# The Sector Map Methodology for Evaluating Energy Affordability Programs

H. Gil Peach, Ph.D.
Anne West, B.S.
Howard Reichmuth, P.E.
Ryan N. Miller, M.S.

**ABSTRACT**[1]

In the United States, many low-income customers of natural gas, electric and water utilities have trouble paying their utility bills. This problem is becoming more widely experienced and more frequent since real income is decreasing for many households, trending downwards since the early 1970's. Customer assistance programs are designed to help make these bills affordable. Affordability of utility service is the most important criterion to use in evaluating customer assistance programs. The Reichmuth Sector Map method shows whether and to what extent a utility offers affordable bills to its low-income customers. The method yields results that are sharp and unambiguous in an area in which results have often been cloudy or even misleading. The Sector Map is a modeling tool that shows the full population in a color-coded grid format with an identical number of homes within each cell. This paper provides a short contextual introduction and provides an example of the technical method.

## I. INTRODUCTION

Prior to the sector map approach, low-income customer assistance programs were designed according to the criterion of "increasing affordability" or "moving in the right direction." The criterion for evaluation was how the program worked "on average" overall or "on average" for large blocks of customers. However, the point of affordable bills is not to serve an "average" customer or an "average low-income" customer. The root question is whether or not affordable natural gas, electricity, or water is provided to every customer. A subsidiary question is which customers are provided affordable bills and which are not, and there are other matters of degree of affordable service.

The premise of the sector map approach is that the public interest is served when each household is presented with affordable energy and water bills. Sector maps are a useful tool in achieving this

---

[1] Suggested Citation: Peach, H. Gil, Anne West, Howard Reichmuth and Ryan N. Miller, "The Sector Map Methodology for Evaluating Energy Affordability Programs," technical paper presented at the Seventeenth Annual Conference of the American Evaluation Association meeting in Sparks, Nevada, November 2003.

objective. They can be used to optimize an affordability program; to make a program more cost-effective, efficient, and accountable.

# II. THE CONTEXT

The choice among available technical methods stems in part from consideration of the measurement problem (specifically, what is to be measured) and in part from the social and material context (including history or development). We assert that for evaluation of affordability programs the Sector Map approach (or something like it, that is, a method that shows the full distribution of homes so that material effects can be fully understood across the distribution) is a requirement for valid and precise analysis and for clear presentation of results.

## A. The Problem with Averages

In addition to the problems introduced by the fact that the word "average" could signify a mean, median, or a mode or that a mean might be an arithmetic mean, a geometric mean, or some other kind of average, there is the problem of the behavior of the arithmetic mean of a highly skewed distribution (Huff 1954). We now commonly speak of a "Lake Wobegon Effect" after a popular radio show on National Public Radio. In Lake Wobegon "all the children are above average." Work with income and cost distributions shows a "Reverse Lake Wobegon Effect" where "nearly everybody is below average." The skew of income distribution causes this effect. A few very high income individuals can raise the average income of a community to a level above that which most members of the community actually experience (Huff 1954). Income in the United States is currently highly skewed (Brouwer 1998).

Inequality of income is illustrated in Figure 1. It is obvious in this figure that analysis based on the "average" customer would be inherently misleading. With the top 5% of households claiming more than one-fifth of the household income (or the top 20% of households claiming about half of all household income) any calculations including these groups would obfuscate the material situation of bills and income of the bottom 80% of households. The inherent failures of such analysis would be especially extreme for the bottom 20% of households who share less than four percent of household income.

So as not to be unintentionally misleading in calculations or in presentation of results, work that relates costs of essential services and incomes should employ distributions rather than averages.

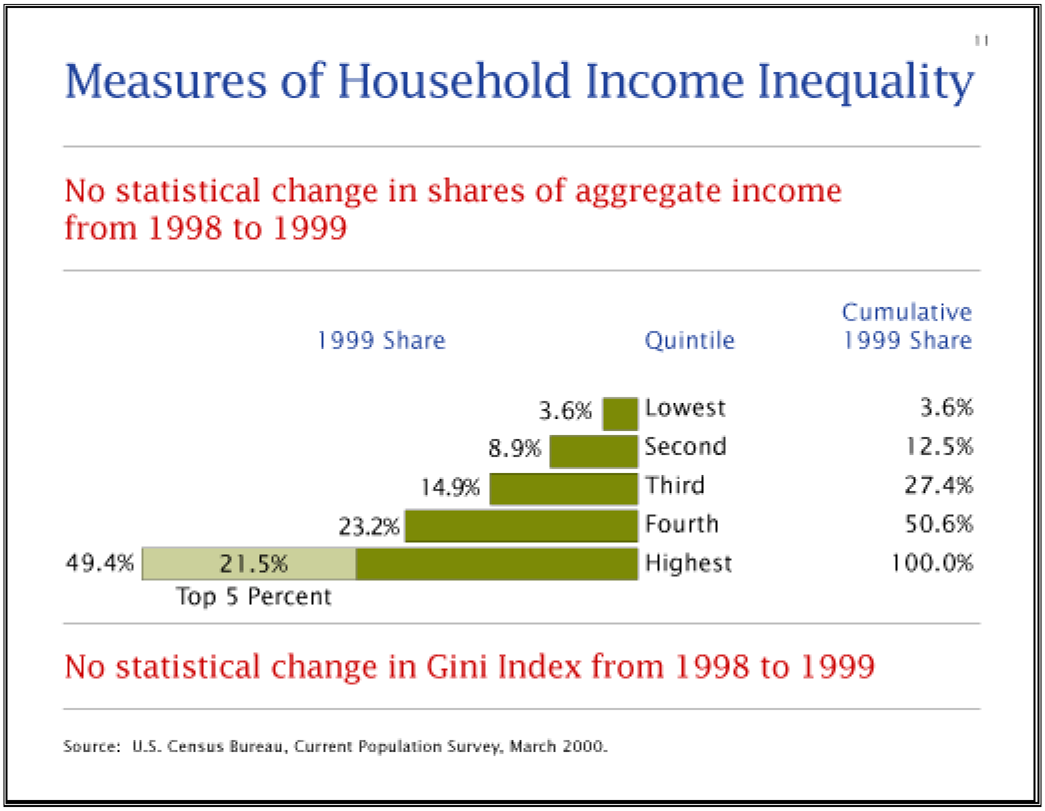



**Figure 1: Unequal Income.**

### B. A Legal & Regulatory Concern

There is also a legal and regulatory concern. This is a question of public intent expressed in law, regulatory directives and guidelines. Generally, regulatory and legal formulations concerned with affordability do not specify that regulations or law applies "on average." Instead, regulations and law apply equally. For this reason analysis of low-income issues must incorporate distributional concerns,and the choice of appropriate technical method has an inherent ethical character. There is a moral imperative to select distributional techniques over techniques that employ or produce results in the form of averages.

To put this another way, for example in the State of New York, law or regulation should apply with equal effect to top households and to households in the bottom 20% of the income distribution (See Figure 2, in which Census 2000 data is presented as an income donut). Of course, a material application of the principle of equality would not be that noted by Anatole France who "…celebrates the impartiality of law by remarking that rich and poor alike are forbidden to steal bread or to sleep under bridges.[2]" It is exactly and materially the other way around; legitimate law and legitimate

[2] Quoted in Joseph Wood Krutch, The Measure of Man, P. 53 (Krutch, J. W. (1954).

regulation exerts a positive force to insure the material welfare of the community as a whole by preventing the social exclusion of any household, even one.

