Incorporating IPMVP and Six Sigma Strategies into Monitoring and Evaluation

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Introduction

- Energy efficiency offers the largest and most cost-effective opportunity available to mitigate global warming.
- The foundation of energy efficiency is the assumption that Energy Conservation Measures (ECMs) will reduce energy use.
- Customers, businesses, utilities, and government agencies need to know how much energy will be saved and how long savings will last when they invest in energy efficiency.

Introduction (Continued)

- The International Performance Measurement and Verification Protocol (IPMVP) is a worldwide standard for evaluation, measurement, and verification (EM&V) of energy savings.
- Six Sigma is a worldwide performance target for improving efficiency, quality, customer satisfaction, market share, and profits.
- This paper provides an example of how to incorporate IPMVP and Six Sigma strategies into monitoring and evaluation studies of energy savings from ECMs.

What is IPMVP?

- IPMVP is a resource savings-verification tool.
- IPMVP defines four options to quantify energy, power, water, and renewable energy savings from energy or water conservation measures.
- None of the four IPMVP options allow exclusive use of stipulated values.
- Unreasonable stipulations create risks and uncertainties especially if savings are based on unreliable stipulated values or laboratory testing procedures which lack similitude with in situ conditions.

History of IPMVP

- In 1994, USDOE worked with hundreds of industry experts throughout the world to develop a consensus approach to measuring and verifying energy efficiency investments.
- The 1st edition of IPMVP was published in 1996. In 1997, twenty national organizations from a dozen countries worked to publish a 2nd edition.
- In 2002, a 3rd edition was published with input from twenty-five national organizations.
- 4th edition of IPMVP was published in 2006.
- IPMVP has been used for in California for evaluation and monitoring since 2000.

What is Six Sigma?

- Six Sigma is a performance target that applies to a single critical-to-quality characteristic (CTQC) and focuses on nonconformance.
- Six Sigma means 3.4 defects per million opportunities. The typical corporation in the United States operates at 3.5 sigma or 22,750 defects per million opportunities.
- The difference between 3.5 and 6 sigma can be illustrated with an example. If a 150 m^2 carpet were cleaned to 3.5 sigma, about 3.4 m^2 would be left dirty. If the carpet were cleaned to Six Sigma, the dirty area would be less than 5 cm^2.

History of Six Sigma

- Six Sigma was invented at Motorola in 1979.
- Prior to Six Sigma, Motorola spent 5 to 20% of annual revenue correcting poor quality at a cost of $850 million per year.
- Detecting and fixing defects led Motorola to only four sigma (6,210 defects per million opportunities) – placing it ahead of average US companies, but behind foreign competitors.
- Motorola virtually eliminated defects with Six Sigma by making improvements in all operations producing results more rapidly and cost effectively.

IPMVP and Six Sigma Framework

IPMVP	Six Sigma
1. **Recognize or Select** IPMVP Options consistent with ECMs.	1. **Recognize** business state: 1) defect-free products, 2) on-time, 3) lowest cost.
2. **Define ECM boundaries**.	2. **Define** plans to realize improvement.
3. **Measure** ex ante assumptions and CTQ Characteristics.	3. **Measure** business system, frequency of defects, CTQ Characteristics.
4. **Prepare** EM&V Plan, **analyze** gaps in savings.	4. **Analyze** gaps in performance when and where defects occur, identify variations.
5. **Design**, **install, and test** measurement equipment.	5. **Improve** systems to achieve goals, relationships, and operating tolerances.
6. **Commission** measures to ensure CTQC compliance.	6. **Control** or verify CTQC, validate measurement systems, implement controls.
7. **Gather energy and operating data** from post-retrofit period.	7. **Standardize** and adopt systems that prove to be best-in-class.
8. **Compute and report savings**.	8. **Integrate** best-in-class systems.

