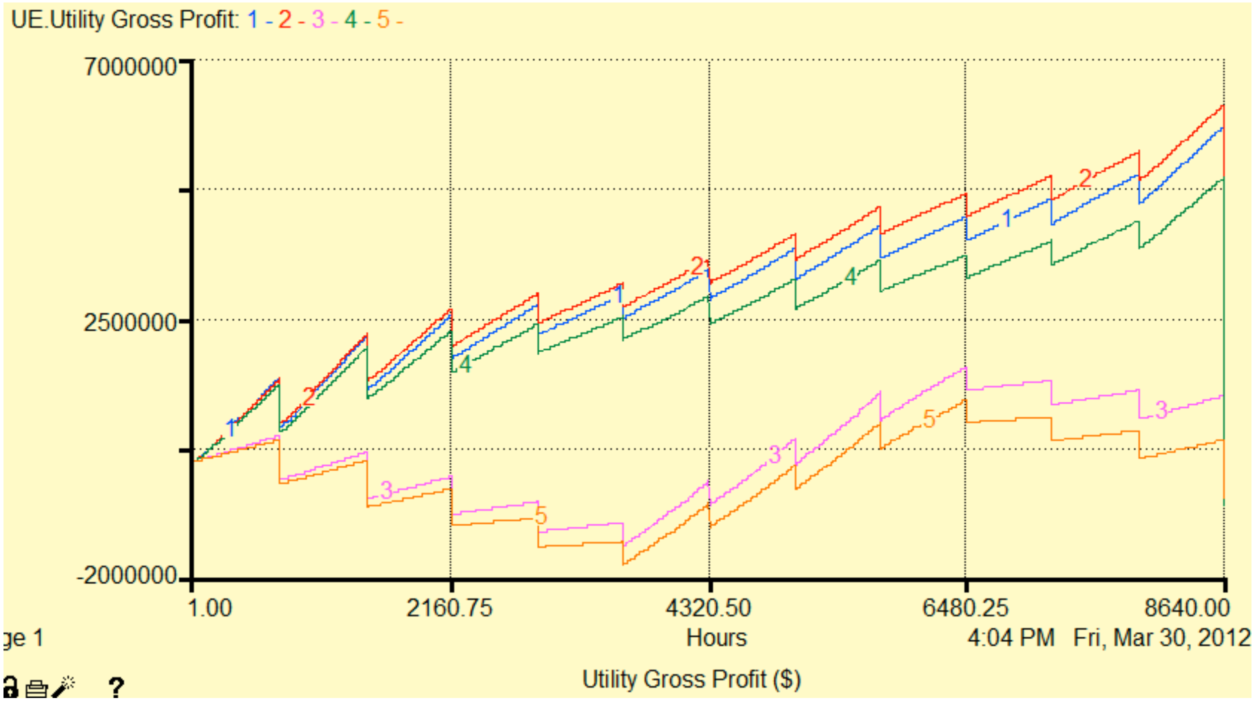

Figure 22- Annual Gross Profit from Runs 1 and Runs 8 through 10 (2,3,4,5 on graph)

The graphs in ***Figures 21 and 22*** show how HEC's profit accumulates over one year from monthly billings. The cause for the sawtooth shape in the graphs is the CP charge that significantly lowers profit as it is calculated at the end of each month. The profit climbs as sales accumulate and then when the CP demand charge is calculated at the beginning of the next month, the profit takes a drop. The lower data lines on both graphs are a result of the TOU rates being implemented. This drastic effect on profits was a surprise to HEC and to the author. The common wisdom is that TOU rates are detrimental to the customer but this shows differently. By analyzing the graphs, one can see that the rates are only good for HEC during the months June through September (hours 3600 through 6480). This effect can be accounted for by the larger load swings between peak and trough during the day for these months which allow HEC to earn more money at the peak rate than during other times of the year. In other words, HEC's daily load has a greater differential during the summer months. The percent difference between a peak and a trough during the summer months is greater than the winter months and much greater than the shoulder months of April, May, October, and November. The cause is most likely due to the increase use of air conditioning during the summer months which is a large portion of the total residential consumption during the summer.