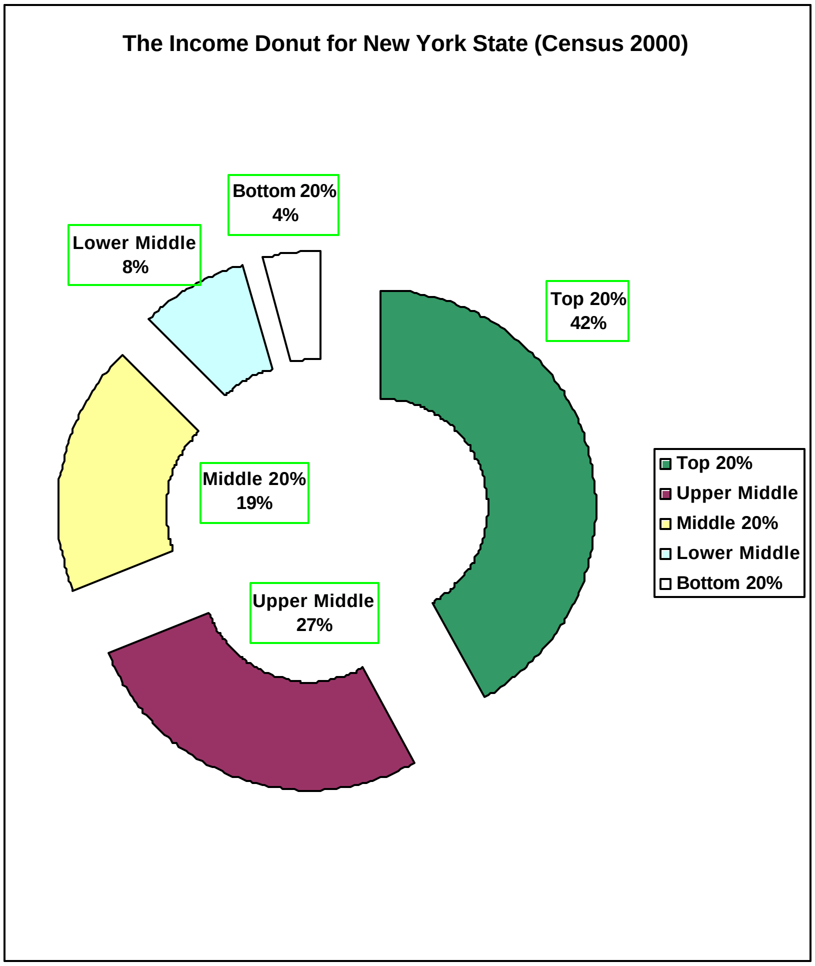



**Figure 2: Distribution in State of New York**

## C. Social Tendencies

The dominant social tendency is the de-development or the "under-developing process" of the United States as a whole due to the effects of globalization. These effects include increasing inequality and distributional allocations that are pulling the society apart giving rise to a small, ever richer, elite and a large number of subordinated households that lose real income from year to year, sometimes dramatically.

### *1. Increasing Inequality*

The Gini Coefficient is used to quantify the inequality of income distribution. In Figure 2, the straight line from bottom left of the graph to the top right of the graph is the reference line. This 45 degree line represents an equal distribution of income to all households. Actual income distribution is shown by the curved line. The Gini coefficient is the ratio of two areas on the graph. The area between the actual income distribution and the reference line is divided by the area below the reference line.

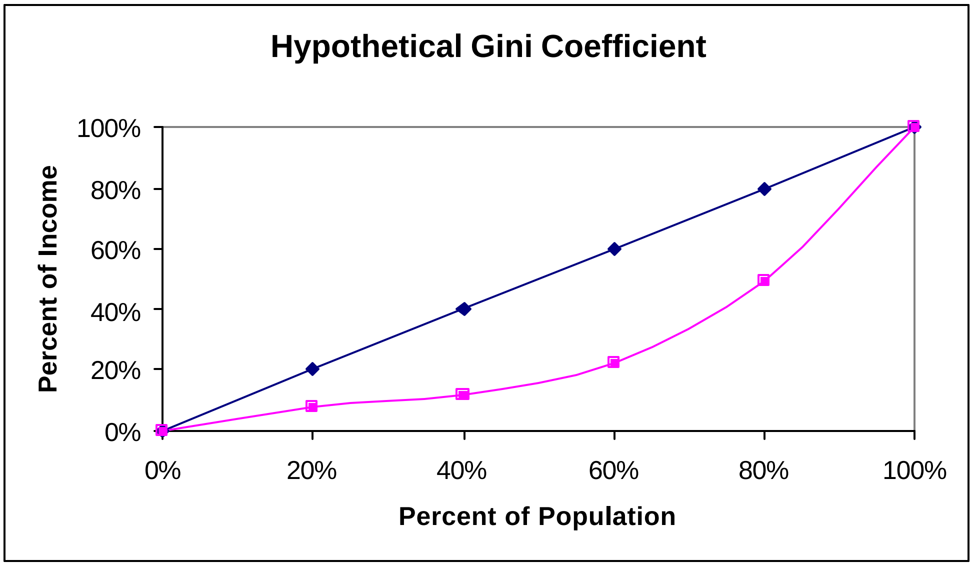



**Figure 3: High Inequality of Income.**

If income were distributed equally, the Gini coefficient would be zero ("0"). At the other extreme, the Gini coefficient would be one ("1"). In general, industrial democratic societies moved from having a high Gini coefficient in the early stages of their transformation to a business system to a low Gini coefficient. High Gini coefficients are traditionally associated with underdevelopment – markers of societies in which income is highly concentrated within a small economic oligarchy at the top, with a very small middle class and a vast number of impoverished people at the bottom.

The Gini coefficient for the United States in 1998 (according to the Census Bureau) was 0.456. To interpret this, inequality has increased notably in the US since the beginning of the 1970s. *The US has crossed a border to re-enter the region of underdeveloped countries.* This is part of a global trend of increasing inequality also affecting many European countries as globalization becomes a stronger force across national economies. However, the effect is much stronger for the US than for Europe (the Gini coefficient for Canada is about 0.37, for Germany approximately 0.33, for Norway about 0.26).

### 2. *The Severity of Distributional Effects*

The Center on Budget and Policy Priorities has analyzed federal data on incomes for families and for families with children (Bernstein 2000; Bernstein 2002). Figure 4 (for families) and Figure 5 (for families with children) show these results for the US as graphs, after adjusting the series to use a common deflator.

