# A Comparison of Approaches to Estimating the Time-Aggregated Uncertainty of Savings Estimated from Meter Data

Bill Koran
SBW Consulting, Inc.

**2017 IEPEC Conference — Baltimore, Maryland**

# Agenda / Overview

- Introduction
  - Background and Need
  - Regression Statistics Basics
- Methodology
  - Data Sets
  - Analyses
- Results
- Summary and Conclusions

# Introduction: Background and Need

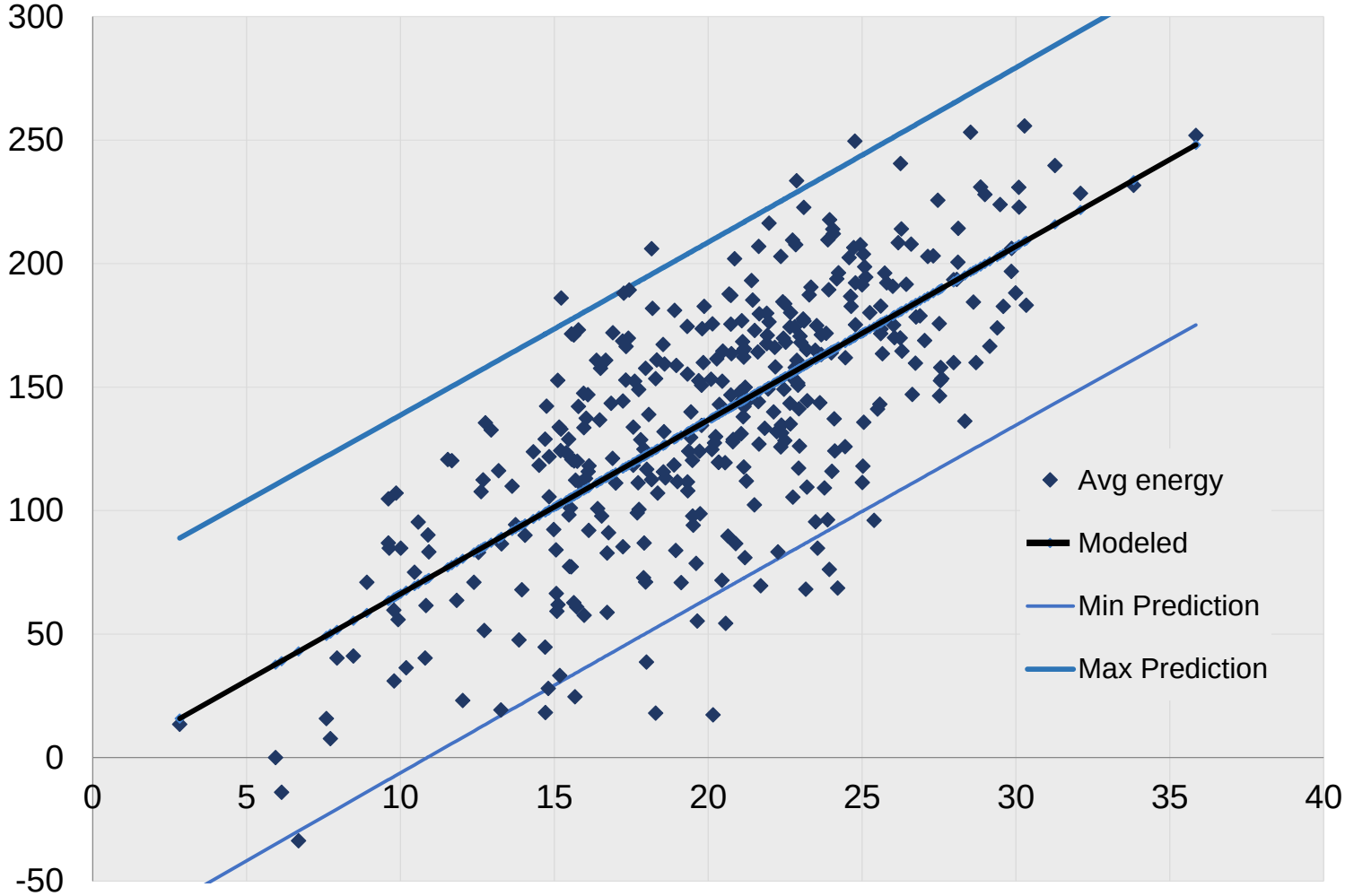
- Increased ‘Measurement’ of Savings at the meter
- IPMVP Option C Whole Facility
- California Legislation (NMEC)
- Strategic Energy Management (SEM)
- Pay for Performance
- A simplified method is needed for energy analysts and engineers

**How good are the models?**

**How well do we know the savings?**

**How *precise* are the estimates?**

# Prediction Interval of Regression at Confidence Level = 0.95



# Combined Uncertainty of Predictions

There is a baseline prediction and associated uncertainty for every point in a reporting period.

What is the combined uncertainty for all predictions?