How to Incorporate IPMVP and Six Sigma into Evaluation Studies

- Residential air conditioner incentive programs implemented by four public utilities in California.
- Programs realized peak kW and kWh savings by paying incentives to consumers for installing high efficiency air conditioners.
- The programs provided rebates for 1,892 high efficiency air conditioners from 2001 through 2003 with $1,344,803 of Senate Bill 5X funds from the California Energy Commission.
- Evaluation study budget was $56,658 (4.2%)

Step 1: Measure Energy Savings

- Six Sigma – recognize true state: 1) defect-free products, 2) on-time/schedule, 3) lowest cost.
- IPMVP – select IPMVP options.
- Option A - measure short-term in-situ EER and compare to manufacturers' data.
- Option B - measure kW demand with short-term or continuous measurements during peak period.
- Option C – billing data to evaluate kWh savings.
- Option D - calibrated building energy simulations to normalize for weather and occupancy.

Step 2: Define ECM Boundaries and Gather Base Year Data

- Six Sigma – define plans to improve program.
- IPMVP - define and characterize ECM boundaries to improve performance.
- Baseline cooling energy use is evaluated using utility billing data for 50 participant sites.
- Weather data is used to obtain normalized baseline cooling energy use from billing data for each site.

Step 3: Evaluate Assumptions and CTQ Characteristics

- Six Sigma– measure systems to support plans.
- Six Sigma - 1) what to measure and when to measure, 2) how to measure, and 3) gaining approval to measure. Reluctance to measure is often based on over promising results.
- IPMVP - Ex ante kWh and kW savings are 92% and 118% greater than other studies.
- Six Sigma - CTQ Characteristics – lack of commissioning (RCA, duct leakage, sizing, etc).

Step 4: Prepare an EM&V Plan to Analyze Gaps

- Six Sigma - Analyze gaps energy efficiency performance benchmarks to understand process improvements.
- IPMVP – Prepare EM&V plan to define ECM savings (i.e., random or stratified statistical sample, 90% confidence, 10% precision, etc.).

Step 5: Design, Install, and Test Measurement Equipment

- Six Sigma – Improve systems to achieve performance goals.
- Six Sigma - Standards for precision, accuracy, traceability, and reliability must be defined.
- IPMVP – Design and test measurement equipment.
- IPMVP – define analytical methods and reporting requirements to improve the program.