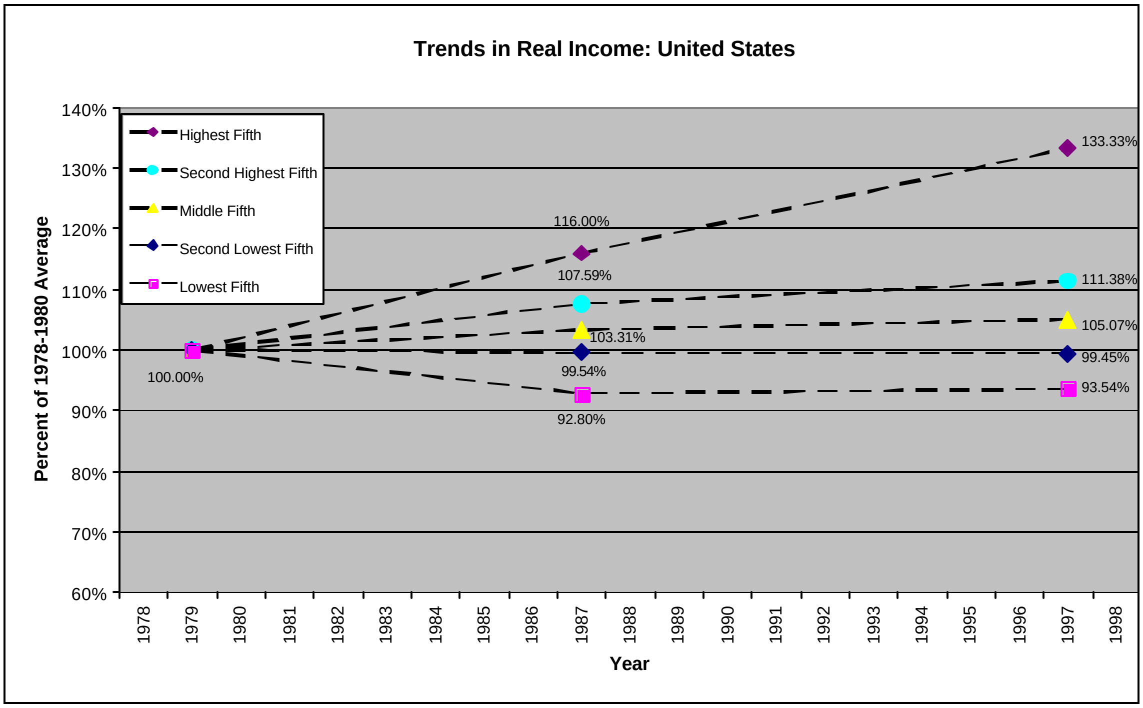



**Figure 4: Pulling Apart - All Families.**

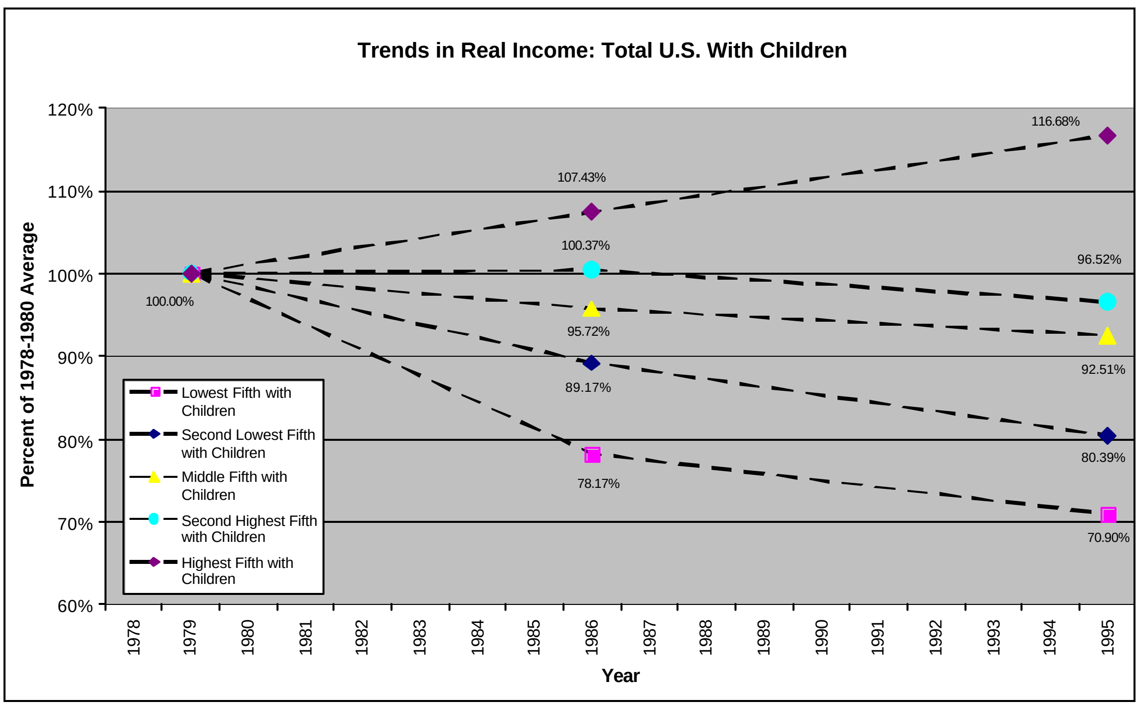



**Figure 5: Pulling Apart - Families with Children.**

As shown in Figure 6, the income effects in are more extreme. In contrast to the national pattern of dramatic increase in relative income (Figures 4 &5), there is a decline in real income even in the top quintile of the city. At the same time there is a radical drop in real income in the bottom quintile of over 54%.

**Figure 6: Income Changes.**

| City vs. Suburbs: Change in Average Real Income 1986-94 | | |
|---|---|---|
| **INCOME GROUP** | **CITY** | **SUBURBS** |
| **Poorest Quintile** | **-54.2%** | **-42.5%** |
| **Middle Three Quintiles** | **-24.5%** | **-11.1%** |
| **Richest Quintile** | **-6.4%** | **+4.3%** |
| Source: Table 7.1, P. 67, Jonathan A. Saidel, City Controller, *1997 Mid-Year Economic and Financial Report*. Philadelphia: Office of the Controller, March 1997. | | |

### 3. *An Economic Theory*

Consider two straight lines that cross, intersecting in a single point. One is called "Demand for Labor" and the other is called "Supply of Labor." These are demand and supply schedules for a locality such as Seattle. The rectangular coordinate system against which these lines are drawn has price (cost of labor) on the vertical axis and supply (of labor) on the horizontal axis. Now suppose we limit the quality and kind of labor represented by the supply and demand lines on the graph to high-level computer programmers.

Next, assume that the market for computer programmers is suddenly (over perhaps seven years) globalized. This allows computer programmers in India and China to compete with the Seattle programmers for the same jobs. However pay in India and China for highly skilled programmers is about 1/12 of the pay package in Seattle. Now Seattle software companies open branch offices in high tech centers in India and China. This shifts the demand curve in Seattle lower – local employment drops dramatically. Also, while it is physically necessary to retain some key positions in Seattle the existence of the outsourced operations in India and China restrains both hiring and pay for the positions that remain.

Take this example across the range of manufacturing and office/professional jobs and the result is the conversion of most of the geography of the US into a peripheral (at the limit, a "third world") economy. Globalization has radical structural implications for everyone below approximately the 88% or 85% point in the income distribution. Below that point, real income will decrease, with the biggest effect on those who start from the least position. Thus it is essential that the distribution of real income be taken into account in all analysis of costs of essential services.