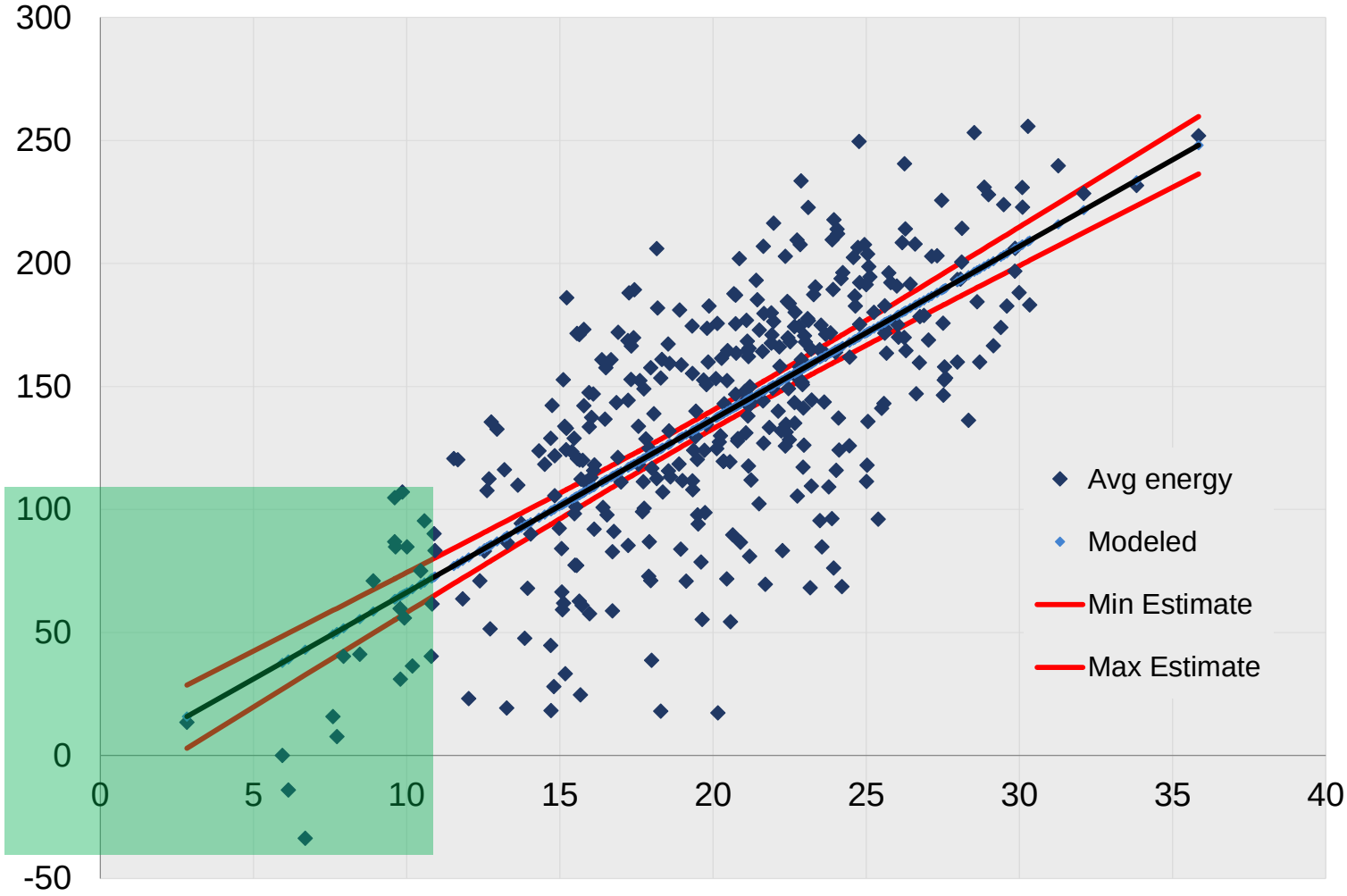
We cannot combine uncertainties in quadrature

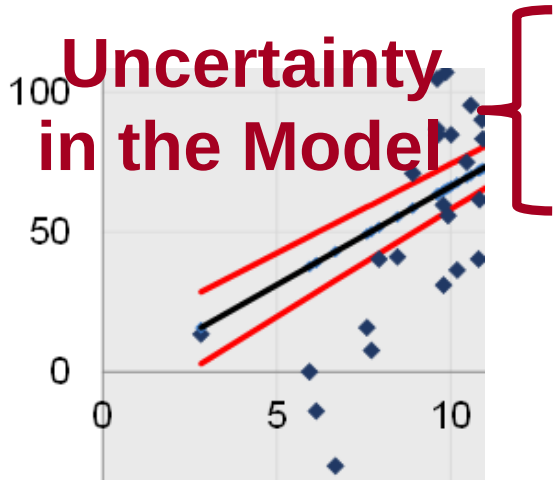
(square root of the sum of the squares)