Step 6: Verify or Commission ECMs and Control CTQ Characteristics

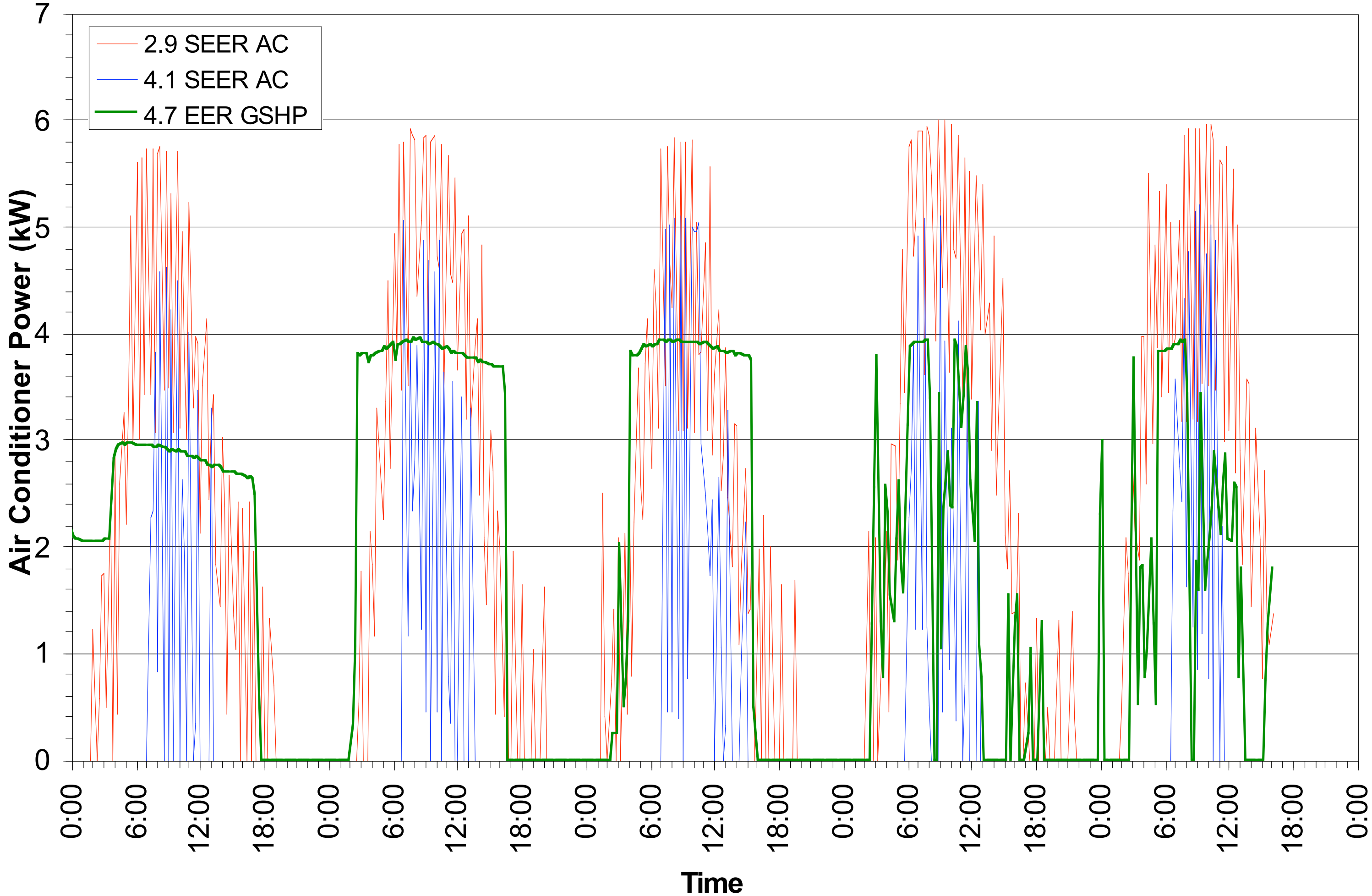
- Six Sigma – Evaluate critical-to-qualtiy characteristics including equipment sizing and quality installation (i.e., refrigerant, airflow, expansion valve, duct leakage).
- Six Sigma – perform system-level audits to evaluate, identify, analyze, and control CTQ characteristics.
- IPMVP – Verify and commission ECMs similar to IEA Annex 40.

Step 7: Gather Post-Retrofit Data and Standardize Best-in-Class

- Six Sigma – standardize and adopt systems that prove to be best-in-class.
- IPMVP – gather energy and operating data consistent with M&V plan.
- IPMVP – Measure EER before and after quality installation to evaluate in-situ efficiency.
- Average EER improvement from proper charge and airflow was 15% with correction of 20%.