*4. Other Considerations*

**Effectiveness and Clarity:** Edward R. Tufte (Tufte 2001), employing the imagery of *Flatland* (Abbott 1952) stresses that good display will attempt to escape two dimensional arrays – "Escaping this flatland is the essential task of envisioning information…. " While the sector maps exist in 2-space, they do include additional dimensions in their design. And, because the problem of affordability has a legal and regulatory dimension, in a more general sense the Sector Maps conform to Tufte's (P. 31) recommendation to use graphical representation to contrast with the linear speech patterns of courtroom presentations.

**Develop Full Information; Avoid Obfuscation and Masking Effects:** Tufte (Pp. 22-23) cites R.A. Fisher's comment on the move within the field of statistics from a focus on averages to a focus on variation (Fisher 1941):

> "…the study of the causes of variation of any variable phenomenon…should be begun by examination and measurement of the variation which presents itself."

As Fisher notes, statistics is concerned with distributions. A distribution contains a richness of information that an average (as a summary statistic) does not. While the average may always be developed from knowledge of a distribution, the full information provided by a distribution is obscured in the form of an average.

**Public Interest:** Finally, Joseph Wood Krutch (P 41) interprets Bernard Shaw's declaration that "the only trouble with the poor is poverty" as meaning simply that poverty is the single dimension of being poor that "…society can most easily control." The Sector Maps show this dimension without ambiguity. The Sector Maps also show how easy it is to control affordability of natural gas, electricity, and water when the maps are used to directly drive utility rate design. Krutch notes (Pp. 32-33) that "…the methods employed for the study of man have been for the most part those originally designed for the study of machines or the study of rats, and are capable, therefore, of detecting and measuring only those characteristics which the three have in common." Although a short step, moving from averages (and the implied normal distribution) to the actual distribution of income in relation to cost is a step into a broader dimension.

## III. SECTOR MAP EXAMPLE

The Reichmuth Sector Map can be demonstrated though an example. The example is based on a combined gas and electric utility in a major Eastern city and for simplicity is limited to households from 1% to 50% of the Federal Poverty Level (it can easily be extended to 250% of the Federal Poverty Level which is the upper limit of a practical definition of poverty).

Low-income households in the range from 1% to 50% of the Federal Poverty Level exist not in only one economic circumstance, but in several. For example, life with income at 50% of the Federal Poverty Level is considerably better than circumstance when income is below 20% of the Federal

Poverty Level. The Reichmuth Sector Map is used to review the "Universal Service" low-income program participants over the whole range of population variation. In comparison with previous analytic methods, this approach permits a much more exact accounting of affordability.

Prior to the use of Sector Maps, the primary tools for understanding the effects of program designs were considerably weaker. These older tools consist of the calculation of averages (means, medians, or modes).[3] Using the prior tools, a program approach could be demonstrated to work on average. But Universal Service law, orders, and guidelines are by definition intended to apply equally, not simply to work for the average customer. Particularly today, when we acknowledge and understand the value and reality of diversity, working "on average" or for a "typical customer" is simply not the relevant criterion. More to the point, the application of an affordability criterion requires equality of application

The Reichmuth Sector Map program as tailored for this study produces a set of conformance maps and associated summary maps. Each map distributes the Customer Assistance Program (CAP) population uniformly into a graphical format or rectangular grid. For the first part of the example, which involves provision of electricity, each square of the grid in the electric part of the analysis represents approximately 73 households.

One axis of each map (the horizontal or "x-axis") represents income level; the vertical (or "y-axis") of each map represents energy usage.[4] When the program population is organized in this manner, patterns in program indicators, such as energy burden (defined as energy bill as percent of income) become quite evident. The sector maps shown in Figures 7 & 8 illustrate the use of the Reichmuth Sector Map applied to a Customer Assistance Program population for electric service.

Figure 7 shows the energy burden as percent of income for the current CAP population at 50% Federal Poverty Level (FPL) and below.

- Most of the participants with incomes above 25% FPL, the right hand portion of the graph, have energy burdens in the range of 0-10% of income shown as a green area.

- The participants with the highest usage in this right hand portion are shown in the upper right with monthly bills in the range of 10% - 30% of income.

In Figures 7 and 8 each square represents 73 participant households. Counting the violet squares in Figure 7 in the upper left which show energy burdens of 30-40%, 21 squares indicate that about 1533 current CAP participants have energy burdens of 30-40% of income.

Figure 8 is in another use of Sector Maps. This type is used to show conformance with affordability as defined by the law or regulation (in this case, the Pennsylvania Code). In this figure, the blue area shows the CAP participants in conformance .. The un-shaded area shows that most households face electric bills not in conformance. In fact, only 15% of the current 1-50% FPL CAP program

[3] Distributional effects were typically shown by 'stem and leaf' plots, and the like.

[4] The horizontal axis shows customer income expressed as a percentage of the Federal Poverty Level. The vertical axis shows relative energy use (actual usage divided by the population mean usage).

participants are within conformance. The participants within conformance are shown to be those with usage well below the average and incomes higher than 25% FPL.