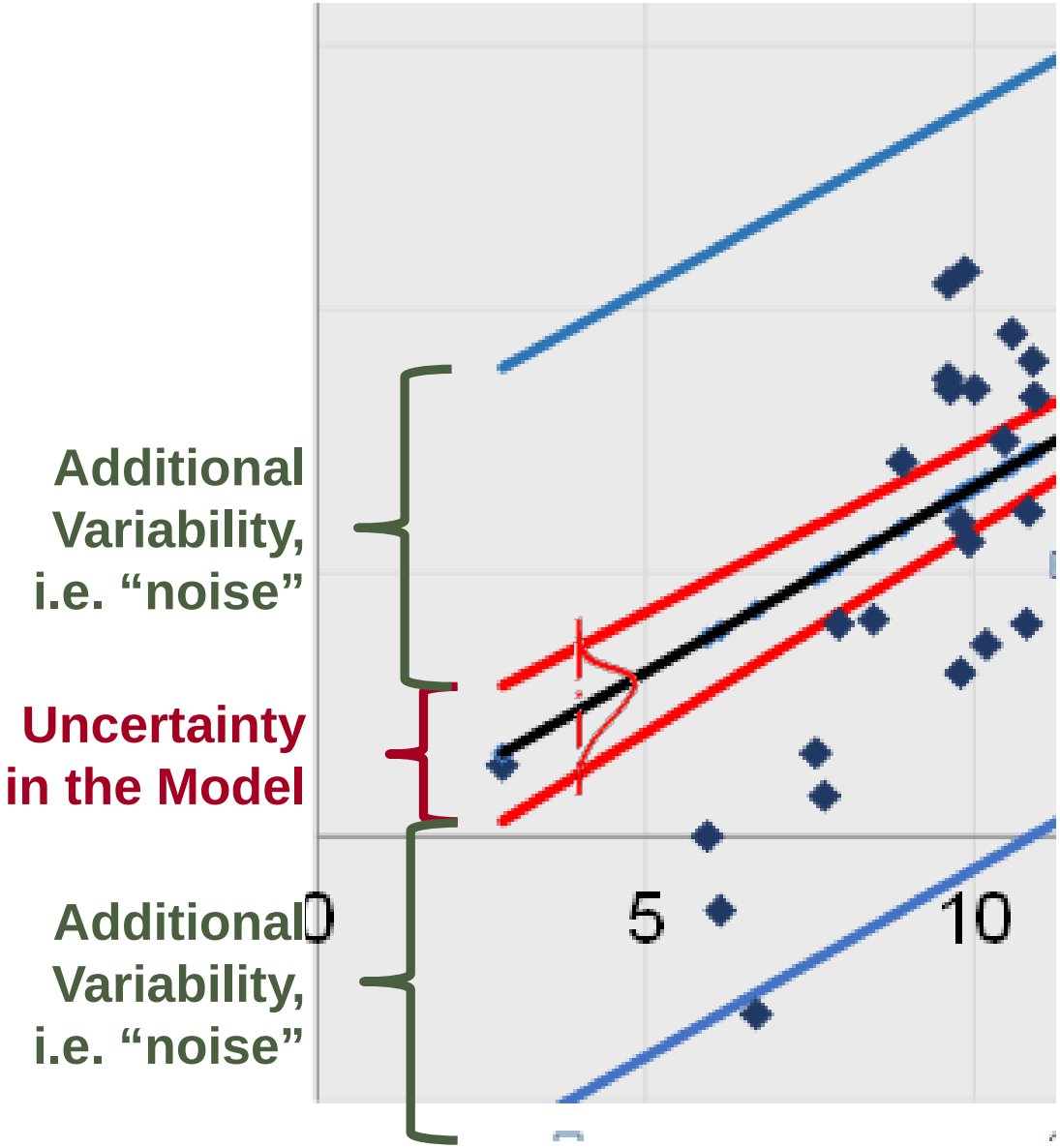
because the predictions are not independent!

***They all come from the same model.***

# Confidence Interval of Regression at Confidence Level = 0.95




Uncertainty
in the Model
100
50
0
0
5
10


Additional Variability, i.e. “noise”
Uncertainty in the Model
Additional Variability, i.e. “noise”
0
5
10