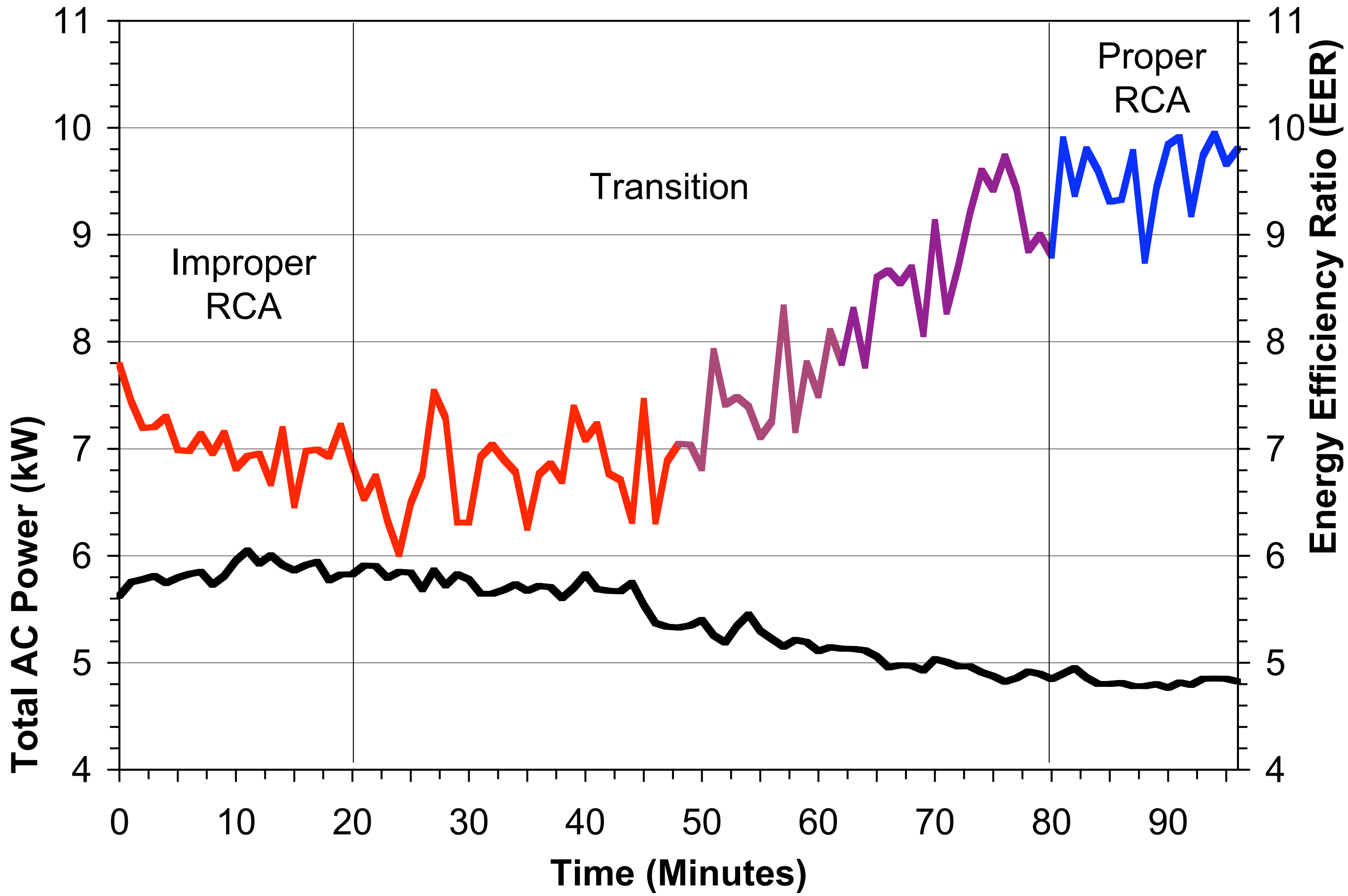
Step 7: (cont'd) Measured kW Savings

Average measured kW savings is 0.4 to 0.8 kW.