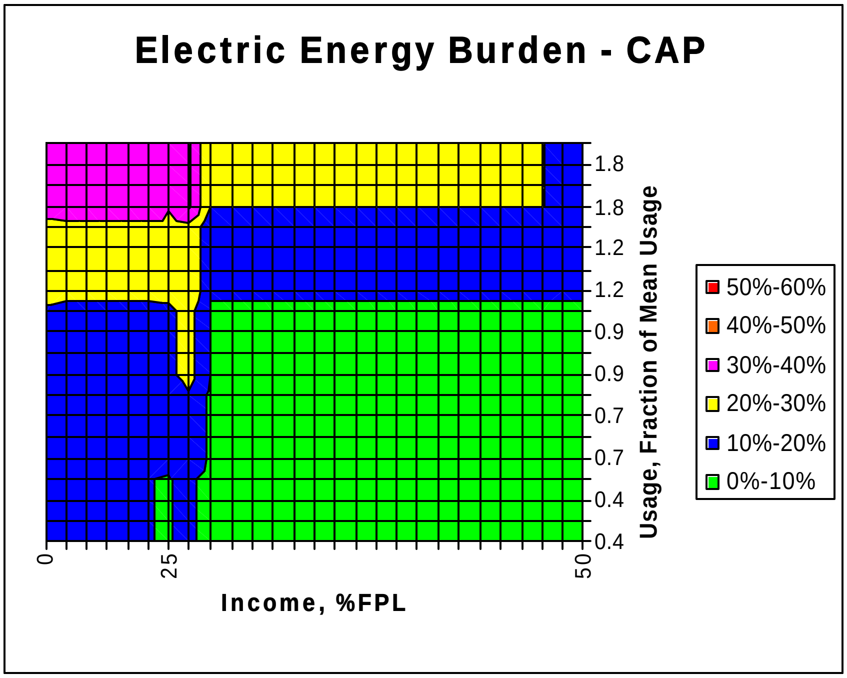



**Figure 7: Proportion of Income for Electricity.**

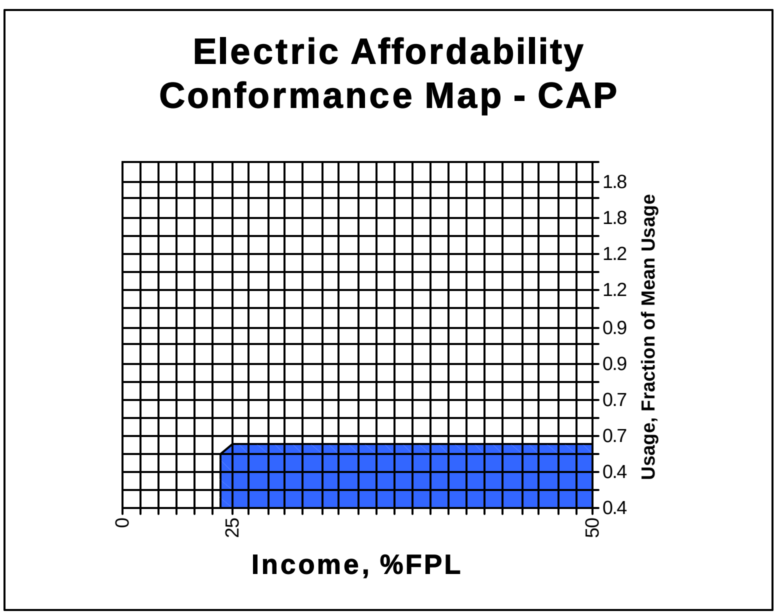



**Figure 8: Conformance with State Affordability Guidelines.**

Essentially the Sector Map is a simple model of the program population. Underlying the tailored application of the model is a set of detailed statistics describing the characteristics of the Customer Assistance Program population in terms of distributions of income, poverty level, and energy use. These characteristic distributions are derived from a study set consisting of 13,524 participants identified as current CAP participants in the Evaluation Database[5]. This study set contains all CAP participants with all the usage and income information required for developing the income and usage distributions used to characterize the population.

The characteristic distributions thus derived from the study set are general, and apply to the full current CAP population and to variations of this population associated with different program growth rates. The characteristic distributions are also detailed enough to support billing estimates of alternative program designs applied to the population. In this analysis the Sector Map is used *first to document* the detailed affordability situation facing current CAP participants. Then it is used *to explore* the affordability associated with alternative program designs.

To contrast alternative program designs, both a graphical form (a conformance map) and two numerical indicators are used. The numerical indicator for the dollar impact is the *difference* of the aggregate CAP Discount amounts of two contrasted program designs (the "ΔCAP discount") *with the Residential Rate held constant*.[6] In this analysis the CAP Discount is defined as the Residential revenue that would have been due minus the CAP revenue actually billed (Figure 9).[7] The important point to note is that the *change* in CAP discount is used to contrast and optimize designs. Note also in this definition of the Discount that no federal energy bill payments (LIHEAP) are included. This exclusion is for convenience. It allows a focus on the basic components of the program billing design with the LIHEAP collection effort considered equal between the reference case and the alternatives.[8]

---

[5] The distributions represent 34% of the 39,469 CAP participants (averaged over 12 months) reported by the utility.

[6] A number of different metrics could be used with equivalence. The metric "ΔCAP discount *with constant Residential Rate*" is simple and straightforward and the "delta" values tend to exhibit high stability across different estimates of program costs.

[7] The design metric used in this study follows from definitions included in the document, *Universal Service Reporting Requirements, Data Dictionary and Clarifications Offered by BCS*. The CAP Discount, as calculated here, is *modeled on but not identical to* the (Total) CAP Credit. The total CAP Credit is, in the first instance, the sum of the CAP credits for all customers who received CAP credits. As a first approximation, it is the difference between the standard billed amount and the CAP billed amount. For example, if the billed amount under the residential rate were $100 and the CAP billed amount were $30, the CAP credit equals $70. Preprogram arrearage forgiveness is not considered in this total. However, the calculation of the CAP Credit would include third party payments in the calculation, such as LIHEAP grants and hardship fund grants. The CAP Discount used in this report is a simplified CAP Credit. It excludes consideration of third party payments. It also excludes current CAP arrearage (payment rates of less that 100% of bill). Other metrics could be used equally well. However, the essential point regarding the CAP Discount and ?CAP Discount as developed for this study is that they are based on billing and do not include either CAP program arrearages (that is, payment rates of less that 100%) or LIHEAP and similar payments. These factors do not affect the development of program design. Use of simplified CAP Discount and ?CAP Discount versions of the CAP Credit facilitate the analysis and presentation.

[8] Conformance with the Pennsylvania Code CAP design elements is, in any case, separate from the objective of maximizing LIHEAP grant assignments.

**<u>Calculation of "Bottom-Up" ΔCAP Discount (Billing Basis)</u>**

CAP Discount$_1$ = GS Revenue Billed$_1$ – CAP Revenue Billed$_1$
CAP Discount$_2$ = GS Revenue Billed$_2$ – CAP Revenue Billed$_2$

**ΔCAP Discount** = (CAP Discount$_1$ - CAP Discount$_2$)

**Figure 9 "ΔCAP Discount" as used in Comparisons**

Specifically, the ΔCAP Discount expressed in dollars is the difference in the aggregate CAP Discount between the two cases. The ΔCAP Discount percent is the ΔCAP Discount for the alternative design divided by the CAP discount for the original design. For the purposes of this analysis the definition of affordability is aligned with the formal definition of an affordable utility bill as given in Pa Code, Title 52 section 69.265. [This is the definition given under the Section of Percentage o Income Payment Programs (PIPP programs.] These formal criteria of affordability as applied to the 0-50% FPL are summarized in Figure 9. (J is the rate rider denoting CAP 1 for 0-100% poverty.)

| CAP RATE | Minimum Bill | Maximum % Income |
|---|---|---|
| RJ (electric baseload) | \$12 -- \$15 | 2% -- 5% |
| RHJ (electric heat)<br>RJ / HJ (electric baseload with gas heat) | \$30 -- \$40 | 7% -- 13% |
| HJ (gas heat) | \$18 -- \$25 | 5% -- 8% |

**Figure 10: Affordability for CAP participants with Incomes less 50% of FPL**

For the purposes of evaluation, the top of the ranges will be used. For example, referring to Figure 10, a rate RJ utility bill is defined as affordable if it is less than 5% of the participant's income and at least \$15. This is a conservative assumption.

This definition of affordability is a formal one that also approximately expresses the practical reality facing low-income customers Therefore, this definition has been used for the affordability compliance criteria in the Affordability Conformance Sector Maps. Again, affordability has been set at the high end of the ranges.