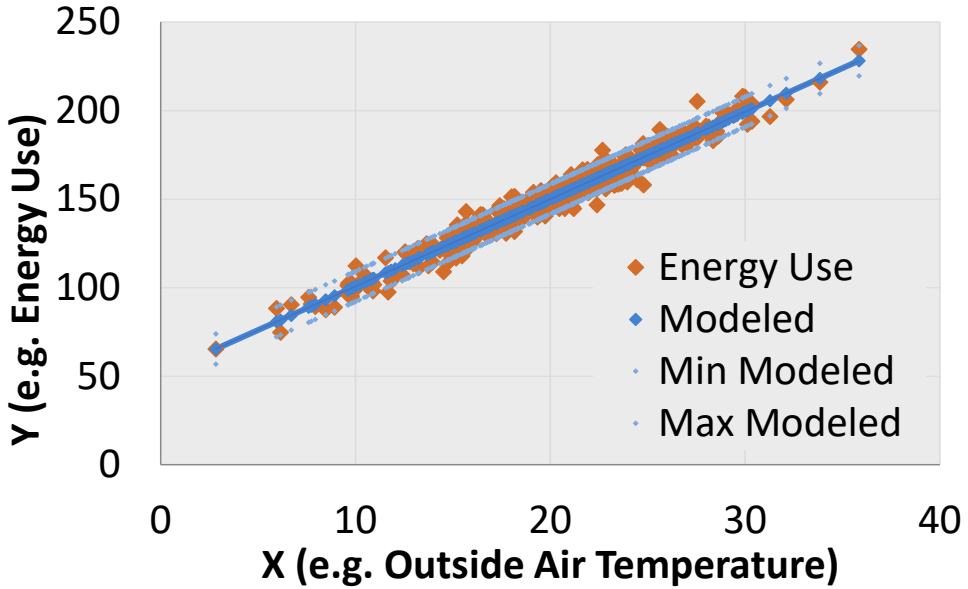
# Combined Uncertainty of Predictions

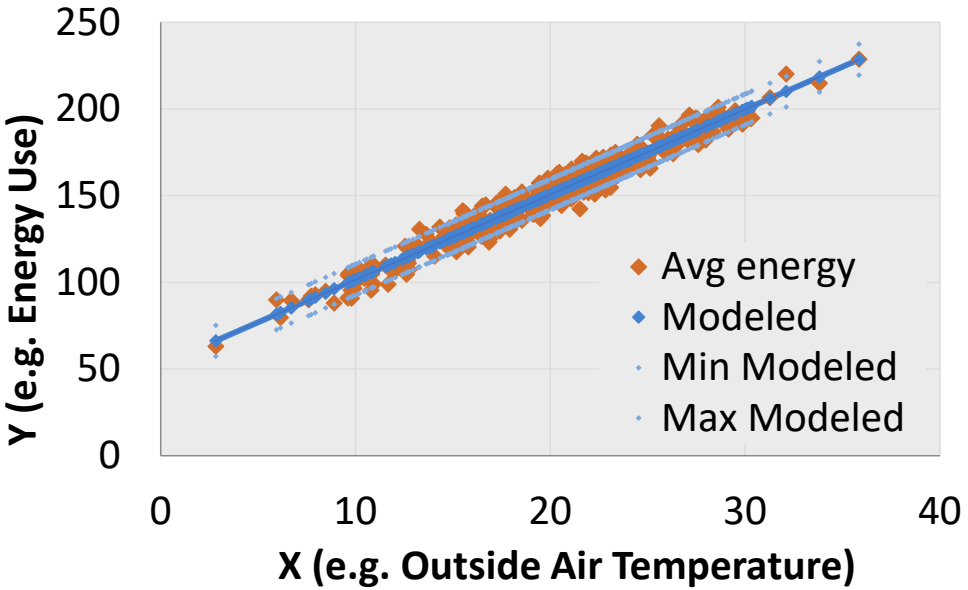
- the model uncertainty aggregates with $m_{post}$
- the noise uncertainty aggregates with $\sqrt{m_{post}}$
- Where $m_{post}$ is the number of points (x-y pairs) in the reporting (post) period

