# Improved Hours-of-Use via Double Ratio Estimation

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**Introduction.** This poster presents a "double ratio estimation" approach to hours-of-use research, a novel application of an established statistical technique which is expected to leverage existing data better than other popular methodologies. Lighting measures are the foundation of most energy efficiency programs nationwide. Decades of research have shown that annual operating hours is the single most important variable in the development of confident estimates of lighting energy savings. Program administrators routinely sponsor hours-of-use studies to refine deemed estimates, e.g. 1,000 hours/year for residential and 3,000 hours/year for retail. This poster demonstrates how double ratio estimation techniques can reduce sample sizes while preserving statistical precision and confidence.

**Methods.** Techniques for estimating hours-of-use in the evaluation community have varied widely over the years. To the distress of many a statistician, one still sees simple random sampling with non-weighted averaging employed for this purpose. Today, preferred techniques exploit the fact that annual operating hours is the ratio of total annual kWh usage over total full-load demand in the population. This is equal to the ratio of annual kWh savings over demand reduction if the program does not alter annual operating hours. The standard stratified ratio estimation approach assumes the usual model relating measured kWh ($y$) to measured kW ($x$). In such an analysis, one would estimate the population hours-of-use with the usual ratio estimator in the sample with case weight $w = N / n$:

$$\text{HOU}_{\text{Estimated}} = \sum_n wy \Big/ \sum_n wx$$

In a recent study, KEMA tested the application of double ratio estimation techniques as discussed by Cochran in "Ratio of Two Ratios."[1] This method is applicable when there are tracking estimates of kWh savings ($v$) and kW savings ($u$). Notice that $v$ and $u$ play no role in the hours-of-use analysis just described. By contrast, the double ratio estimate of the population hours-of-use is:

$$\text{HOU}_{\substack{\text{Estimated}\\ \text{Double Ratio}}} = \frac{\sum_n wy \Big/ \sum_n wx}{\sum_n wv \Big/ \sum_n wu} \times \frac{\sum_N v}{\sum_N u}$$

If $u$ and $v$ are highly correlated with $x$ and $y$ respectively, then one would expect double ratio estimation to better leverage the existing tracking information, i.e. to yield better statistical precision for a given sample size under a suitable sample design.

**Results**. With direct impacts on study cost, sample size always is a key consideration for program administrators embarking on hours-of-use research. When estimating program savings, we know that sample sizes can be reduced if the program provides accurate tracking estimates of savings. Theory suggests that, similarly, sample sizes can be reduced for hours-of-use studies if the program does not affect the hours-of-use in the population and provides accurate tracking estimates of both energy and demand savings. This poster presents sample size implications in a practical context so that others in our industry may optimize sample sizes when the program provides strong tracking information.

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[1] Cochran, William. Sampling Techniques. New York: Wiley, 1977, p. 183.