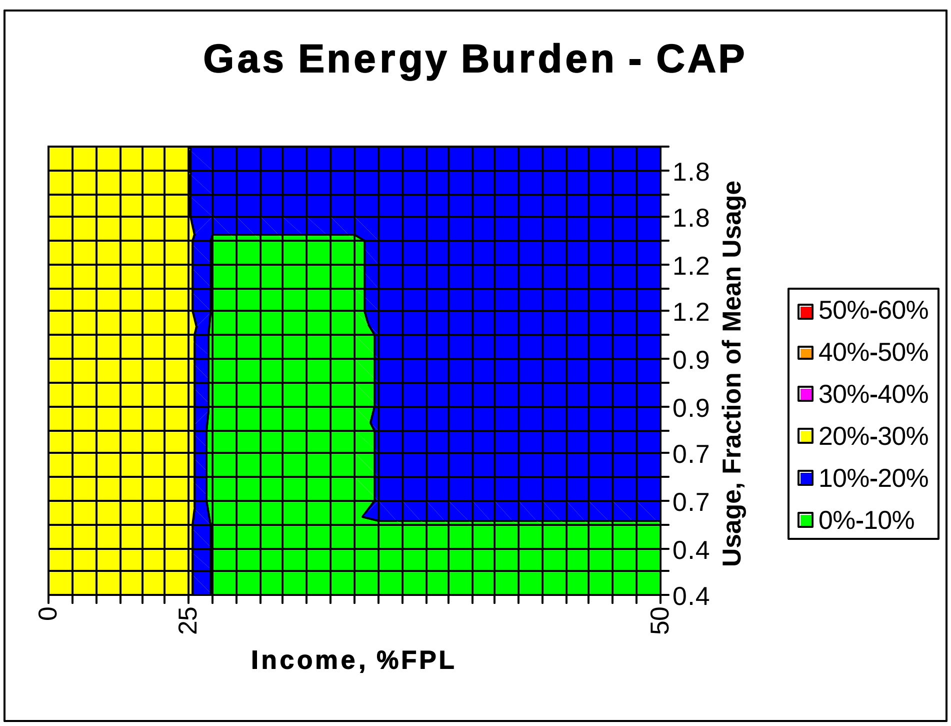
### Current Electricity Affordability

Using this conservative specification, the energy affordability situation facing current electric CAP participants is shown in Figures 7 and 8. These figures show that the only current electric CAP program participants with affordable electric bills are those with very low usage and with incomes above 25% FPL. Only about 15% of current CAP 0-50% FPL participants currently have affordable electric bills under CAP Rate. If these participants were not in the CAP program, they would face an average energy burden of 21%. Fifteen percent of the participants, those with the lowest incomes would face electric bills in excess of 30% of income. Without the CAP Rate program, none of the electric bills presented to this population would be affordable. Clearly, the electric bills presented to customers at or below 50% FPL predominantly exceed the affordability criteria. Almost all of the bills presented to non-CAP customers in this population are not affordable. Only fifteen percent of the bills for CAP Rate participants are affordable.

### Current Natural Gas Energy Burdens

The situation facing gas CAP program participants in the 1 to 50% FPL range is illustrated in Figure 11, a sector map of the gas energy burden for these participants. Note that the sector maps for gas CAP participants or gas and electric CAP participants cover a much smaller number of participants (6,210), and therefore each square in the sector map represents 12 households.

**Figure 11: Gas Energy Burden.**



Gas energy burdens for these participants range from 10% to 25%. 10% of the gas CAP participants see gas energy bills that meet the gas energy affordability criteria, though the participants with the highest incomes and lowest gas use almost fit the affordability criteria.

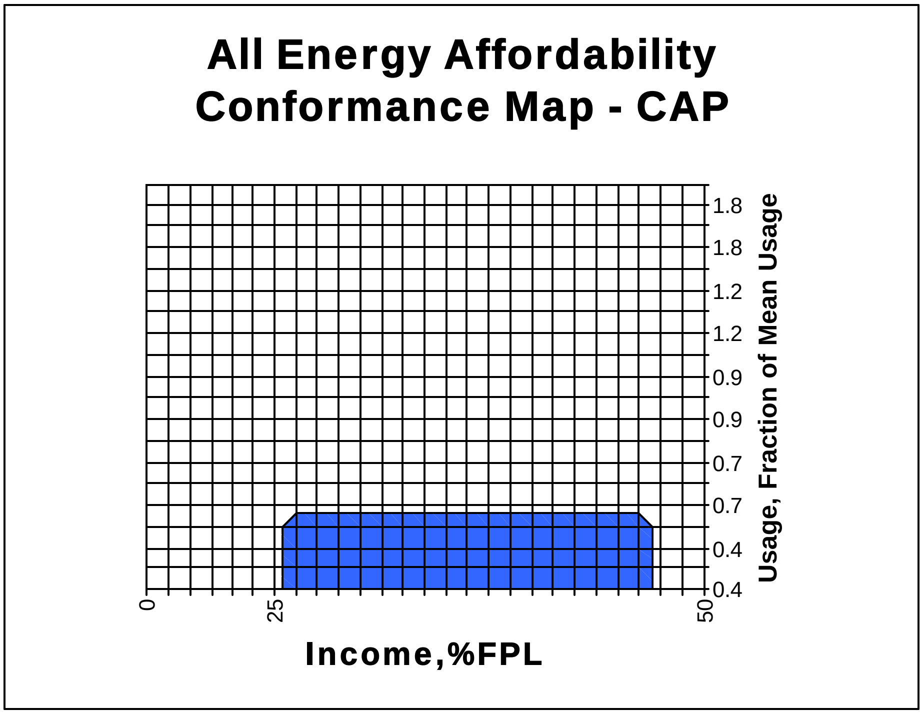



**Figure 12: All Energy Affordability**

Total energy affordability conformance for gas and electric customers with CAP rates is shown in Figure 12. This figure shows that gas and electric CAP participants with incomes above 25% FPL and with below average usage do fall within the affordability guidelines. In all, 14% of the current gas and electric CAP participants fall within the affordability criteria.

### Steps Toward Electric Bill Affordability

The next step in the analysis of electric bill affordability is to explore and test modified CAP Rate designs and other program alternatives against the affordability criteria in Figure 10. The current CAP Rate program designated as Step 0 in Figure 13 (Step 0 is shown in graphical form in Figure 8). The program design is then modified one step at a time in an attempt to increase the number of participants in conformance with the affordability criteria of the Pennsylvania Code (Figure 10). The affordability optimization criterion is "Fraction in conformance," in the final column of Figure 13. Cost optimization is given by "Delta %."

| Step No. | Design Change | Aggregate Delta CAP Discount (low bound 39,500) | Aggregate Delta CAP Discount (high bound 90,000) | Delta% (Low Bound) | Electric Bill % Discount from Res | Fraction in Conformance |
|---|---|---|---|---|---|---|
| **Step 0** | Current CAP | $0 | $19,774,916 | 0.0% | 35.9% | 15.3% |
| **Step 1** | Increase eligible kWh to 2000/mo | $4,834,132 | $30,789,393 | 31.3% | 48.4% | 15.3% |
| **Step 2** | Increase discount to 60% | $9,391,008 | $41,172,149 | 46.3% | 60.0% | 16.9% |
| **Step 3** | Increase discount to 70% | $13,281,301 | $50,036,109 | 53.4% | 70.0% | 50.6% |
| **Step 4** | Increase discount to 77% | $15,852455 | $55,894,434 | 55.7% | 77.0% | 73% |
| **PIPP (reference case)** | | $15,852,455 | $55,894,434 | 50.4% | 72.4% | 100% |

**Figure 13: Steps Toward Electric Bill Affordability**

Data and calculations for Figure 13 are based on all CAP customers provided by the utility for the evaluation database with poverty recorded from 1% through 50% of the Federal Poverty Level who are also recorded as on a “J” Rate (that is, who are billed within the first tier of the current two-tier discount). The dollar values reported have not been subjected to a final true-up with utility financial records and so may vary from utility estimates depending on assumptions, however the “Delta %” values are stable (will not change when the true-up is carried out). For simplification, LIHEAP is not included, nor are program administration and program savings offsets.