# Methodology: Data Sets 1 & 2

**Data Set 1 is a simple linear model with all points independent.**

**Data Set 2 fits the same relationship as Data Set 1, but has lag 1 autocorrelation.**

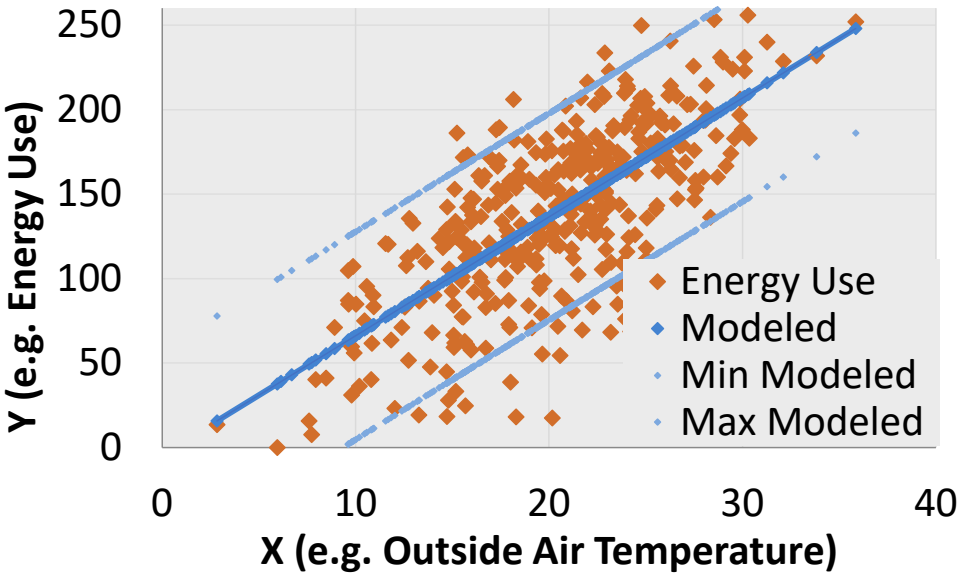


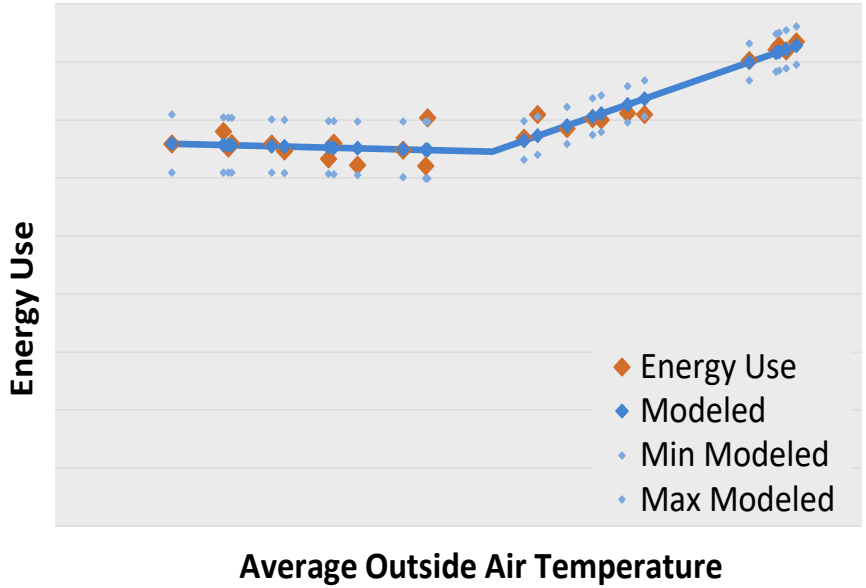



# Methodology: Data Sets 3 & 4

**Data Set 3 has more scatter and significant autocorrelation.**

**Data Set 4 is monthly billing data from a real building. The model is not a straight line.**

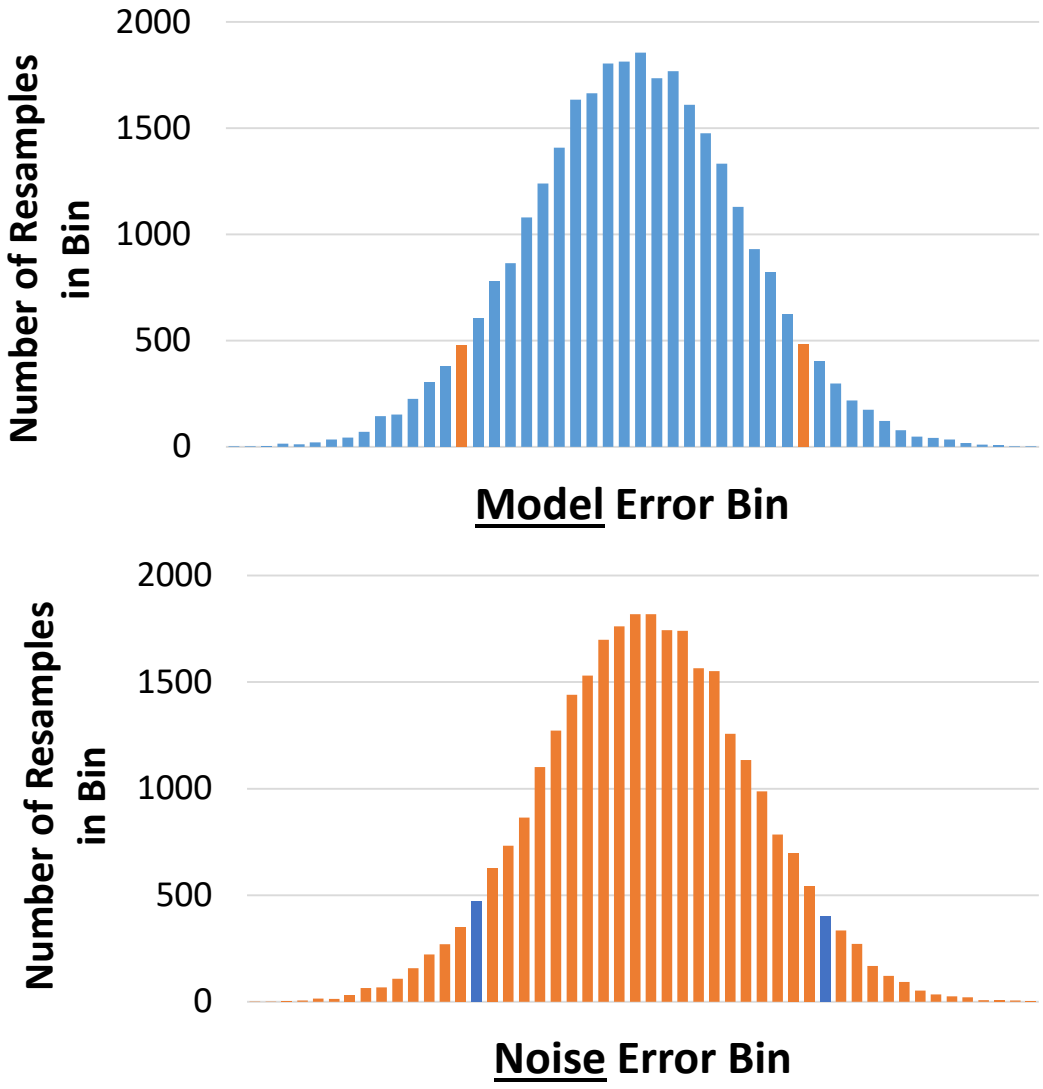