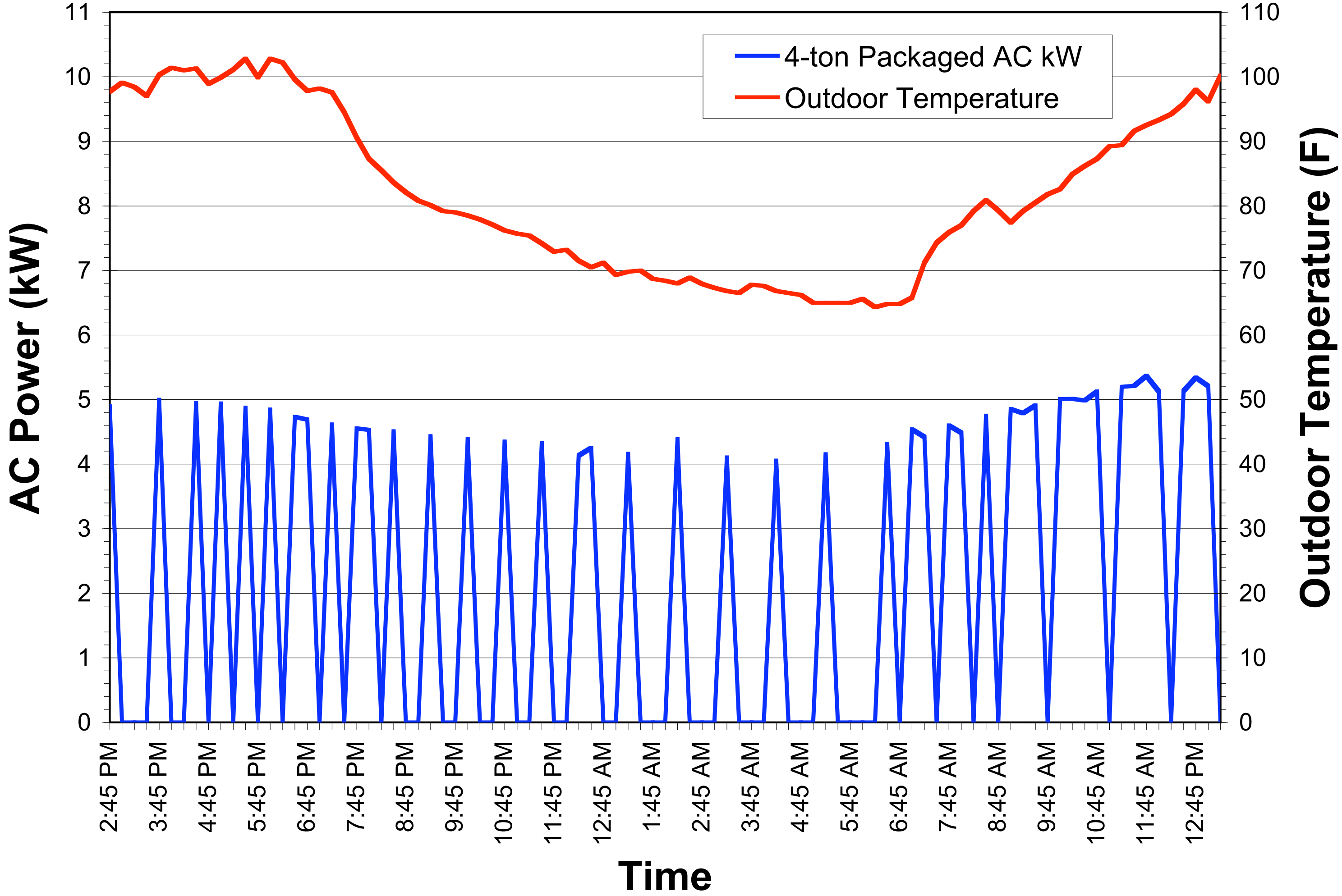
Step 7: (cont'd) Installation Defects

Installation defects are reduced with verification of refrigerant charge and airflow per IPMVP Option A.



Step 7: (cont'd) Preventing Peak kW

Efficient over-sized air conditioners increase kW.



Step 8: Gather Post-Retrofit Data and Standardize Best-in-Class

- Six Sigma - integrate best-in-class systems. Best-in-class systems become integrated when their cross-applicability is interwoven into operating policies and procedures and reinforced through reward and recognition systems (e.g., white tags).
- IPMVP - compute and report savings and process evaluation recommendations to improve the programs.

Conclusions

- Net realization rates for the four residential air conditioner rebate programs are 0.53 ± 0.1 for kWh and 0.58 ± 0.04 for kW.
- Realization rates are lower than anticipated due to lower baseline usage, lower ex post savings, and free riders.
- Utilities haven't previously conducted evaluations and were unfamiliar with tracking accomplishments and measuring results.
- Findings for the four utility programs underscore the importance of measuring performance and not over promising results.

Conclusions

- IPMVP and Six Sigma help in understanding failure mechanisms, testing procedures, and design, manufacturing, and installation defects.
- Incorporating IPMVP and Six Sigma strategies into monitoring and evaluation will help utilities, consumers, corporations, and government agencies better understand the value of energy efficiency to reduce global warming.
- Thank you!