In Step 1 the eligible monthly kWh subject to the CAP Rate is increased from 500kWh/mo to 2000 kWh/mo. This removes the “500 kWh limit” for RJ and RHJ customers whose incomes are below 50% of the poverty guidelines (Figure 14). The CAP discount would be approximately 31.3% higher than the alternative of no change to the current CAP Rate design. The increase in affordability is negligible (Figure 14).

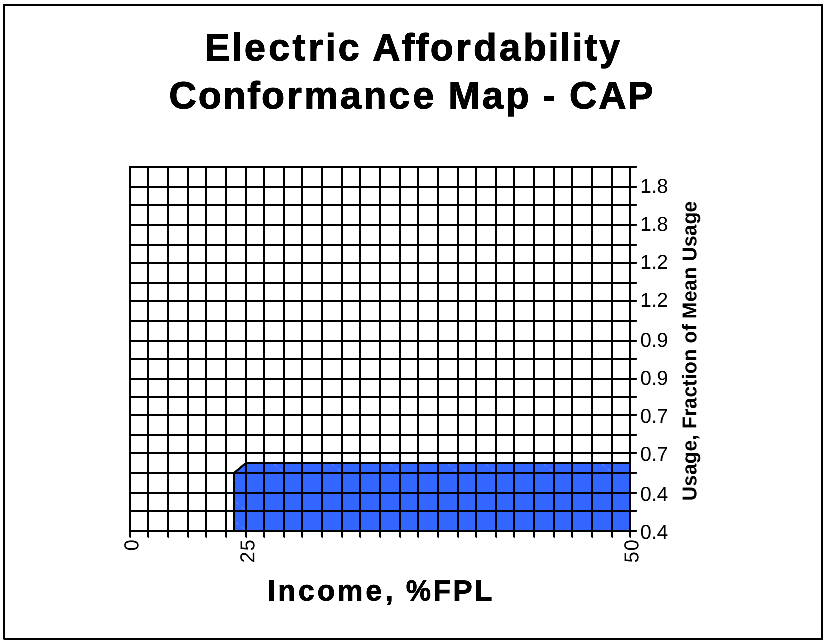



**Figure 14: Step 1: Increase kWh Limit from 500 to 2000 kWh/mo.**

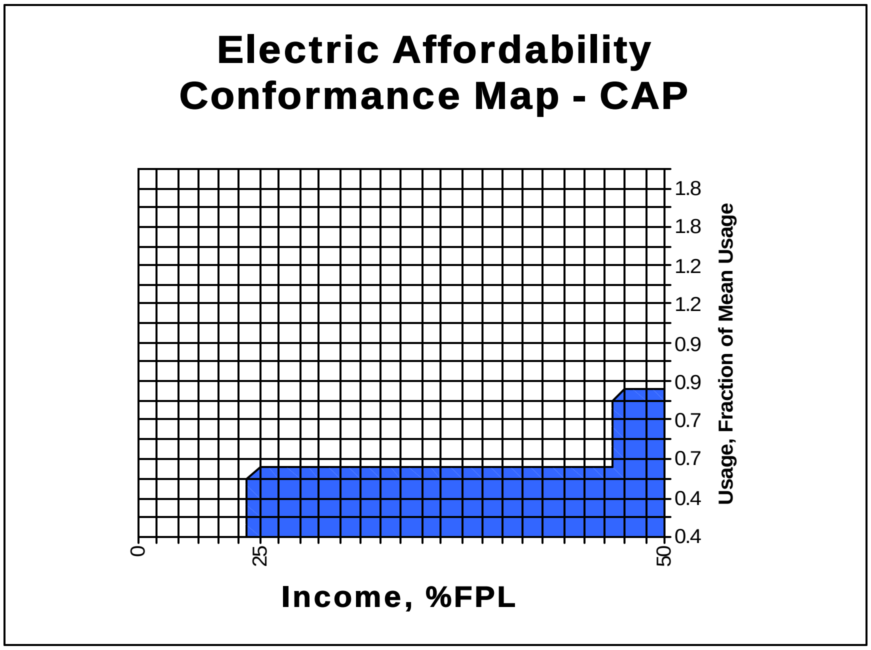



**Figure 15: Step 2 -- Increase Discount from 35% to 60%.**

In Step 2 the CAP rate is reduced so that the average CAP Rate electric bill is reduced from the current 35.5% of the bill under the standard rate to 60%. This large change only slightly increases the conformance.

In Step 3 the CAP Rate is further reduced so that the average CAP Rate electric bill is reduced from 35.5% of the bill under the standard rate to 70%. This brings 50% of the participants into conformance.

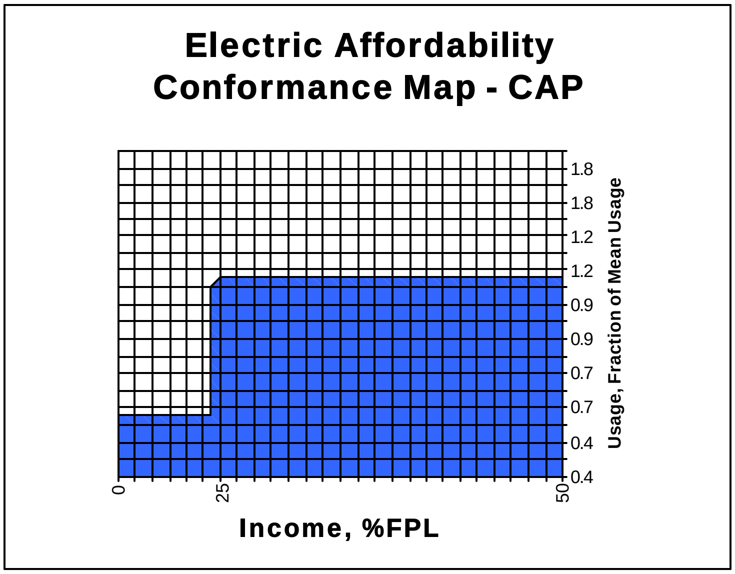



**Figure 16: Step 3 - Increase Discount for 35% to 70%.**

In Step 4, the CAP Rate is again further reduced from 35.5% of the bill under the standard rate to 77%. Even a drastically reduced CAP Rate for the group of customers at or below 50% of the Federal Poverty Level still leaves about 27% of customers (including those with the lowest incomes and higher usage) facing electric bills exceeding the affordability definition of the Pennsylvania Code.