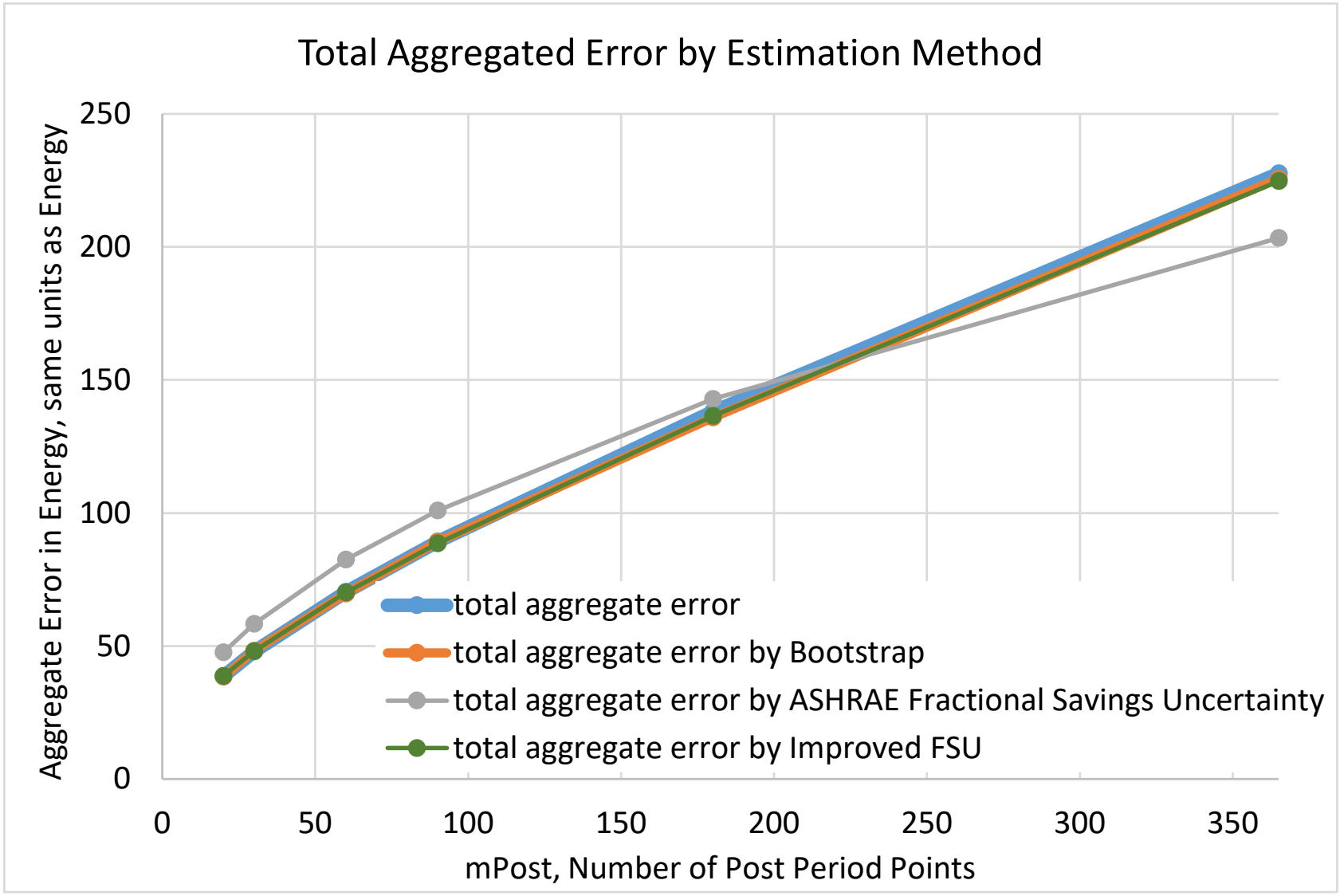
# Methodology: Approaches

- ASHRAE Guideline 14 Fractional Savings Uncertainty (FSU)
- Improved Approach Based on ASHRAE FSU
- Exact Equation for Ordinary Least Squares Regression
- Bootstrap Approaches
  - Resample Data X-Y Pairs
  - Block Bootstrap: Resample X-Y Pairs in Blocks for Autocorrelated Residuals
  - Resample Residuals: for Data with a Relationship Between Independent Variable Values