2. Which one of the combinations from question number 1 provides the best outcome for the profitability of the utility?

As shown in ***Table 1***, Peak shifting without TOU rates (run number 2) will not affect the customer bill and give HEC the highest profitability increase. The model projects an increase in annual profit of $499,682 which represents an increase of 8.6%. This is due to the fact that the Coincident Peak demand charge is a significant portion of the utility's costs. Any reduction in

Peak Demand will positively affect HEC's profitability. All other scenarios reduce this increase in profit by either reducing total sales of electricity or adding to the cost of the electricity sold by HEC.

3. Which one of the combinations from question number 1 provides the best outcome for the saving of the most energy?

The only strategy that actually reduces consumption, as discussed earlier and shown in *Figure 8,* is the EE strategy. The model run number 6 reduces Total Consumption the most. Run number 7 also reduces Total Consumption but not as much. The difference between # 6 and #7 is that the annual cost to implement the EE with all three implementations (run # 6) is more than the actual electricity cost savings based upon the current normal rate from HEC. Because of this cost, run #6 will not be considered viable. Run #7 provides the best outcome for saving the most energy and saves approximately 4,000,000 kWh which amounts to a 1.9% savings in consumed electricity.

The model provides for calculation of an '***adoption rate***' of the EE strategy based upon payback or return on investment. The curve determining the adoption rate is an S-shaped growth pattern that can vary between 6.5% and 83% with a beginning value of 16% of the whole residential customer class for HEC. The input range is based upon simple assumptions of early adoption and actual market potential. The values are meant for comparison purposes only and would have to be refined through market research to be more accurate. The calculation is updated at the end of every year so with HEC's lack of interest in multi-year analysis at this point, there was no further refinement made. However, the adoption rate would affect the extent of the potential savings from EE since the costs and savings have a linear relationship to number of adopters. In other words, a greater payback would entice a higher adoption rate and result in higher reductions in electricity consumption for the HEC residential market.

Another viewpoint can also be considered for this question. Based upon previous discussion of energy policy, our country's goal is to have electricity that is cheap, secure, and clean. If moving away from fossil-fuel based generation allows the policy goals to be met, then perhaps including electricity that comes from low-carbon or no-carbon sources can be considered a similar outcome to saving energy. Renewable energy by definition means that the source has no external inputs that deplete over time which is the reason society wants to 'save energy'. If this logic is sound then using the renewable DG sources can also contribute to 'saving energy' by not using a resource which can be depleted such as coal and natural gas. In this case, run number 10 shows the amount of electricity that is saved from EE and further saved from the amount that comes from FIT/DG that is based upon solar photovoltaics. This run indicates a total savings of approximately 8,800,000 kWh or 4.2% savings from run number 1 which represents 'business as usual'.

4. What changes in the regulatory environment would improve the prospects for adopting these policies?

Although HEC has no regulatory obligations, it is worthy to discuss how these strategies might affect regulatory policy for other utilities since the model is designed to serve other regions and utilities too. A Feed-in Tariff is normally a regulatory policy that could help HEC by lowering peak demand costs. A problem arises from the utility having to absorb the cost of these payments. FIT costs, the amount paid to the owners of the DG, would have to be recovered in some way to make it viable to the utilities. Some FIT plans have tried to recover costs through a tax vehicle but because taxes are political in nature, this method has a high failure rate [10]. Other FIT programs add a charge to the customers' bills. This extra charge could be split evenly across all customers as a fixed fee or it could be in the form of a per kWh rider. The application of the rider could protect certain types of customers such as intensive users of electricity like heavy industry or the rider could be restricted from low income customers [56]. The idea is to promote the DG that the FIT pays for but spread the new cost over a larger group. These rate policies would have to implemented through some form of regulatory body. For HEC, that would be its board of Commissioners. For other utilities such as Dominion Virginia Power, that authority would be the State Corporation Commission. FIT plans have been proposed at the local, state, and even federal level in the past but have had little success. Having a more flexible regulatory environment and progressive political climate would help FITs to be implemented.