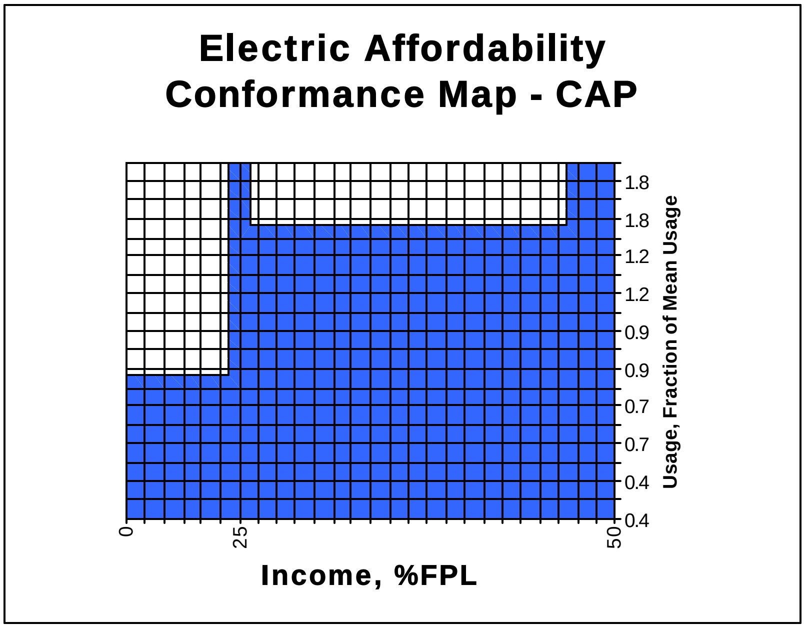



**Figure 17: Step 4 -- Increase Discount from 35% to 77%.**

**A design dilemma:** Setting a common discount for a large block of customers (as in the current two-tier structure of CAP Rate) poses a contradictory situation. If the CAP Rate is set low enough to bring households in the lower regions of the block into conformance with affordability of bills as defined by the Pennsylvania Code, then the rate will be too low for the middle to upper part of the block. Households in those ranges will enjoy a free ride on rates that are set well below where they would be placed according to the affordability criteria. There are two ways to control this problem: add several tiers, or go to a Percentage of Income Payment Plan (PIPP) design.

This step demonstrates that there is a significant diminishing return from lowering a CAP Rate. This diminishing return effect illustrates that the CAP Rate is structurally incompatible with the affordability conformance criteria.

The PIPP reference case (Figure 13, bottom row) produces 100% conformance with the affordability of bill definitions of the Pennsylvania Code. This means that the Conformance Map for the PIPP would be entirely blue (not shown). From a billing perspective, it substantially reduces under billing of customers compared to a CAP Rate design with large rate blocks. The PIPP reference program illustrated here is exactly aligned with the affordability criteria and represents the maximum billings that can be collected consistent with the affordability criteria.[9]

[9] **Mathematical Proof:** A mathematical proof that the PIPP rate design yields the maximum aggregate billing consistent with an affordable rate is, briefly, as follows: the billings for any rate design will include a portion comprised of over billings and a portion comprised of under billings relative to the affordability criteria. For rate designs that fully comply with the affordability criteria, the over billed portion is zero and the billing difference between rates rests in the under billed portion. For the case of a rate exactly congruent with the affordability criteria the under billed portion is also equal to zero. This congruent rate therefore represents the highest aggregate billing that can be associated with a fully affordable rate. This is the rate tailored to each household, the PIPP.

**Figure 18: Steps Toward Gas Bill Affordability.**

| Step No. | Design | Aggregate Delta CAP Discount from Res low bound | Aggregate Delta CAP discount high bound | Delta% | Gas % bill discount from Res | Fraction in Conformance |
|---|---|---|---|---|---|---|
| Step 0 | Current CAP | $0 | $1,940,807 | 0.0% | 29.3% | 9.8% |
| Step 1 | Average discount from 30% to 69% | $1,846,550 | $6,148,136 | 121.6% | 65.0% | 81.3% |
| Alt. Step | PIPP reference case | $1,629,776 | $5,654,220 | 107.4% | 60.8% | 100% |

### Steps Toward Gas Bill Affordability

Gas CAP Rate participants will have gas bills that meet the affordability criteria if the gas CAP Rate is significantly reduced. Figure 18 summarizes the effects of a stepwise reduction in gas CAP Rate in a manner similar to that applied to the electric CAP Rate.

Step 0 represents the current gas CAP Rate. In Step 1 the gas CAP Rate is markedly reduced so that gas bills are reduced from standard gas bills by 65% instead of the current gas CAP reduction of 30%. Even with this large reduction, approximately 19% of the gas CAP participants remain outside the affordability criteria.

**A design dilemma.** The same diminishing returns phenomenon applies to the gas CAP Rate as to the electric CAP Rate. In Figure 18, a gas PIPP presents affordable bills to 100% of the gas CAP participants yet it reduces the average gas bill by 61% instead of the 65% reduction tested in Step 1. Here again, a PIPP Rate exactly congruent with the affordability criteria will produce the highest bills consistent with the affordability criteria. The PIPP approach provides the best fit to the affordability guidelines of the Pennsylvania Code. It is also the least-cost alternative, provided that the utility is committed to providing affordable rates to low-income customers.

A rate discount approach cannot approximate this result unless it is split into many tiers. However, in that case, it approximates a PIPP in the limit. From the customer, least-cost to the Company, and regulatory compliance perspectives, a PIPP approach is the better approach than a rate discount.

**Summary**

The current rate discount approach does not work in relation to actual customer household incomes and energy use for customers with lower incomes and higher energy use. In fact, it does not work for most customers below 50% of the Federal Poverty Level.

Prior to the employment of Sector Maps, the above analysis would have been conducted on the basis of averages or of averages within customer income blocks. Using an analysis based on averages as the criterion for analysis and for program design, neither precise analysis nor clear presentation could have been achieved. Further, optimal design could not have been grounded. The incorporation of distributional complexity is a small step beyond the analysis based on the summary data contained in averages. But without it, optimal analysis and optimal design is not possible. The Reichmuth Sector Maps provide a means for optimal analysis and optimal design.

## IV. REFERENCES


Abbott, E. A. (1952). *Flatland; A Romance of Many Dimensions*. New York,, Dover.

Bernstein, J., Elizabeth C. McNichol, Lawrence Mishel & Robert Zahradnik (2000). Pulling Apart, A State-by-State Analysis of Income Trends. Washington DC, Center on Budget & Policy Priorities and Economic Policy Institute.

Bernstein, J., Heather Boushey, Elizabeth McNichol & Robert Zahradnik (2002). Pulling Apart, A State-by-State Analysis of Income Trends. Washington DC, Center on Budget & Policy Priorities and the Economic Policy Institute.

Brouwer, S. (1998). *Sharing the Pie, A Citizen's Guide to Wealth and Power in America*. New York, Henry Holt and Company.

Fisher, R. A. (1941). *Statistical Methods for Research Workers*. Edinburgh [etc.], Oliver and Boyd.

Huff, D. (1954). *How to Lie with Statistics*. New York, W.W. Norton & Company, Inc.

Krutch, J. W. (1954). *The Measure of Man; on Freedom, Human Values, Survival, and the Modern Temper*. Indianapolis,, Bobbs-Merrill.

Tufte, E. R. (2001). *The Visual Display of Quantitative Information*. Cheshire, Conn., Graphics Press.


Note: Authors of this paper may be contacted through the website: www.peachandassociates.com.