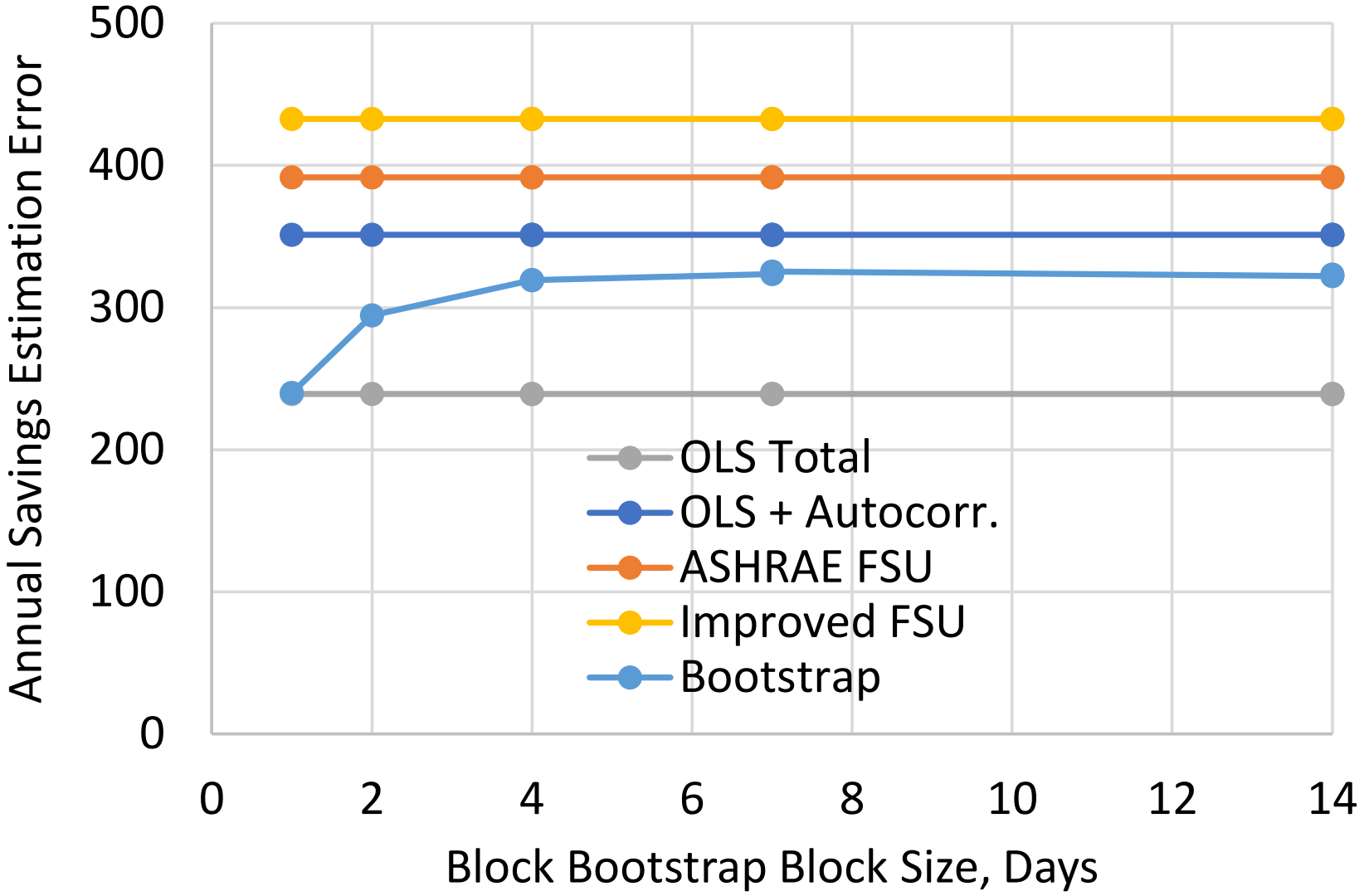
# Sufficiency of 30,000 Bootstrap Samples