Another recurring issue for DG and its implementation is the problem with power islanding. This problem occurs when a grid connected generating source such as solar PV continues to produce electricity after the rest of the grid as failed. This failure may come from storm damage or from utility work that requires removing power from distribution lines. The utility is concerned for the safety of its personnel as well as damage to its equipment from the errant PV source. With the advent of advanced power electronics, this threat is easily addressed. The problem lies with the regulatory and other oversight bodies that set standards for the industry. They have been slow to adopt changes that require these new capabilities. Currently, there are proposed changes to the two main standards in this area. They are sections of the IEEE 1547 and UL 1741 standards that address the issues associated with islanded power sources so DG can serve as standby power and continue to operate after the rest of the grid has failed. The bodies that adopt and enforce these standards need to move as quickly as possible to allow for the expansion of FIT/DG policies.

The last potential influence that regulators can have on these strategies is in the area of Energy Efficiency implementation. By allowing or requesting utilities to promote these measures, the regulators can accelerate their adoption. There are incentives that utilities have been given to implement EE policies with their customers. These come in form of tax breaks or credits and must be approved by legislative bodies which are certainly regulatory bodies. As with the FIT policy, a more progressive political climate will be necessary to widely implement these type of incentives. Otherwise, implementation of EE will take much longer as we wait for better product and cheaper costs.

Conclusions

The concluding thoughts for this paper relate to the lessons learned and what further action might be taken to enhance the model and create a more useful tool for its intended user audience.

This paper is a culmination of hundreds of hours of research and modeling effort. The author is convinced that there is little disagreement about the challenges ahead for the electricity sector of the energy future in the U.S. The difficulty lies in the debate on how to solve them. Hopefully this thesis has addressed a portion of this debate and pointed to the utilities as being the key stakeholder in making meaningful changes. Through the simulations and conversation with HEC, this thesis has shown that there are possible strategies that can be implemented to help meet the new energy policy goals of cheap, secure, and clean.

Although this thesis represents a great deal of work, the project is still not complete. There are several areas that need further attention and study.

First and foremost, it is important to expand the time scale of this analysis to see multiyear behavior of the stakeholders. Many human behaviors cannot be studied on a scale of less than one year. The adoption of technology, the acceptance of new ideas, and the changing of how people behave all take years to measure. Although the longer term dynamics did not have immediate interest to the client, knowing or at least trying to understand possible outcomes of new strategies has to make sense to any business. Understanding the give and take of the regulatory process is also important to many of the potential users of this simulator. The current model is built to accept these new feedbacks and has already included some. However, due to the size and complex nature of the model it might be more practical to build a more aggregated (having less detail) model with just corporate and consumer behaviors accounted for and fewer measurable quantities such as the hourly load data used in this model. A more aggregated model would simplify the structure and show the new, long-term behaviors more clearly. It might not be necessary to see the interaction of the human behaviors with electricity metrics to the detailed perspective that this paper's model provides.

The other area where the model could be augmented and improved would be in the market dynamics of the pricing of the strategies. The stated goal of a FIT is to create a market for renewable energy so that economies of scale may be realized. Currently there is no feedback or other mechanism that deals with this dynamic. It may be instructive to include a mechanism to alter the capital cost of the strategy as market penetration grows. This effect has been well documented in the successful implementation of FIT's around the globe[10]. This mechanism could also be applied to the EE strategies. LED lighting prices have dropped significantly over the past 10 years because of greater market size which leads to new research and development for better efficiencies and greater market competition over time.

An area that needs further analysis is in the introduction of Time-of-Use rates for HEC. As stated earlier, it is common understanding that TOU is beneficial for utilities and difficult for homeowners to use for their advantage. In the case of HEC, the load data used in the model is the utility's total load that is rationed by customer class. It may be found that the load data shape (size of peaks and troughs) for all customer classes is different than the shape for just the residential class. In other words, the total loads may have different percent load changes during the day than the residential class. There are other customer classes that might contribute greatly to the overnight loads such as street lights or industrial users that would cover up the significant drops in residential troughs. If this is in fact the case, then the residential swings might be greater than modeled and the TOU rates would have a greater detrimental effect on the residential customer class leading to a better scenario for HEC.

The last comment is an invitation. There are many topics discussed in this paper and the author recognizes that the reader may have expertise that can shed additional light on the strategies and models developed here. If the reader has suggestions for model improvements, please contact the author, Brooks E Taylor at TaylorBE@Dukes.JMU.edu.

Hopefully you have gleaned some new insight or even have formed new ideas about the problems presented and their possible solutions. That, of course, is the major goal of the work.

Respectfully submitted,

Brooks E Taylor