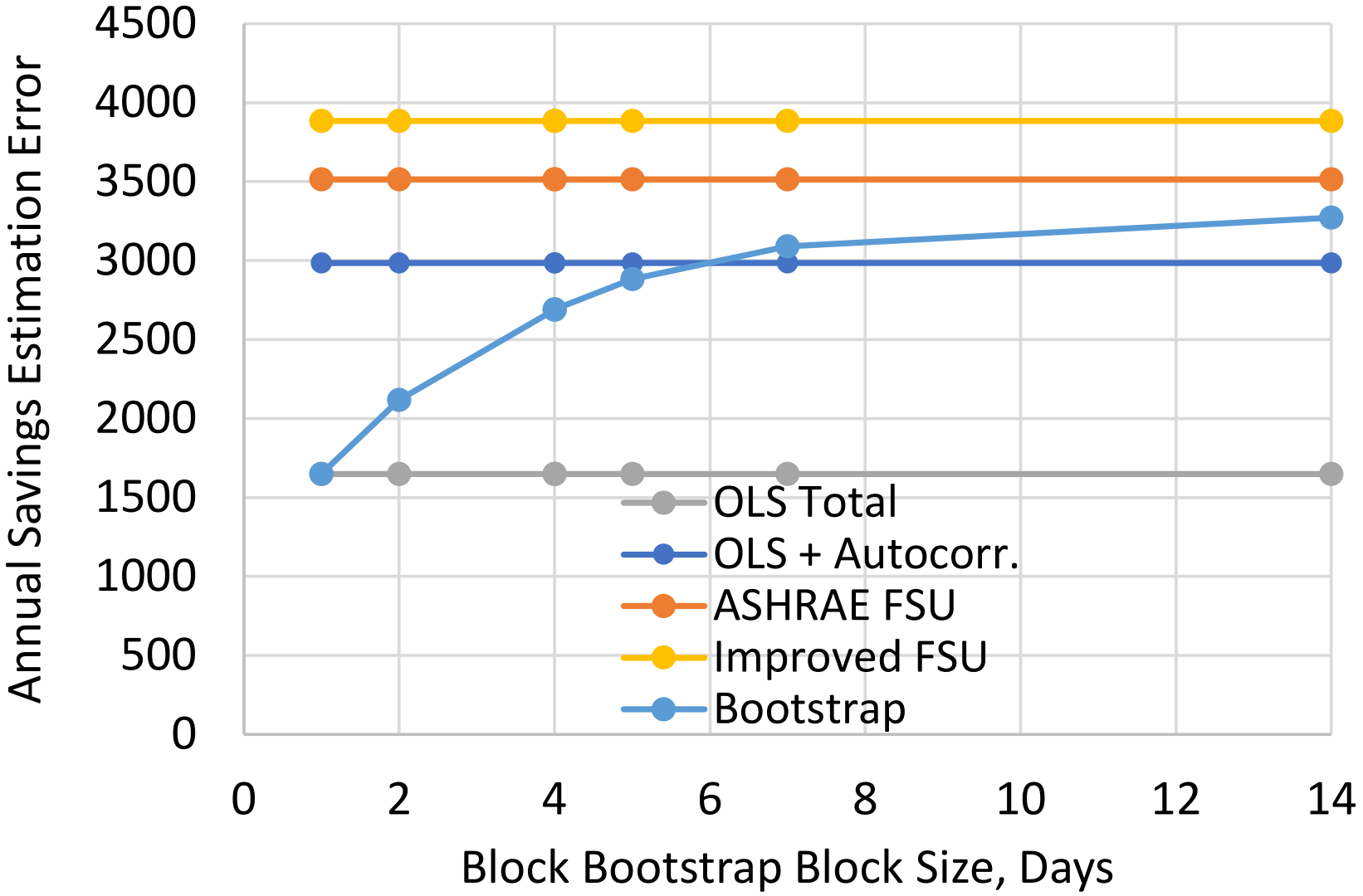
# Results for Data Set 1



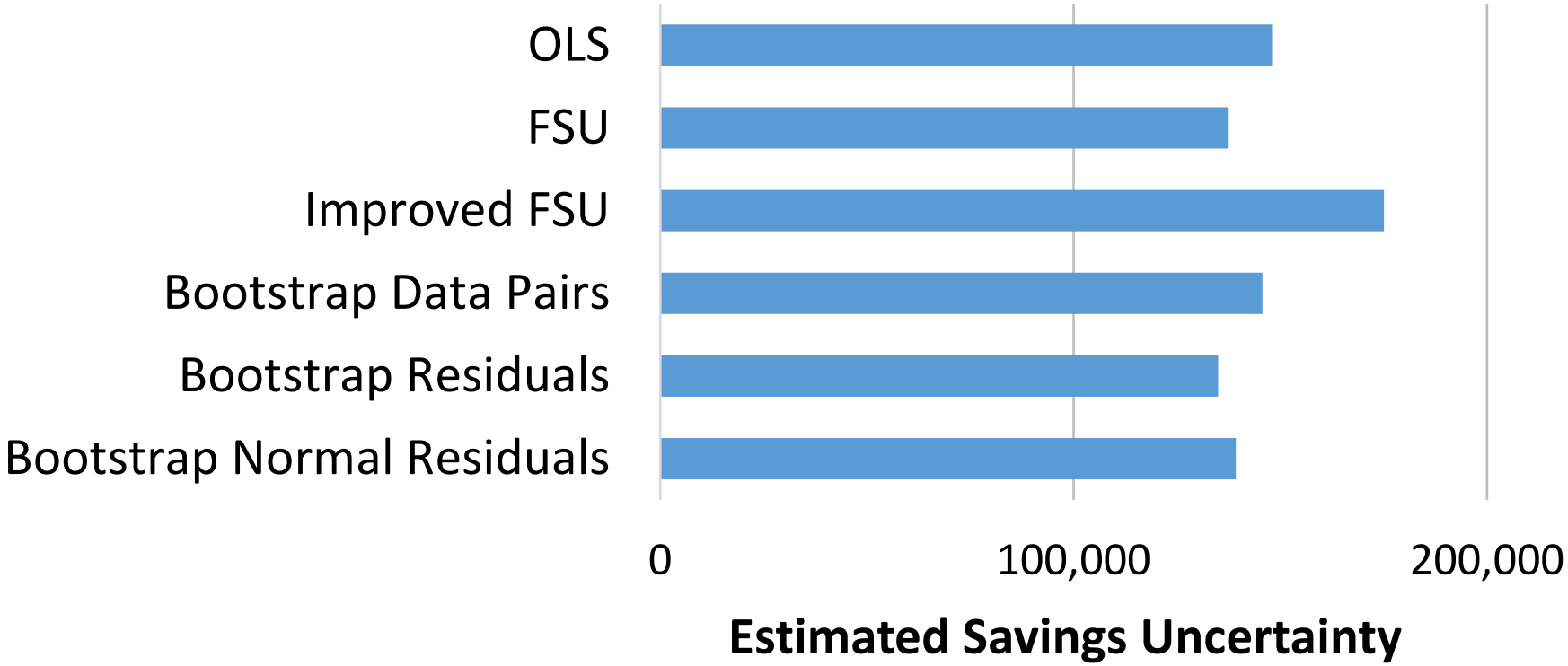
# Results for Data Set 2



# Results for Data Set 3



# Results for Data Set 4



# Summary and Conclusions

- The two components of uncertainty—model and noise—aggregate differently.
- The bootstrap is an effective way to estimate uncertainty, especially for complex models.
- The ASHRAE adjustment for autocorrelation may overstate the impact for small lag orders.
- Further study is needed for more complex models and for models using short data intervals.

# Thank You!

Bill Koran, P.E.
Senior Energy Analytics Engineer
SBW Incorporated
Tel. 503-974-9741
bill.koran@sbwconsulting.com
sbwconsulting.com

sbw

ENERGY • WATER • EFFICIENCY